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NATIONAL REPORT ON GRAVITY IN AUSTRALIA,
JULY 1970 TO JUNE 1974

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SUMMARY

A new National Gravity Base Station and datum value was adopted by Australia in 1973 (Sydney A = 979 671.86 mGal). This followed the completion at this site of an absolute determination of gravity by the National Standards Laboratory, and the measurement of the gravity interval Sydney A to Moscow (Ledovo) in 1972 by Soviet scientists using five OVM pendulums. The Soviet Union and Australia carried out a co-operative survey along the 3 Gal Australian Calibration Line in 1973. Eight GAG-2 gravity meters defined a gravity scale to an accuracy of 2.5 parts in 10^5, and this scale has been adopted for Australia.

The reconnaissance gravity survey of Australia that was started in 1959, was completed in 1974. The minimum station density is one station per 130 km^2, but one quarter of Australia has a station density of more than one station per 50 km^2. About one half of Papua New Guinea is now covered with reconnaissance or detailed gravity surveys. In Australia and Papua New Guinea about 600 000 land gravity stations have now been observed. Data from all gravity surveys are being recomputed to obtain more accurate principal facts based on the 1973 gravity scale and datum, and on new Australia-wide altitude and position networks.

A marine gravity survey covered the Australian and Papua New Guinea continental slope, and parts of the shelf and deep sea floor, during 1970 to 1973. The survey comprises 176 000 km of profiles, with a line spacing varying from 37 to 56 km.

Earth-tide records are being obtained from a set of two Verbaandert-Melchior horizontal pendulums installed in a tunnel near Armidale, New South Wales.

Work in physical geodesy includes the determination of a new astro-geodetic geoid, a new free-air geoid, and a new determination of the vector defining the location of the Australian Geodetic Datum relative to the Geocentre.

1. INTRODUCTION

This report is intended for presentation at the seventh meeting of the International Gravity Commission (IGC) of the International Association of Geodesy, to be held in Paris in September 1974, and covers the period July 1970 to June 1974. Earlier periods are covered by the national reports to previous meetings of IGC prepared by Dooley (1959), Langron (1966), Dooley (1965a), and Barlow (1970). The IGC reports are overlapped by national reports to the general assemblies of the International Association of Geodesy.

Acknowledgment is made of information supplied by Division of National Mapping, Department of Minerals and Energy; National Standards Laboratory of the Commonwealth Scientific and Industrial Research Organisation; Mines Departments of South Australia and New South Wales; Geology Department, University of Tasmania; and School of Surveying, University of New South Wales. Acknowledgment is also made to petroleum and mineral exploration companies who have contributed to the gravity coverage of Australia.

The Bureau of Mineral Resources, Geology and Geophysics (BMR) is the responsible Australian Government authority on gravity matters. This report has been prepared in the Geophysical Branch of BMR.

2. NATIONAL GRAVITY BASE STATION

In the period 1950 to 1973 gravity measurements in Australia were made relative to the Melbourne pendulum station (45474A, BMR No. 5099.9901). A value of 979 979.00 mGal (Cook, 1957) was adopted for this station by Dooley _et al._, (1961).

In 1973 a new National Gravity Base Station in Sydney (45331A: BMR No. 5099.9905) and a gravity value of 979 671.86 mGal were adopted (Boulanger _et al._, 1973). This station is adjacent to the site of the absolute determination of gravity in Sydney (Bell _et al._, 1973), and is accurately tied to Moscow and Potsdam by recent Soviet OVM pendulum work (Gusev, 1973). Gravity meter ties from other countries to Sydney are stronger than to any other place in Australia, Sydney being the main international airport. The IGSN 71 value for Sydney A (Morelli, 1974, pers. comm.) results from the latest analysis of these gravity meter results. Three nearly independent values for the Sydney station 45331A are given by the above sources as follows:

Absolute determination	979 672.00 ± 0.20 mGal (3xs.d.)
IGSN71	979 671.86 ± 0.021 mGal (s.d.)
Soviet result	979 671.84 ± 0.06 mGal (s.d.)

where s.d. is standard deviation

The values agree within their stated accuracy. The IGSN71 value for Sydney A was adopted as the new datum for Australia.

3. ABSOLUTE MEASUREMENT OF GRAVITY AT SYDNEY

An absolute measurement of the acceleration due to gravity has been completed by Bell et al., (1973) at the National Standards Laboratory, Sydney. The experiment was of the rise and fall type in which measurements were made of the vertical motion of a cube corner reflector in vacuo (Gibbings et al., 1971).

The final value of gravity is based on 192 measurements, 160 with a standard length approximately 0.415 m long, and the remainder with a standard length approximately 0.219 m long. The measured values were corrected for the tidal effects of the moon and sun but were otherwise untreated. The value of gravity obtained at the measurement point is 979 671.60 mGal, and this value is considered to be in error by not more than 0.2 mGal (3 standard deviations).

The measurement point (BMR Station No. 7299.9999) is 1.2 m above floor level and 1.50 m north of the Sydney permanent gravity station 45331A (5099.9905). The gravity difference between these stations was determined by four La Coste & Romberg gravity meters (Wellman et al., 1974). The final value for the permanent gravity station 45331A is 979 672.00 ± 0.20 mGal (Bell et al., 1973).

4. PENDULUM MEASUREMENTS

In December 1972 the Central Research Institute of Geodesy, Aerial Survey and Cartography (TZNIIGAIK, Moscow) of the Soviet Union carried out a tie with a set of five Soviet OVM pendulums between Moscow (Ledovo) and Sydney. The purpose of the work was to determine accurately the gravity interval between the Sydney absolute gravity site and the other absolute sites in the world, so that the absolute measurements can be intercompared, and an accurate correction to the Potsdam datum determined. Arrangements for the tie were made by Professor Yu.D. Boulanger of the Soviet Geophysical Committee of the USSR Academy of Sciences and by BMR.

The gravity interval between Moscow (Ledovo) and Sydney A was determined to be -1879.54 ± 0.06 mGal (s.d.) (Gusev, 1973). The gravity interval between Potsdam and Ledovo has been determined as 291.327 ± 0.019 mGal; hence in relation to the old adopted value of 981 274.00 ± 0.00 mGal for Potsdam, Sydney A value is 979 685.79 ± 0.06 mGal.

During the period 1971 to 1973 BMR carried out experiments aimed at developing a relative pendulum apparatus which could measure gravity intervals to an accuracy of 0.1 mGal. The equipment consisted of a GSI relative pendulum swinging chamber, with three pendulums of fused quartz with steel knife edges. A light beam, supplied by a 2 mW He-Ne laser, was detected by a photofet, and the period was calculated electronically using a rubidium frequency standard for time. Three sets of pendulums were used; the original GSI set with approximately 120° angle knife edges, and two other sets manufactured by National Standards Laboratory with 178° and 173° angle knife edges. The pendulum, optical and timing system measured the mean period of 50 swings to an accuracy equivalent to 0.1 mGal standard deviation. With the 120° angle pendulums the periods change by only 2 parts in 10^7 during 1000 swings; however, useful results could not be obtained because the periods were not reproducible. This is thought to be because of non-elastic deformation of the knife edges and agate flats when the pendulums are brought down onto the agate flats and swung. The National Standards Laboratory (CSIRO) suggested that there may be only elastic deformation with a knife edge with a 178° angle. However, pendulums with 178° knife edges give periods changing by 1 part in 10^4 during 1000 swings, and a compromise knife edge with 173° angle gave a period changing by 5 parts in 10^5 during 1000 swings. These results were not encouraging and development work on the pendulum apparatus was not continued.

5. GRAVITY SCALE

In the period 1950 to 1965 Cambridge pendulum results with a magnetic correction were used to control scale in Australia (**Dooley et al.**, 1961). Between 1965 and 1973 a 'mean Australian milligal' was used; the average given by the two intervals Melbourne - Cairns and Melbourne - Darwin as calculated from the values of a 1962 adjustment of Dooley (1965b). This scale is compatible with the scale given by the 1950-51 Cambridge pendulum results calculated without magnetic correction (Barlow, 1970).

Results from various subsequent surveys (Woollard and Rose, 1963; Japanese Government, 1959, 1970; Whalen, 1966) indicated that gravity intervals calculated using the 'mean Australian milligal' were too small, but the new pendulum and gravity meter results did not define a new scale sufficiently accurately to warrant a change.

In 1973 the Geodesy and Cartography Survey of USSR and the Soviet Geophysical Committee of the USSR Academy of Sciences in co-operation with BMR carried out GAG-2 gravity meter measurements at seventeen airports along the Australian Calibration Line (Boulanger et al., 1973; Wellman et al., 1974). The GAG-2 gravity meter operates on the same principle as the Norgaard gravity meter; it has an astatic quartz torsion system and gives superior results (Sazhina & Grushinsky, 1971). Scale along the 3000 mGal calibration line was defined to an accuracy of 2.5 parts in 10^5, and the 'mean Australian milligal' was shown to be 5 parts in 10^4 too small. This ACL scale established with GAG-2 gravity meters, was adopted as the new scale for Australia in 1973 (Boulanger et al., 1973). Subsequent work and calculations (Wellman et al., 1974) show that this scale is compatible with overseas absolute measurements, and overseas Gulf, Cambridge and OVM pendulum measurements within experimental error.

Gravity scale in Australia is now primarily defined along the 3000 mGal Australian Calibration Line, consisting of airports between Laiagam in Papua New Guinea and Hobart in Tasmania (Plate 1). Gravity values at these airports are used to calculate values for stations of the Australian National Gravity Network, and are also used to **calibrate LaCoste** & Romberg gravity meters. LaCoste & Romberg gravity meter surveys along this calibration line have been carried out in 1965, 1966, 1970, 1971, 1972 and 1973. The 1970 to 1973 LaCoste results have been used to calculate accurate gravity values for the airport stations on the new Sydney A datum and GAG-2 ACL scale. These gravity values have an internal consistency of better than 0.01 mGal (Wellman et al., 1974).

The Worden and Sharpe gravity meters used for much of the Australian gravity work are calibrated using ten local calibration ranges (Plate 1) (Barlow, 1967; Wellman et al., 1974). A replacement calibration range for Perth was established in 1973. In Port Moresby the calibration range has been changed several times because of building changes and excavations; Wellman et al. (1974) adopted a value for the present range.

6. AUSTRALIAN NATIONAL GRAVITY NETWORK

The Australian National Gravity Network (Dooley, 1965a; Barlow, 1970) consists of a series of east-west traverses between airports of nearly equal gravity, joined by three north-south traverses (Plate 1). This network was established over Australia and Papua New Guinea in 1964, 1965 and 1967, with minor strengthening near Perth in 1973. Gravity values on each traverse are based on the value of the most easterly airport, which is also part of the Australian Calibration Line; the values are not based on the other two less accurate north-south traverses. Gravity values are estimated to have a standard error of 0.1 mGal relative to the other stations on the same east-west line.

The original gravity values assigned to this network (May 1965 Isogal values) can be adjusted to the datum Sydney A = 979 671.86 mGal, and to the scale given by the GAG-2 gravity meters by the provisional formula

$$g_{1973} = 979\,671.86 + 1.0005118\,(g_{1965} - 979\,685.74)$$

7. LAND AND MARINE GRAVITY COVERAGE OF AUSTRALIA AND PAPUA NEW GUINEA

Land Coverage

The reconnaissance gravity survey of Australia is now complete, the final 20% having been covered in the last four years. Gravity stations are approximately on a square grid, with a station density of one station per 42 km^2 in South Australia and Tasmania, and one station per 130 km^2 elsewhere (Plate 2). This has mainly been carried out by contract, using the cell technique of helicopter surveying described by Hastie & Walker (1962). Altitudes were determined with micro-barometers. Using this technique the precision of gravity determinations is about 0.5 mGal, and altitude determinations 10 m; hence gravity anomalies with a precision of about 2 mGal are obtained.

Major semi-detailed gravity surveys have been carried out in areas of economic interest by oil and mineral companies. Some of these surveys have been subsidized by the Australian Government under the Petroleum Search Subsidy Acts.

Detailed and semi-detailed gravity surveys have also been carried out along bench-mark traverses, along seismic traverses, along shorelines, in mineralized areas, and in local basins to determine alluvium thickness. The government and university authorities that have carried out most of these surveys are the Mines Departments of South Australia and New South Wales, the Geology Department of the University of Tasmania, and BMR.

Papua New Guinea non-marine gravity work consists of semi-detailed surveys by oil companies south of the highlands districts and reconnaissance coverage elsewhere by BMR. The 1970 to 1974 private company surveys consist of helicopter and boat traverses in the Fly River catchment. BMR work in the period 1970 to 1974 consists of reconnaissance helicopter coverage over the remainder of east Papua, and an extension of the surveys in the rest of the highlands. Where landing sites were sparse because of jungle, the stations are irregularly spaced but still about 11 km apart. At present about one half of the land area is covered by reconnaissance or semi-detailed surveys (Plate 2).

Marine Coverage

A marine geophysical survey was carried out between December 1970 and January 1973 by Compagnie Generale de Geophysique under contract to the Bureau of Mineral Resources in order to determine the extent of the Australian continental margins, and to obtain regional information on the geological structure. The survey covered the continental slope and marginal plateaux around Australia and Papua New Guinea, parts of the continental shelf, and some oceanic areas in the Tasman and Bismarck Seas (Plate 2). A total of 176 000 km was traversed in waters between about 50 m and 5000 m deep, at a line spacing which varied from 37 km off the east coast to 56 km off the west.

Primary position fixes were obtained at approximately two-hour intervals by satellite Doppler. Intermediate positions between the satellite fixes were obtained by sonar Doppler backed by Chernikeeff electromagnetic log, pressure log and gyrocompass records.

A LaCoste & Romberg marine gravity meter (No. S24) mounted on a gyro-stabilized platform near the centre of the ship, provided gravity data which was recorded on digital tape together with navigational data, water depth and the total magnetic field. An analogue magnetic tape recorded the results of a 120 kilojoule sparker used for sub-bottom seismic profiling.

The drift of the gravity meter was about 0.5 mGal/month throughout most of the survey. The presence of about six major tares, or unrecorded gravity meter adjustments, result in a mean uncertainty in the gravity meter of about one milligal. However, the largest errors in gravity mapping are those in position. An estimate of the accuracy of the free air anomalies is given by the discrepancy of the anomalies at the line intersections; these have a standard deviation of 5.6 mGal. The quality of the data gathered during this survey is described in the field progress reports of the Compagnie Generale de Geophysique. Final reports are in preparation by BMR.

Plate 2 shows the present marine coverage with gravity meters, including both the 1970 to 1973 survey and earlier surveys. The main areas of poor or no coverage are Bass Strait, the Great Barrier Reef area, and the Gulf of Carpentaria.

8. AUTOMATIC COMPUTING, COMPILATION OF GRAVITY DATA & GRAVITY MAPS OF AUSTRALIA

Automatic computing

Digital computers are applied in Australia to reduce the results of gravity surveys by BMR, South Australian and New South Wales Departments of Mines, and the Universities of Tasmania, New South Wales and New England.

The most comprehensive suite of programs has been developed by BMR for the CDC Cyber 76 computer. For land surveys, gravity and micro-barometer readings are fed into the computer together with calibration data and fixed station values (fixed nodes). The readings are corrected for scale, earth tides, diurnal variation in pressure, and drift. A least squares program calculates gravity and altitude values. These data are integrated with station positions to provide principal facts, and are stored on magnetic tape. Programs are available to edit and sort the data rapidly, and to make systematic corrections. Gravity data can be extracted either by area blocks or by survey number, and are either presented as a combined principal facts and anomaly listing, or are automatically plotted on a map of the required scale and projection. The maps can be automatically contoured using the two dimensional interpolation method developed by Briggs (1974). For a 1:250 000 sheet area with 150-250 gravity stations the extraction of principal facts, plotting and contouring takes approximately 15 seconds CPU time, 15 minutes plotting time, and costs approximately $A20. The programs to carry out these and supplementary tasks are described by Murray (1974).

BMR has also written programs to reduce, store, and manipulate marine gravity data. These programs are part of a set written to process the navigational, magnetic, depth, and gravity data received from the continental margin survey of 1970-1973. At present an attempt is being made to recover the gravity data at ship turns by calculating gravity during the turn using only low frequency components.

Programs are also available to compute the gravity effect of two and three-dimensional bodies, to calculate iteratively models that are consistent with the gravity field, and to carry out two-dimensional frequency analysis.

Compilation of gravity data

Geodetic investigations, crustal studies, and geological interpretation of gravity data over broad areas, such as extensive sedimentary basins, require integration of the data of a number of gravity surveys to a common datum and common milligal scale. The compilation of all available gravity data in Australia and its territories and presentation of gravity maps of Australia are functions of BMR. A copy of all available gravity information is held in the Regional Gravity Group of BMR. Retrieval of data is facilitated by key maps that show the areas covered by all known gravity surveys.

Much of the gravity data is currently in the form of written documents, but eventually the principal facts for all gravity stations in the Australian region will be stored on magnetic tape, with gravity values based on the new Sydney A datum and GAG-2 ACL scale (Boulanger et al., 1973), and altitudes based on Australian Height Datum (Roelse et al., 1971).

The total number of gravity stations observed on land in Australia and Papua New Guinea is estimated to be about 600 000 from 650 surveys. Of these, 230 000 stations (270 surveys) were observed by BMR or by organizations under contract to BMR, and 370 000 (380 surveys) were observed by other organizations. In June 1974 about 110 000 stations (100 surveys) were on BMR magnetic tape, about 80 000 stations (150 surveys) are not worth recomputing, and the remainder are being recomputed by BMR either directly or by contract.

Most of the principal facts on magnetic tape have been supplied to the Hawaiian Institute of Geophysics, transmitted through them to the Aeronautical Chart and Information Center, and should be available internationally through the United States Department of Defence Gravity Library.

Gravity maps of Australia and Papua New Guinea

A delay is inevitable in the production of an accurate compilation of the gravity data of a whole continent. A map showing a less rigorous integration of gravity work is suitable for many purposes, so preliminary Bouguer anomaly maps of Australia have been produced. These maps are on Melbourne A = 979 979.00 mGal datum and 'mean Australian milligal' scale. The most comprehensive map is the preliminary Bouguer anomaly map of Australia (BMR map No. A/B2-50) prepared as an overlay for the 1960 Tectonic Map of Australia at a scale of 1:2 534 400 (Geol. Soc. Aust., 1960). The Bouguer density varies from survey area to survey area.

The contour interval is 5 mGal. A similar map for Papua New Guinea is available at 1:2 500 000 (BMR map No. PNG/B2 -29 - 3). Preliminary Bouguer anomalies, free air anomalies and water depths over the continental shelves and slopes are given in three series of eight 1:250 000 sheets (see Plate 5). The preliminary Bouguer Anomaly map of Australia has been redrafted as an overlay for the 1971 Tectonic Map of Australia and New Guinea (Geol. Soc. Aust., 1971) at a scale of 1:5 000 000 (BMR map No. A/B2 - 85). A reduction of this map is given in Plate 7. All these maps may be purchased as prints or transparent overlays from the Production Section, Commonwealth Printing Office, Wentworth Avenue, Kingston A.C.T. 2604 Australia.

Two coloured maps, showing gravity data of Australia and its surroundings available to 1966, have been printed at a scale of 1:5 000 000 by the Ministry of Geology of USSR (1971); one map shows Bouguer anomalies on land and at sea, and the other shows Bouguer anomalies on land and free air anomalies at sea. The South Australian Department of Mines (in press) is at present printing a 1:1 000 000 preliminary Bouguer anomaly map of South Australia and has released a map at this scale covering the South Australian part of the Great Artesian Basin (Milton & Moroney, 1973).

Maps showing the gravity stations and preliminary 5 mGal Bouguer anomaly contours in most of the 1:250 000 map sheet areas have been printed by BMR at 1:500 000 scale. Keys to available maps are shown in Plates 3 and 4.

After correction to currently accepted datums and gravity scale, gravity data in the Australian region will be used to prepare several series of new gravity maps in which the gravity unit will be micrometres per second squared ($\mu m/s^2$). The main series will be at a scale of 1:250 000 and will show station positions, elevations and Bouguer anomaly values with 50 $\mu m/s^2$ contours. Maps at scales of 1:1 000 000, 1:2 500 000 and 1:5 000 000 will be produced with Bouguer and free air contours.

9. GRAVITY MEASUREMENTS IN ANTARCTICA AND ON OCEANIC ISLANDS

In the period 1970 to 1974 strong gravity ties were made with LaCoste & Romberg gravity meters to bases outside Australia. A tie from Melbourne to Macquarie Island was made by the University of New South Wales in 1970, and by Antarctic Division, Department of Science, in 1972. Repeat ties were made between Melbourne and Casey by Antarctic Division, and between Melbourne and Mawson by BMR. In 1973 BMR used two meters to make a strong tie from Perth to Christmas Island, and later three meters to make a ladder sequence of observations Sydney-Christchurch-McMurdo-South Pole, the U.S. Air Force providing transport south of Christchurch. In a co-operative project with New Zealand accurate gravity intervals were measured between Auckland, Wellington, Christchurch, and Dunedin.

In three areas gravity observations were carried out by Antarctic Division as part of their glaciological program. Near Casey new and repeat observations were made on the Law Ice Dome. The gravity station interval is 1.6 km along a grid of traverses 16 km apart (for earlier work see Allan & Whitworth, 1968). In the southern Prince Charles Mountains, south of Mawson, **eleven** glaciological strain nets have been set up to measure ice strain and snow accumulation, at points away from the mountains. These stations were observed in 1972 and reobserved in 1974. On Heard Island a gravity traverse across the Vahsel Glacier was made in 1971.

BMR geologists made regional observations in the Mawson-Davis-Prince Charles Mountains area. The stations are on rock, about 40 km apart. This work, together with the 1957-59 glaciological traverses (Fowler, 1971) and the 1972-1974 glaciological stations provide a regional coverage over an area of 200 000 km^2.

10. GRAVITY INTERPRETATION IN TERMS OF EARTH STRUCTURE

Descriptions of the relations between gravity anomalies and structure are given in reports following regional gravity surveys: Barlow (1966), Darby (1969a, 1969b), Gibb (1966, 1967), Lonsdale (1965), Lonsdale & Flavelle (1968), Whitworth (1970), Johnston (1972), and Fraser (1973, 1974a, 1974b, and in prep.). Reports on Papua New Guinea include: St John (1970), Milsom (1973), Watts (1969), and Zadoraznyj & Coutts (1973). Reports on marine surveys include: Geophysical Associates (1966), Jones (1969), and Whitworth (1969). The relation between gravity anomalies and geology was systematized by the concept of gravity provinces (Darby & Vale, 1969).

Correlation between gravity anomalies and sedimentary thickness has been widely studied. The most detailed studies are the reports of gravity surveys subsidized by the Australian Government. Other studies were carried out by BMR and the South Australian Mines Department.

Dooley (1974) has inferred the lithosphere strength from the amplitude and wavelength of gravity anomalies in central Australia. Dooley (1973) concluded from the negative free air gravity anomaly in Central Australia, that the earth was not expanding rapidly as proposed by Carey (1970). Wellman (in prep.) has used relationship of wavelength and amplitude for altitude and free air anomalies to infer the extent of isostatic compensation and the lower limit to significant horizontal density variations. Wellman (1974) has used the trend of gravity anomaly areas to divide Australia into crustal blocks, and has inferred the relative ages of the blocks using cross-cutting relations. Isostatic models of the Australian crust consistent with gravity, altitude, sediment thickness, and seismic data were calculated (Wellman, 1973).

11. RESEARCH IN PHYSICAL GEODESY

Geoid in Australia and Papua New Guinea

In 1971 a geoid map of Australia controlled by astro-geodetic data was produced by the Division of National Mapping (Fryer, 1971). This work was carried out in two phases; the first phase determined an astro-geodetic geoid, and the second phase refined this geoid by using gravimetric data to interpolate within the astro-geodetic loops.

The first phase was a least-squares adjustment of 124 sections of astro-geodetic geoidal profiles, suitably weighted, forming 49 loops among 76 junction points. Each section of profile was then individually adjusted, holding its terminal junction points fixed, to give final values of N at each of the 1133 astro-geodetic stations. The total length of geoidal profiles is about 50 000 km, of which 24 650 km are major profiles with astronomic observations at every traverse station, or more rarely, in geoidally smooth country, at every second station. The remaining profiles have astronomic observations at widely varying spacing, making use of the astronomic work done to provide Laplace azimuth control in the geodetic survey. The average misclosures of the 49 loops, without regard to sign, is 2.0 m, the average loop length being 1656 km. The greatest standard error at any junction point relative to the Johnston geodetic station in the centre of Australia is 1.5 m.

In the earlier 1966 geodetic adjustment, Johnston had been held fixed with zero separation between the geoid and the spheroid. In order to fit the Australian National Spheroid more closely to the geoid, a value of N = -6 m at Johnston has been adopted, which minimizes the scale change between the 1966 geodetic adjustment and any future work.

The second phase was carried out in co-operation with BMR, which supplied Australia-wide gravity data, and the School of Surveying, University of New South Wales, which undertook the task of computing the gravimetric interpolation, with the Division of National Mapping supporting the task and providing geodetic control data. The School of Surveying computed 1679 values of N, Xi and Eta at 30 minute intervals from the gravimetric observations, and adjusted the values, loop by loop, into terms of the astro-geodetic values around the loop perimeters (Mather et al., 1971).

Maps of N, Xi and Eta were produced by Division of National Mapping on a rectangular projection at a scale of 15 mm per degree on an automatic flat bed plotter. The contour interval is 1 m for N, and 2 seconds of arc for Xi and Eta. A diagram was also plotted automatically showing the deflection of the plumb line by a short vector at all astro-geodetic stations on the Australian Geodetic Datum.

A preliminary geoid calculation in New Guinea and adjacent islands based on widely spaced astro-geodetic information was completed in April 1971 (Fryer, 1971).

Grushinsky & Sazhina (1971), of Moscow State University and the Ministry of Geology of USSR have independently calculated a new free air geoid for Australia. They compared the various geoid solutions then published.

Other investigations

During the period 1970 to 1974 the School of Surveying, University of New South Wales, continued to carry out investigations into physical geodesy.

Proposals have been made for the establishment of a world geodetic system from gravimetry (Mather, 1971b; Mather, 1972c). Preliminary investigations are underway as a co-operative venture with the Geodynamics Branch at Goddard Space Flight Center, Greenbelt, Md, USA, with the support of the US National Academy of Sciences.

Gravity data were used to determine the geocentric orientation vector defining the location of the Australian Geodetic Datum and the Geocentre. Initial investigations made with a preliminary geoid solution (Mather, 1971a) were considerably improved by the 1971 astro-geodetic determination, and revised parameters have been determined (Mather, 1972a; Mather, 1972b).

The indirect effect on the free air geoid has been investigated (Fryer, 1970) using a solution of the geodetic boundary value problem. An alternative approach using models of the topography and its compensation have also been used, and investigations are in progress (Anderson, 1974).

Procedures for the computation of deflections of the vertical from gravity anomalies are being investigated in detail in a gravitationally disturbed region in northern New South Wales where astro-geodetic determinations are available (Kearsley, 1974). A three-dimensional calibration network is also being established in New South Wales using a state-wide network of approximately 80 stations. Gravity surveys have been completed around these stations, thus making it possible to study the nature of errors of intermediate frequency in the definition of the gravity field. This project is a co-operative effort with the Department of Civil Engineering at the University of Newcastle.

The equivalence of truncation functions to other quadrature methods has been studied and algorithms have been developed for their use in calculations in physical geodesy (Ojengbede, 1973).

Investigations have commenced into theoretical problems associated with the definition of geoids from gravity data for the definition of sea surface topography from satellite altimetry. A proposal to use the GEOS-C spacecraft (due for launch at the end of 1974) to study the reported departures in northeastern Australia, has been accepted in principle by NASA (Mather, 1973a; Mather, 1974a). The role gravity anomalies play in present-day determinations where global gravity coverage is still not available has also been studied (Mather, 1974b).

The gravity data bank at the School of Surveying, University of New South Wales was used to compute a geopotential network for Australia (Mitchell, 1972).

12. CALIBRATION AND PERFORMANCE OF GRAVITY METERS

LaCoste Romberg gravity meters

Repeated calibration of these gravity meters on the Australian Calibration Line has shown (Wellman et al., 1974) that the scale factor of one meter (G132) has stayed constant to within 1 part in 10^5 during a period of 3 years, while other meters changed in scale factor by 1 part in 10^4 during one year. These meters were checked before and after surveys by measurements on the Canberra Calibration Range of 55 mGal. Generally seven or more readings are taken alternately at the two stations. The calibration range results have been useful in quickly determining gross changes in meter scale factor.

The performance of these meters has been mainly limited by two intermittent problems. Mercury thermostats have at times produced heating cycles of irregular duration, and the consequent minor oscillations in meter temperature have resulted in instrumental drift and poor reading repeatability. The mercury thermostats have now been replaced by thermistor bridges with solid state switching circuits, and since then there has been no subsequent trouble from this source. Numerous tares of about 0.1 mGal continue to be a problem with some meters (Wellman et. al., 1974).

Results of the multi-meter survey along the Australian Calibration Line during 1973 can be used to calculate the accuracy of measurement of gravity intervals (Wellman et al., 1974). When gravity stations differ in value by less than a milligal and are 5 minutes walk apart, the measured gravity intervals when corrected for gravity meter drift and scale factor have an accuracy of 0.015 mGal (standard deviation). The same accuracy is retained when the gravity stations differ in value by up to 60 mGal and are up to 30 minutes car drive apart.

Where gravity stations differ in value up to 400 mGal and are 1 to 3 hours DC3 flight apart, the gravity intervals after correction for gravity meter drift and scale factor have an estimated accuracy of 0.03 mGal (individual meter precision is about 0.015 mGal). This poorer accuracy is thought to result from the effects of an increased number of small tares due to the longer time intervals, and the vibrations experienced by the instruments. Effects of tares of less than 0.05 mGal were not removed by the rejection procedures applied to the data.

Worden and Sharpe gravity meters

The BMR Worden and Sharpe gravity meters have been repeatedly calibrated on the Melbourne and Canberra calibration ranges of about 55 mGal. Measured calibration factors can vary up to 0.1% in a few hours (Barlow, 1967), and 0.2% over several months, but over several years the calibration factor remains constant within about 0.5%.

Several factors lead to low accuracy of intervals from quartz type gravity meters. The 'drift' is sometimes high and erratic, due to either erratic high continuous drift or tares. Ground vibrations, for example from a nearby helicopter, were found to change readings by several milligals (B.C. Barlow, 1973, pers. comm.). Using data from the 1973 ACL survey the accuracy of gravity interval measurement using Worden gravity meters can be compared with that from LaCoste & Romberg gravity meters; for ground measurements the intervals with Wordens have an accuracy of 0.03 mGal.

13. EARTH TIDE RECORDING

In 1971 BMR installed a set of two Verbaandert-Melchior horizontal pendulums in a tunnel 100 m underground near Armidale, New South Wales (Barlow et al., 1974) to measure tidal deflections of the vertical. The observations are a co-operative project between BMR and the Department of Geophysics, University of New England. This department measures components of earth strain in the same tunnel system (Sydenham, 1973). The tunnel is in extremely hard garnetiferous carbonaceous slate. The pendulums were installed following the instructions of Melchior (1966) in a niche at the end of a tunnel. Most records are unusable, because of high drift rates directly after installation and after later disturbances, and because of water condensation effects and mechanical failures. Usable records are often marred by poorly focused traces, a high drift rate in one pendulum, small tares with and without recovery, and periods of high noise. To date, three sets of records of usable quality have been obtained, July and August 1972, June and July 1973 and January to May 1974. The data from these three sets of continuous records are being scaled for transmittal to Brussels for detailed analysis.

Belgian tidal gravity meters are to start recording at seven sites in Australia and Papua New Guinea in late 1974. This will be a co-operative project between the Permanent Commission for Earth Tides, Brussels, the School of Surveying, University of New South Wales, and BMR.

Further work by BMR to bring a North American gravity meter into operation as a recording earth tide gravity meter was stopped. At the suspension of the work two problems were restricting the quality of the records-high meter drift and inadequate temperature control.

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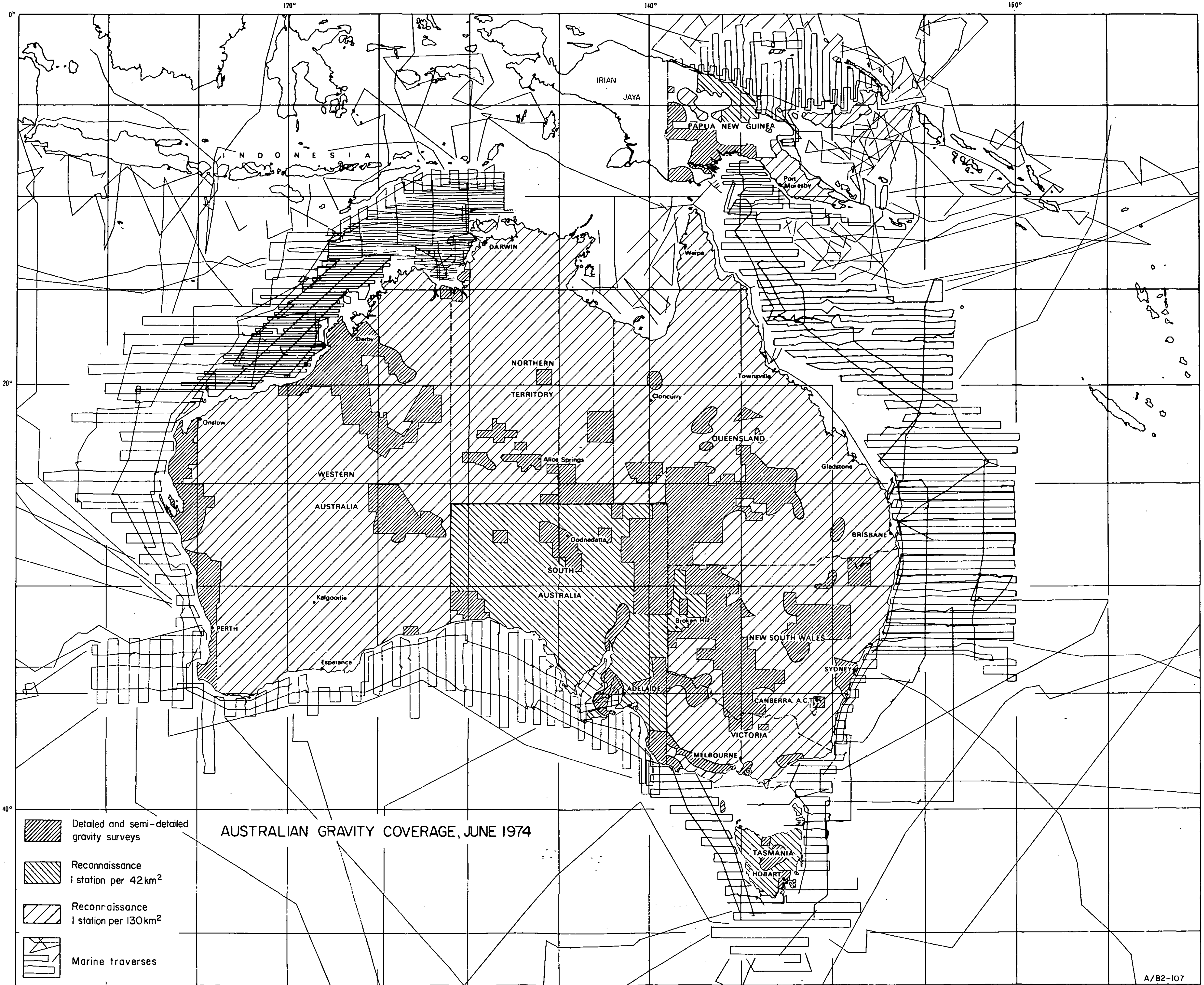
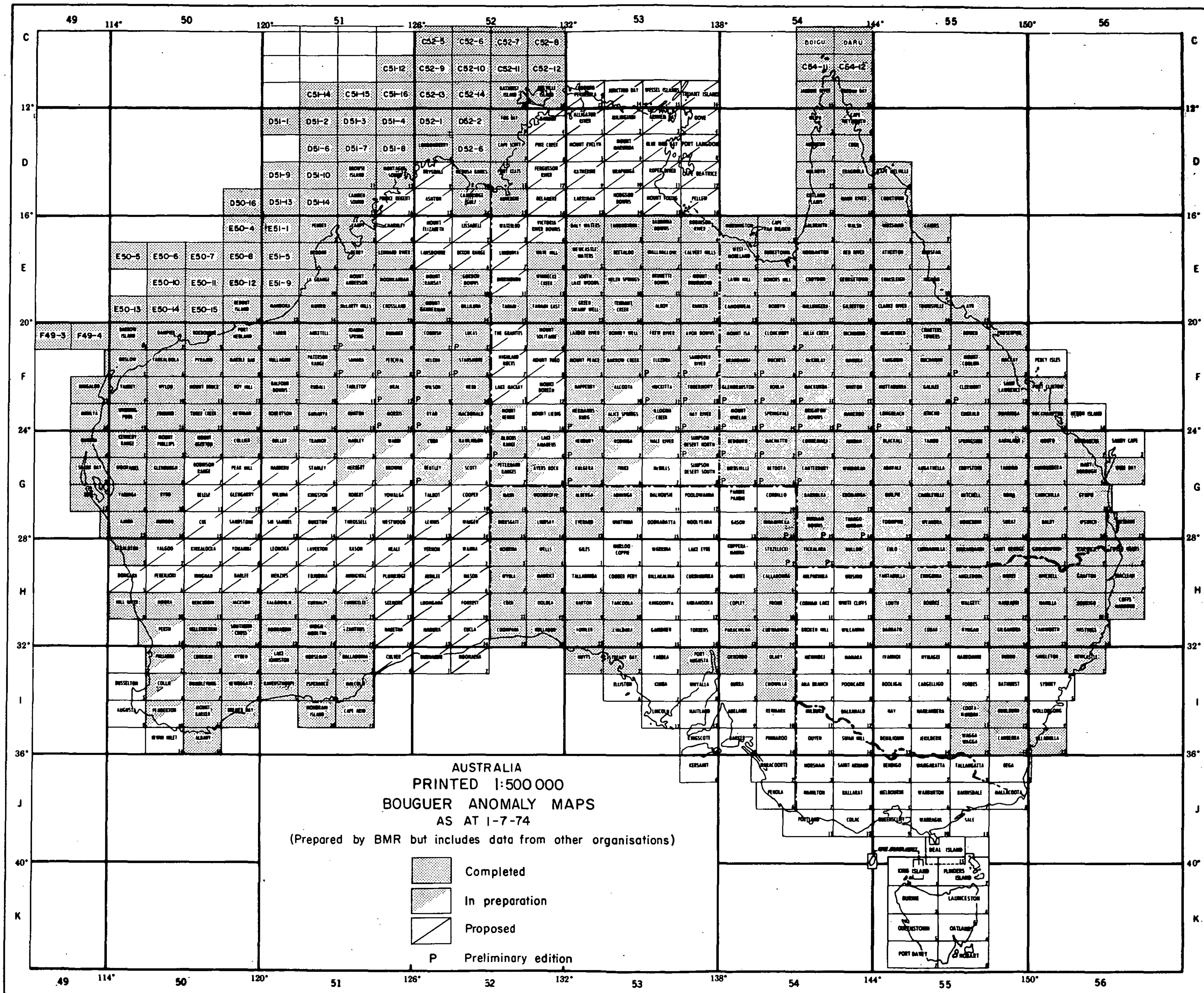
AUSTRALIAN NATIONAL GRAVITY NETWORK 1964 TO 1973
LEGEND
CAMBRIDGE PENDULUM STATION
ISOGAL PRIMARY STATION
ISOGAL SECONDARY STATION
CALIBRATION RANGE (C.R.)
AUSTRALIAN CALIBRATION LINE
AUSTRALIA AND PAPUA NEW GUINEA
NEW GUINEA
PAPUA
NORTHERN TERRITORY
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA
INDIAN OCEAN
ARAFURA SEA
TIMOR SEA
CORAL SEA
TASMAN SEA
GREAT AUSTRALIAN BIGHT
Momote
Wewak
Rabaul
Mt Hagen
Lae
Daru
Port Moresby (C.R)
To Honiara
Yirrkala Mission
Weipa
Darwin
Wyndham
Victoria River Downs
Daly Waters
Derby
Halls Creek
Tennant Creek
Normanton
Cairns
Townsville (C.R.)
Anna Plains
Tanami
Cloncurry
Mount Isa
Hughenden
Port Hedland
Mackay
Onslow
Alice Springs (C.R)
Boulia
Clermont
Longreach
Rockhampton
Mundiwindi
Giles
Birdsville
Carnarvon
Warburton Range Mission
Maryborough
Wiluna
Oodnadatta
Quilpie
Roma
Mount Magnet
Laverton
Brisbane (C.R.)
Tibooburra
Geraldton
Forrest
Watheroo
Kalgoorlie
Eucla
Leigh Creek
Woomera
Walgett
Merredin
Ceduna
Cobar
Armidale
Perth (C.R.)
Whyalla
Broken Hill
Esperance
Parkes
Mildura
Hay
Albany
Adelaide (C.R.)
Wagga Wagga
Sydney (C.R.)
Canberra (C.R)
Mount Gambier
Melbourne (C.R.)
Kallista
Bombala
Yarram
Launceston
Hobart (C.R.)
Record No. 1974/114
A/B2-95-1



AUSTRALIAN GRAVITY COVERAGE, JUNE 1974

(BASED ON A/B8-70) *Record No. 1974/114*

PLATE 3



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A/B2-31-1

Record No. 1974/114

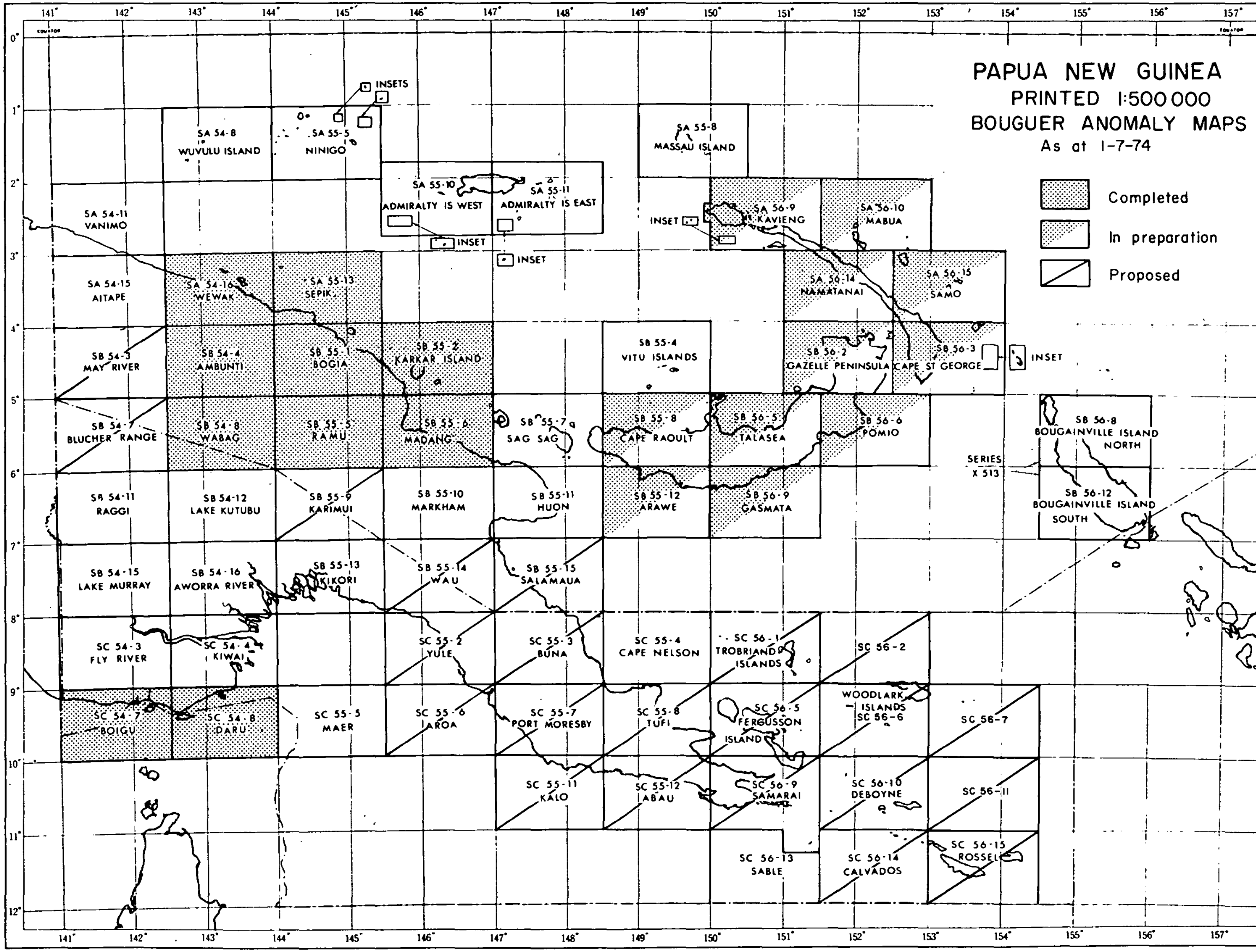

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PLATE 4

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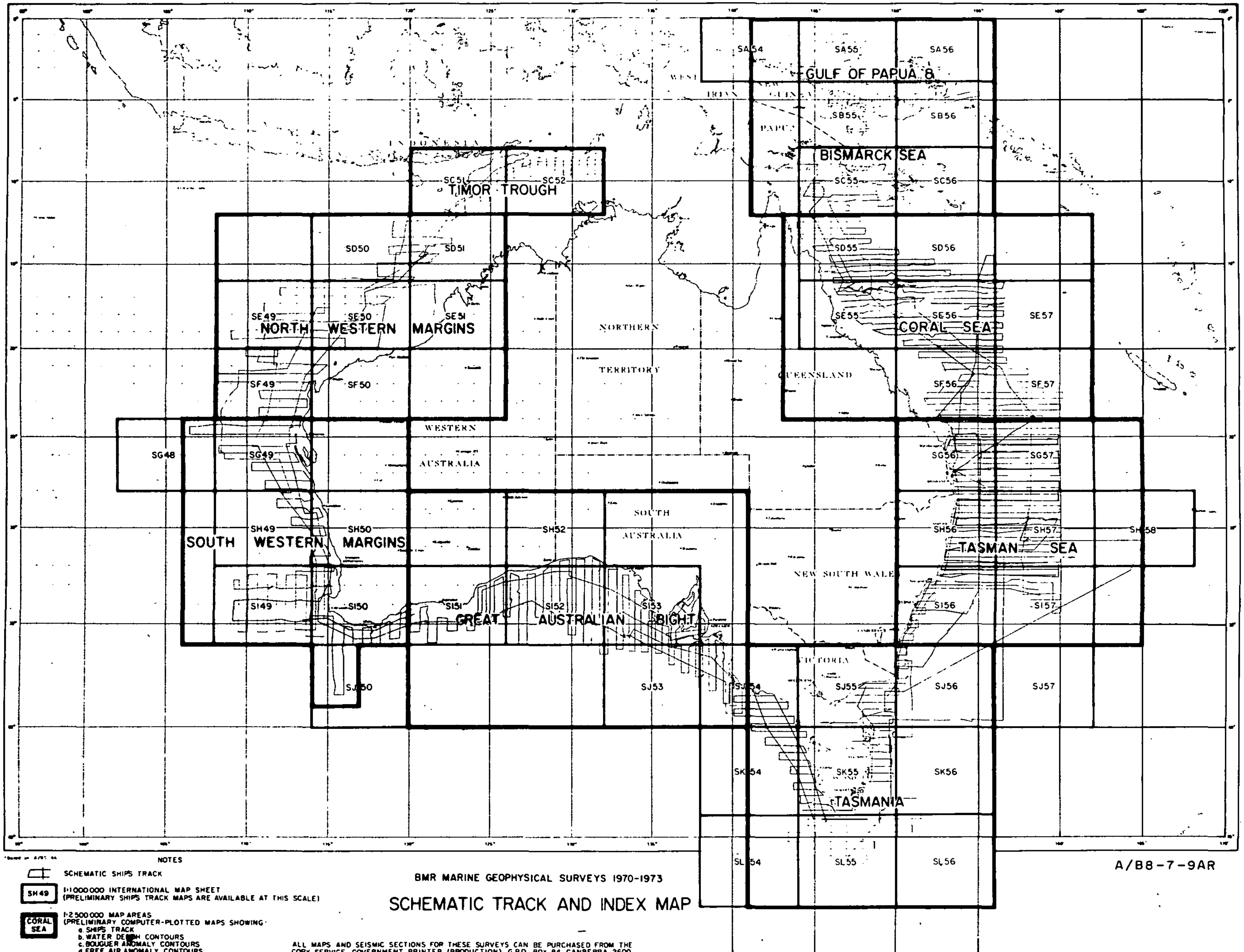

NOTES

SCHEMATIC SHIPS TRACK

SH49 — 1:1000000 INTERNATIONAL MAP SHEET (PRELIMINARY SHIPS TRACK MAPS ARE AVAILABLE AT THIS SCALE)

CORAL SEA — 1:2500000 MAP AREAS (PRELIMINARY COMPUTER-PLOTTED MAPS SHOWING
a. SHIPS TRACK
b. WATER DEPTH CONTOURS
c. BOUGUER ANOMALY CONTOURS
d. FREE AIR ANOMALY CONTOURS
e. MAGNETIC ANOMALY CONTOURS
ARE AVAILABLE AT THIS SCALE)

BMR MARINE GEOPHYSICAL SURVEYS 1970-1973

SCHEMATIC TRACK AND INDEX MAP

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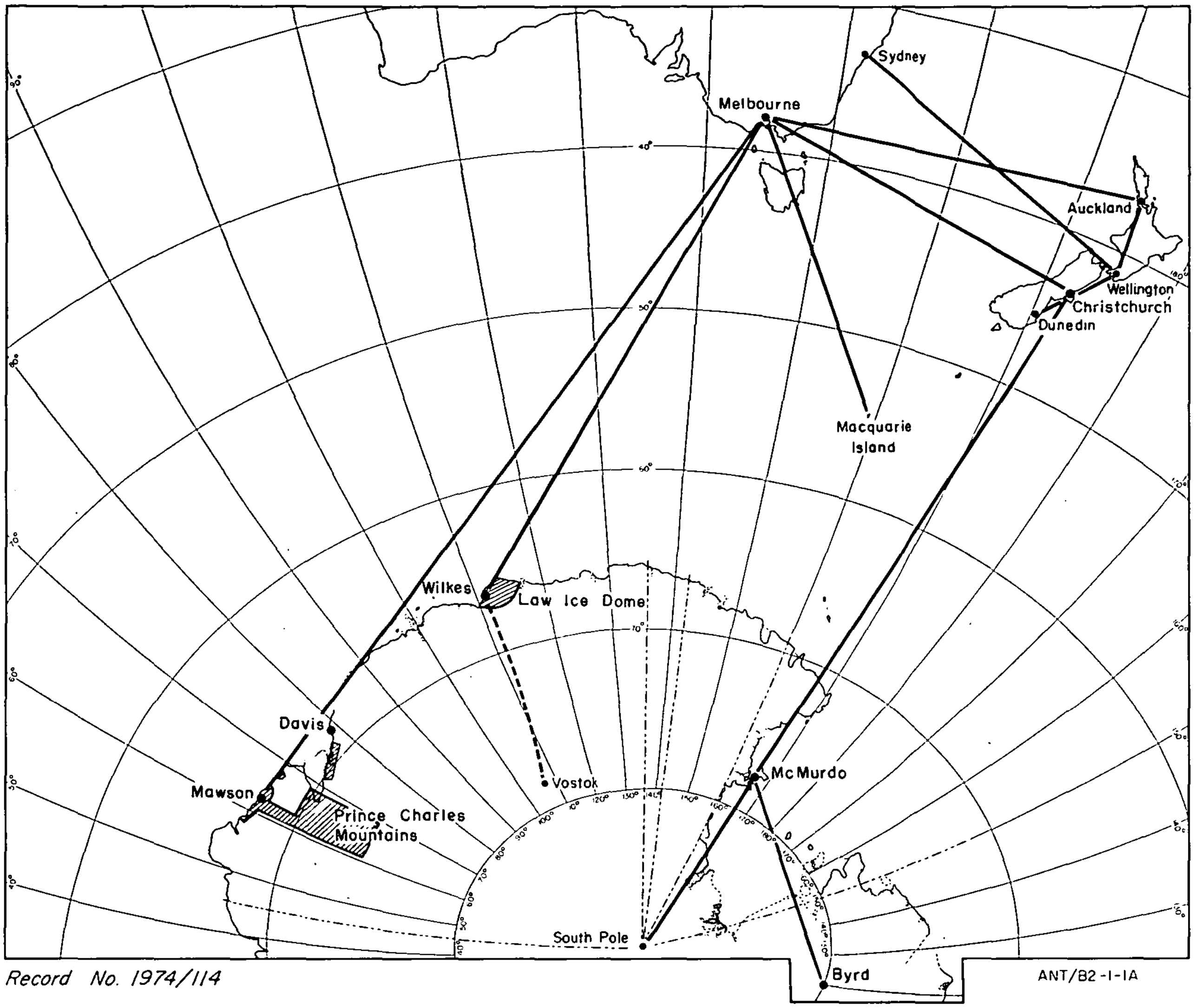
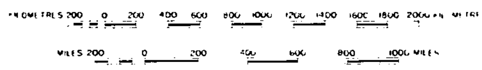
PLATE 5



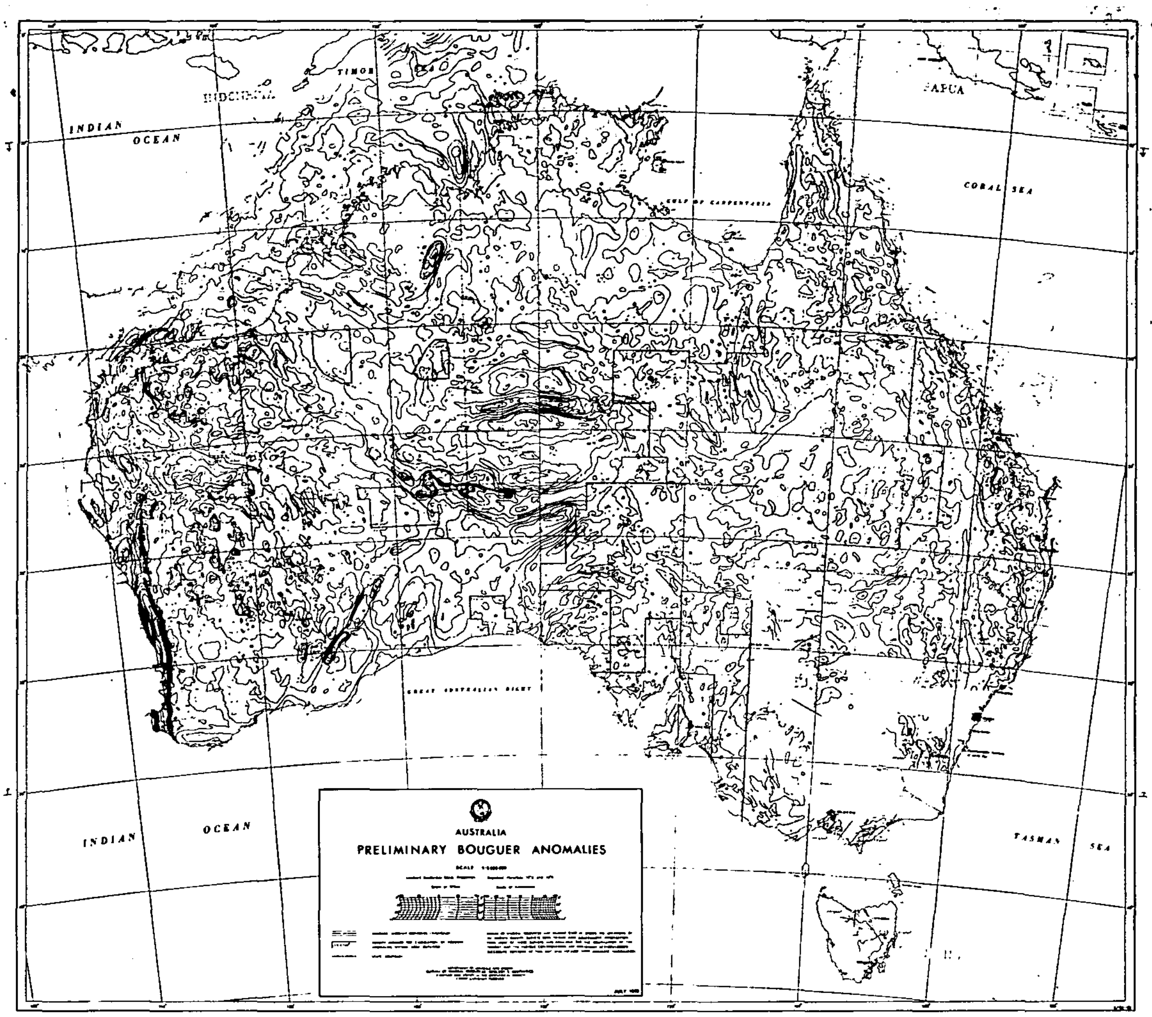


AUSTRALIAN GRAVITY MEASUREMENTS IN ANTARCTICA AND NEW ZEALAND, 1956-1974

- - Gravity traverse

— Gravity tie

▨ Gravity observations


INDIAN
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SEA