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INTERNATIONAL UNION FOR GEODESY AND GEOPHYSICS
INTERNATIONAL ASSOCIATION OF GEODESY
FIFTEENTH GENERAL ASSEMBLY
MOSCOW, U.S.S.R.
1-14 AUGUST 1971

AUSTRALIA

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT

FOR THE PERIOD 1 JANUARY 1967 TO 31 DECEMBER 1970

(Part B: National report on gravimetry for the period 1967-1970. BMR Record 1971/145)

INTERNATIONAL UNION FOR GEODESY AND GEOPHYSICS
INTERNATIONAL ASSOCIATION OF GEODESY
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NATIONAL REPORT FOR AUSTRALIA

1967 - 1970

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COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON GEOMETRICAL GEODESY

FOR THE PERIOD 1967/1970

The attached diagrams show the geodetic traverses, triangulation and Aerodist trilateration in Australia and in New Guinea at the end of 1970.

The geodetic work during the period has been carried out by the Division of National Mapping of the Department of National Development, the Royal Australian Survey Corps of the Department of the Army and the Survey Branch of the Department of the Interior and the Lands Departments within their own States or Territories.

Geodetic Survey

	High Precision Traversing	Traverse & Trig		Aerodist Trilateration	
		1st Order	2nd Order	New Stations	Lines Measured
	km	km	km		
1967	1580	1390	8351	194	632
1968	2616	481	7714	175	749
1969	2204	3472	4248	111	408
1970	645	4436	4291	154	647
Total	7045	9779	24604	634	2436

Satellite Base Lines

Two base lines for the Pageos Satellite World Triangulation have been measured by the Division of National Mapping. The east-west base line between Culgoora in NSW and Perth is 3280 km long and the south-north base from Culgoora to Thursday Island near the tip of Cape York Peninsula is 3048 km long.

The survey of the base lines started in 1966 and until the successful introduction of Laser Model 8 Geodimeters in late 1969 distances along the bases were measured with MRA4 Tellurometers Each distance was measured on two days.

Since the introduction of Laser Geodimeters, of which there are now five in Australia, specifications stipulate that high precision traverse distances should be measured with a Laser Geodimeter, but where this is impracticable with MRA4 Tellurometers. Measuring frequencies of these instruments have been checked with a frequency counter every two weeks.

Lines of up to 68 km in length have been measured with Model 8 Geodimeters employing 42 prisms. Smoke, dust particles, shimmer and haze restrict the use of the Laser Geodimeter over geodetic distances in Australia whereas high humidity in coastal regions limits the range of MRA4 Tellurometers. Simultaneous reciprocal vertical angles are observed when the Geodimeter is used to measure distances in excess of 30 km, to determine the coefficient of refraction.

Astronomic azimuths are determined simultaneously from both ends of a line by observations to Sigma Octantis on two nights. Wild T3 theodolites are used in this work. Astronomic azimuths are observed along each line in a pure traverse and on every second line in triangulation.

A comparison of the chord distances between the BC4 camera axes obtained from the 1966 National Geodetic Adjustment and from the free adjustment of the high precision survey is as follows:

East-West Base line	Chord Distance of E-W Base Line
National Adjustment 1966	3 163625.13 m
Free Adjustment 1969 High Precision Survey Preliminary value	3 163623.54 m
Difference	+1.59 m
	or +0.50 ppm

The maximum discrepancies occur near the middle of the base line amounting to 4.5 m in the direction of the line and 5.1 m at right angles to it.

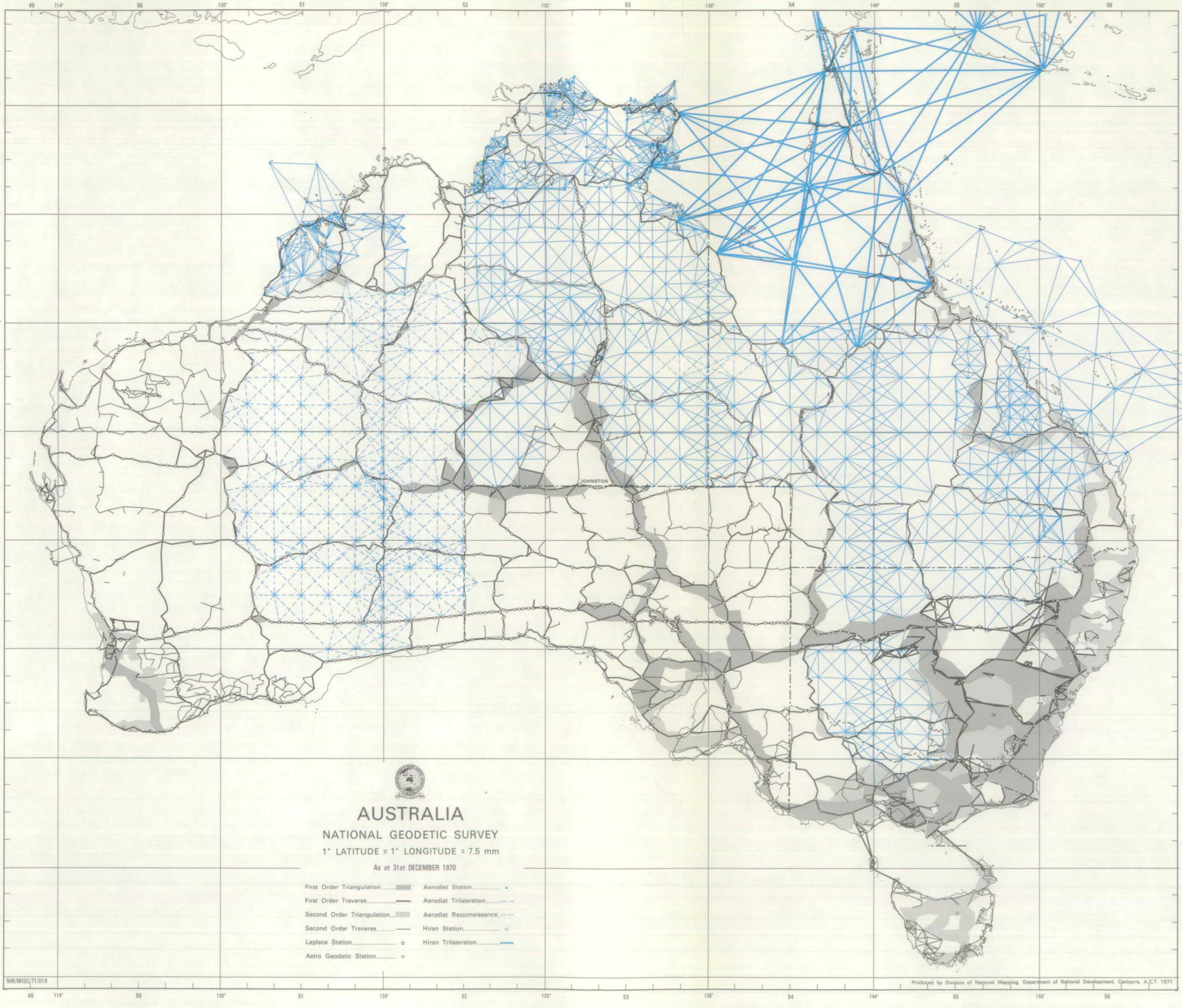
North-South Base line	Chord Distances of N-S Base Line
National Adjustment 1966	2 300207.60 m
Free Adjustment 1970 High Precision Survey Preliminary value	2 300211.92 m
Difference	-4.32 m
	or -1.90 ppm

The maximum discrepancies occur near the north end of the line amounting to 4.5 m in the direction of the line and 4.9 m at right angles to it.

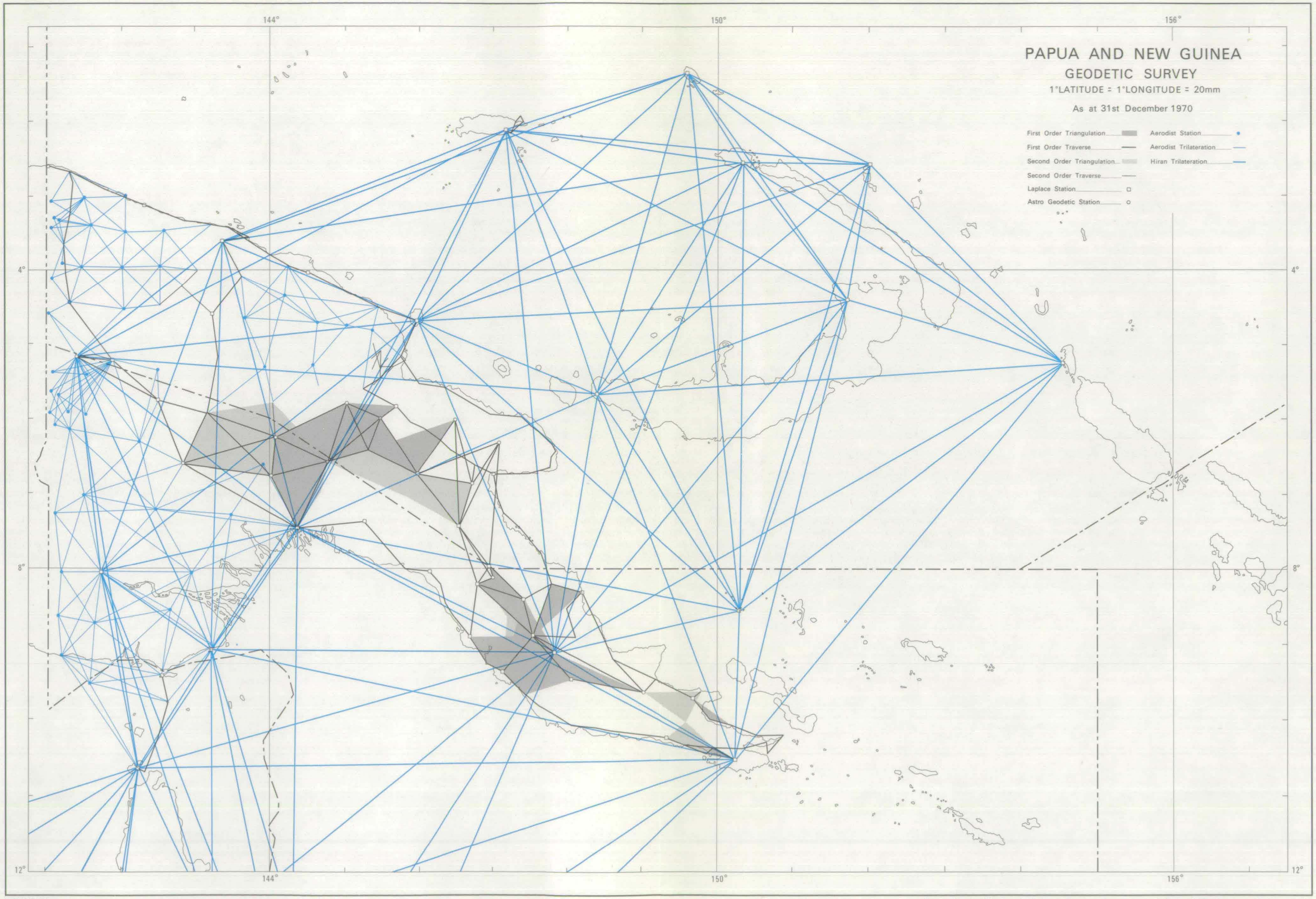
Geodetic Computing

Most geodetic computations in Australia are carried out on electronic computers. The bulk of the computations for the Division of National Mapping and the Royal Australian Survey Corps are done on the CDC 3600 computer owned by the Commonwealth Scientific and Industrial Research Organisation in Canberra. An increasing amount of computations is performed on the CDC 6600 in Sydney through a land-line from Canberra.

A description of new computer programs and details of new computers are recorded in "Electronic Survey Computing" published annually by the National Mapping Council of Australia. Copies are available on request from the Director of National Mapping, Canberra.



AUSTRALIA
NATIONAL GEODETIC SURVEY
1° LATITUDE = 1° LONGITUDE = 7.5 mm
As at 31st DECEMBER 1970
First Order Triangulation
First Order Traverse
Second Order Triangulation
Second Order Traverse
Laplace Station
Astro Geodetic Station
Aerodist Station
Aerodist Trilateration
Aerodist Reconnaissance
Hiran Station
Hiran Trilateration
JOHNSTON
NM/MISC/71/019
Produced by Division of National Mapping, Department of National Development, Canberra, A.C.T. 1971



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Drawn by the Division of National Mapping, Department of National Development, Canberra A.C.T.

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON LEVELLING AND MOVEMENTS OF THE EARTH'S CRUST

FOR THE PERIOD 1967-1970

REPORT ON THE NATIONAL LEVELLING SURVEY

At the end of 1970 the Australian Levelling Survey had been extended to cover all of the Australian continent and the levelling of lines selected for inclusion in the National Levelling Adjustment had been completed.

The levelling network consists mainly of two-way third order levelling observed with automatic instruments and wooden staves. Most of the precision levelling was also observed with automatic instruments but in this work invar staves were used exclusively.

No levelling has been carried out in the Territory of Papua and New Guinea as part of the Australian Levelling Survey.

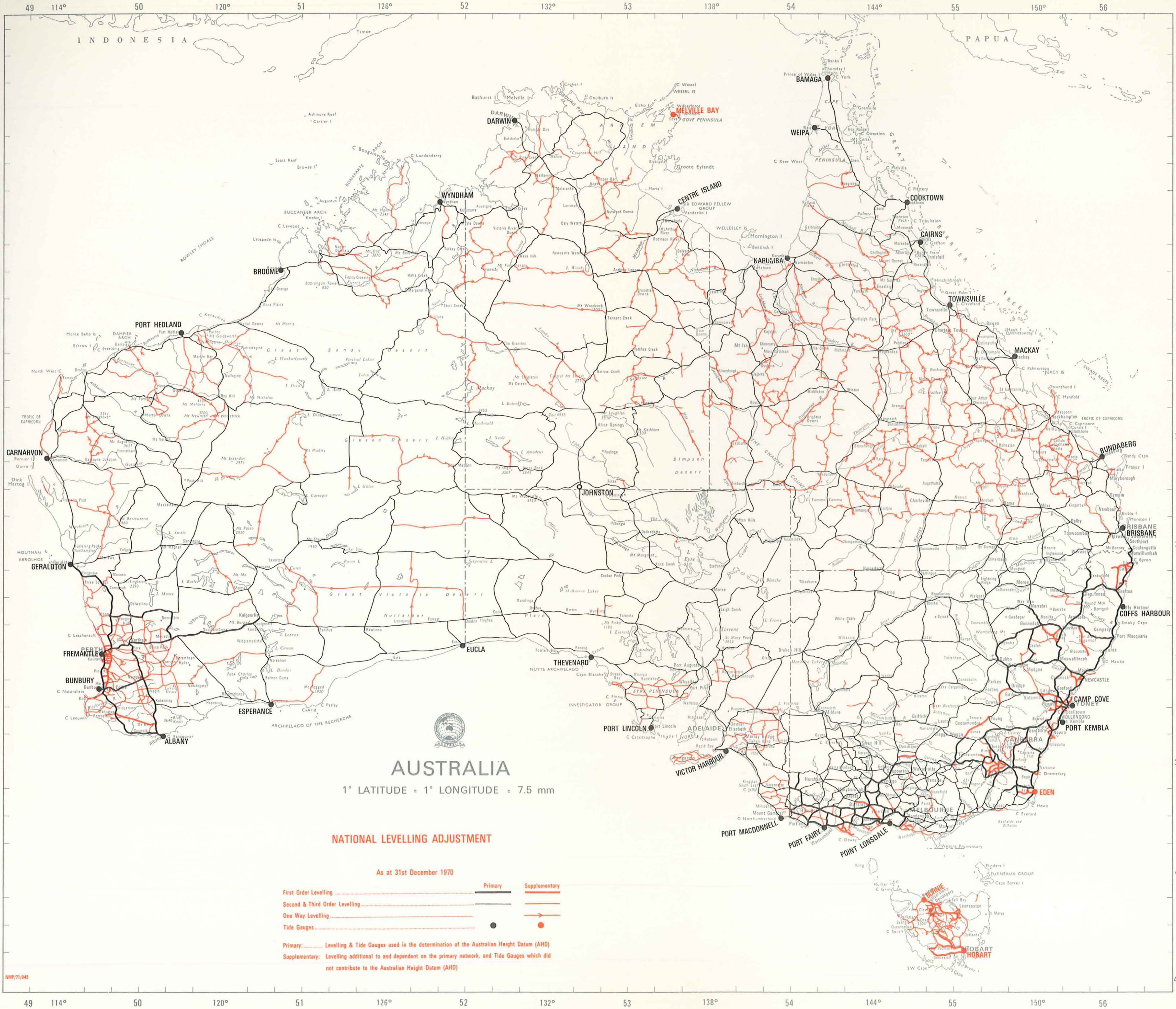
A total of 97,320 km of two-way levelling has been selected for use in the National Levelling Adjustment and for the determination of the Australian Height Datum. This adjustment will be completed early in 1971. Following this adjustment the remainder of the two-way levelling and a great many miles of one-way levelling already observed as part of the network will be brought onto the Australian Height Datum.

The tide recording programme begun on 1 January 1966 ended on 31 December 1968 when the information obtained from the 31 tide gauges on the mainland coast was considered sufficient for the determination of an Australian Height Datum.

Progress in levelling during the 4 year period is given in the table:

Two-Way Levelling (Kilometres)

	Precision	Third Order
1967	573	17 536
1968	507	13 197
1969	946	6 330
1970	534	5 889
	2 560	42 952



NM/Misc/71/019

Produced by Division of National Mapping, Department of National Development, Canberra, A.C.T. 1971

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON GEODETIC ASTRONOMY AND GEOMETRIC STUDY OF SATELLITES

FOR THE PERIOD 1967-1970

FIELD ASTRONOMY

During the four years 1967 to 1970 precise observations were made for latitude and longitude at 750 stations; 129 of these were repeat observations for assessment of accuracies, training and testing of new observers, and at 35 stations re-observation of longitudes observed by stopwatch or other fixed-wire methods. Azimuths were observed at 198 stations, almost wholly in simultaneous reciprocal pairs.

An important step was the introduction of astro-geodetic levelling along geodetic traverses. Two of the profiles were used for the preliminary reduction to the Australian National Spheroid of high precision traverses along two satellite base lines and the scheme later formed an astro-geodetic framework for the determination of the geoid over Australia. A total of 1133 stations were used for the geoid determination.

All astronomic observations had corrections applied as set out in National Mapping Technical Report 1, "Small Corrections to Astronomic Observations" and were reduced to the Conventional International Origin.

Technical Report 10 was published setting out the methods developed in astronomic observations up to mid 1970.

All latitudes and longitudes observed during the period were observed with Kern DKM3A theodolites. Longitudes were observed by the almucantar method, using the double Horrebow bubble and moving wire eyepiece, and latitudes by circum-meridian observations.

Azimuths were observed mostly with Wild T3 theodolites although a few were observed with Kern DKM3A theodolites concurrently with the latitude and longitude observations. Generally 24 zeroes were observed at a station, spread over two nights, to Sigma Octantis.

SATELLITES

Satellite observation stations at 20 localities in Australia and its territories, comprising 51 facilities, have been coordinated on the Australian Geodetic Datum (AGD). Four others, on oceanic islands and the Antarctic continent, have no geodetic connections. The stations carry out telemetry, photography of satellites, tracking of space vehicles, telecommunications, very long base line interferometry and observations of radio stars.

The completed Tranet observation programme gave values for chord distances between nine stations on Australian territory. Comparisons with distances were calculated from the national geodetic survey using geoid-spheroid separations (N) derived from the US Army Map Service 1967 preliminary geoid chart of Australia. They showed an average difference without sign of 4.332 m (2.25 ppm) and with sign -0.891 m (-0.20 ppm). The geodetic distances were longer. A new comparison will be made using geoidal heights on the Australian Height Datum and geoid spheroid separations from the 1971 geoid over Australia. The Tranet distances were calculated on the NWL8D4 datum for seven stations and the NWL 81 datum for Thursday Island and Culgoora.

Comparisons have been made between the Australian Geodetic Datum and five earth centred datums, in the form of differences in X, Y and Z and differences in astronomic deflections and N at the Johnston Origin in the approximate centre of Australia. The average vector displacement $(\Delta X^2 + \Delta Y^2 + \Delta Z^2)^{\frac{1}{2}}$ was 177 m with a standard deviation of 4.7 m. The average deflections were +4".23 in the meridian and -3".78 in the prime vertical.

A comparison of the major geodetic datums with the SAO-C7 datum, published in NASA Directory of Observation Stations November 1970, showed the AGD only 128.2 m separated at the centre of the earth. It was the closest of the major geodetic datums, no doubt because it is the most recently established.

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON DYNAMIC GEODESY

FOR THE PERIOD 1967-1970

The determination of the astro-geodetic geoid in Australia, 1971, was done in two phases by the Division of National Mapping.

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 kilometres, of which 24 650 kilometres 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 metres, the average loop length being 1656 kilometres. The greatest standard error at any junction point relative to the Johnston geodetic station in the centre of Australia is 1.5 metres.

Misclosures of loops of primary geoidal profiles and of all loops of geoidal profiles are shown on the attached diagrams.

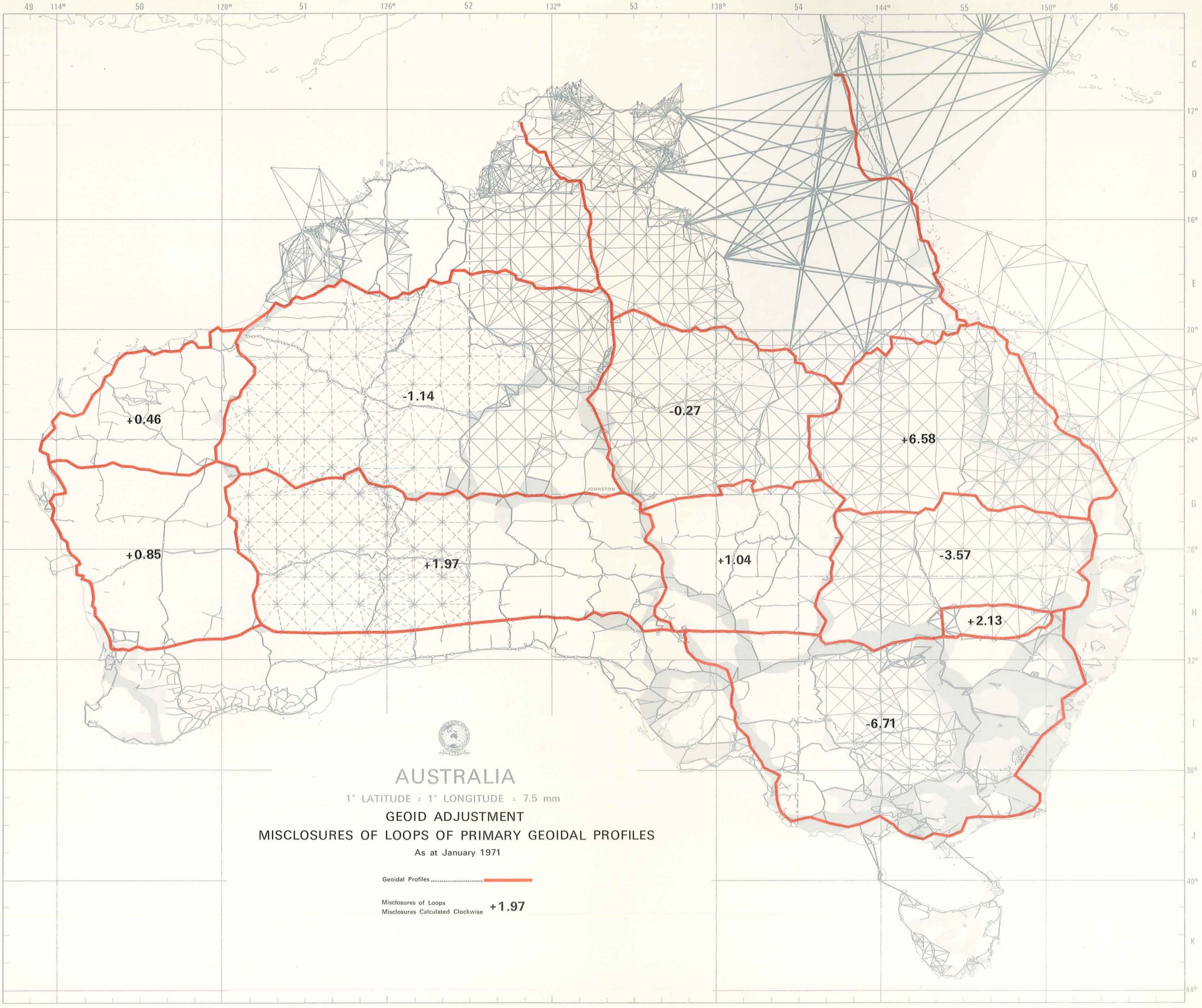
In the adjustment, Johnston was held fixed with zero separation between the geoid and the spheroid. In order to fit the Australian National Spheroid more closely to the geoid, a value of N = -6 at Johnston has been adopted which minimises the scale change between the 1966 geodetic adjustment and any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

The second phase consisted of the computation of 1679 values of N, Xi and Eta at 30 minute intervals from gravimetric observations. This work was carried out at the University of New South Wales. The gravimetric values were adjusted, loop by loop, into terms of the astro-geodetic values around the loop perimeters.

Maps of N, Xi and Eta were produced on a rectangular projection at a scale of 15 millimetres per degree on an automatic flat bed plotter. The contour interval is 1 metre 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 will be completed in April 1971.

A detailed description of the geoid determination in Australia and New Guinea will be given in Technical Report 13 "The Geoid in Australia 1971" by J. G. Fryer to be published by the Division of National Mapping, Canberra, in July 1971.



AUSTRALIA

1° LATITUDE = 1° LONGITUDE = 7.5 mm

GEOID ADJUSTMENT

MISCLOSURES OF LOOPS OF PRIMARY GEOIDAL PROFILES

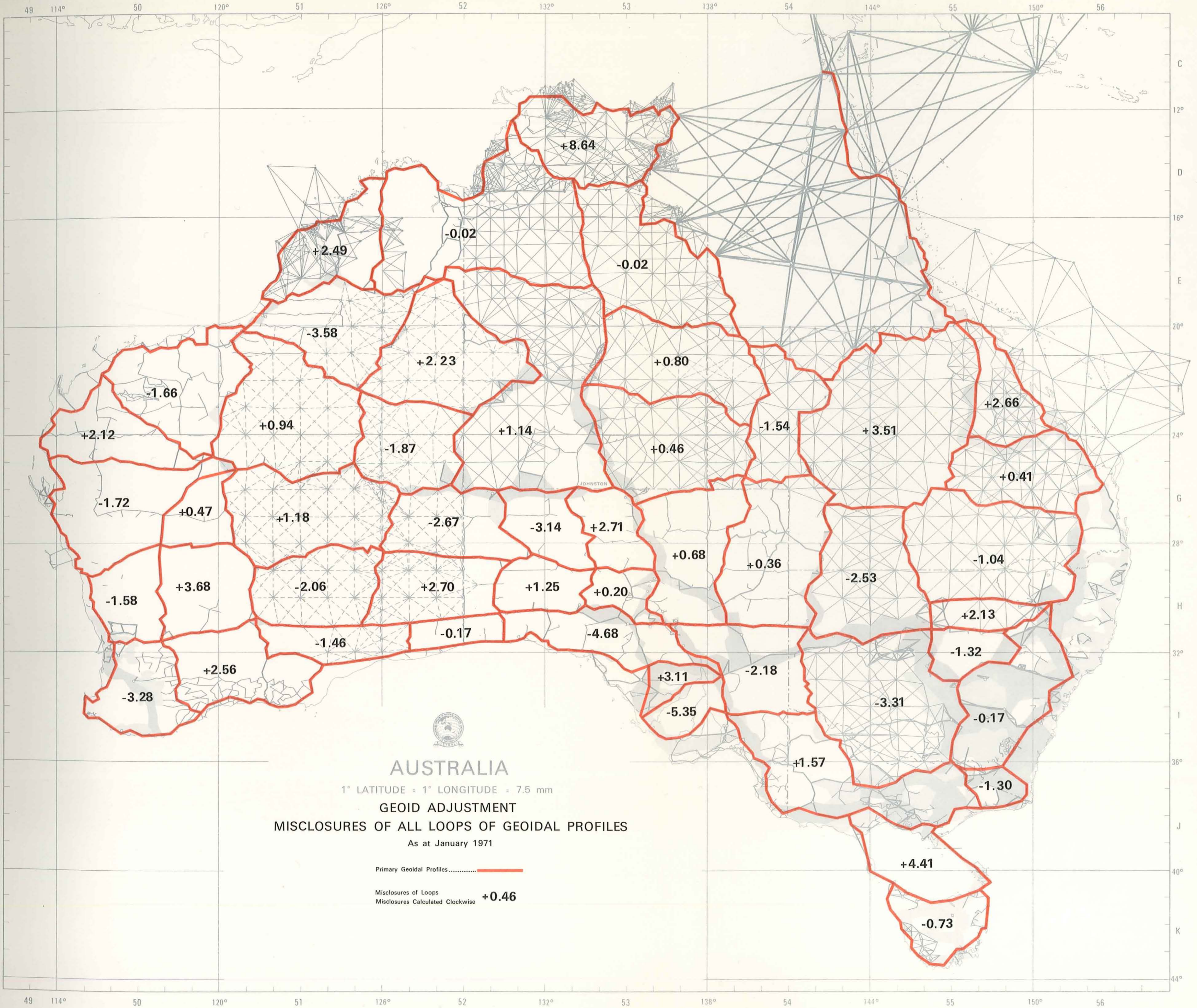
As at January 1971

Geoidal Profiles ....

Misclosures of Loops
Misclosures Calculated Clockwise +1.97

NM/Misc/71/019

Produced by Division of National Mapping Department of National Development, Canberra, A.C.T. 1971



NM/Misc/71/019

Produced by Division of National Mapping, Department of National Development, Canberra, A.C.T. 1971

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Part B

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON GRAVIMETRY
FOR THE PERIOD 1967/1970

1. INTRODUCTION

The following report gives an account of gravity work in Australia and Australian Territories between 1 January 1967 and 31 December 1970. It incorporates and summarises the report prepared for the Sixth Meeting of the International Gravity Commission at Paris in September 1970 (Barlow, 1970) and brings up-to-date the report prepared for the Fourteenth General Assembly of the International Association of Geodesy (Barlow, 1968).

The contribution of gravity data from other Commonwealth and State Government organisations, universities, numerous private companies, and visitors from overseas is acknowledged. This report was prepared in the Geophysical Branch of the Bureau of Mineral Resources, Geology and Geophysics (BMR).

2. ABSOLUTE DETERMINATION OF GRAVITY

The National Standards Laboratory (NSL) is making an absolute measurement of gravity at Sydney by the method of free rise and fall of a metal corner reflector through planes defined interferometrically. A preliminary value based on 51 determinations with a standard deviation of 0.2 milligal corresponds to a value of 979 671.7 milligal at Sydney A and indicates a correction of -13.9 milligal to the previous Potsdam datum (Gibbings et al, 1970).

3. INTERNATIONAL GRAVITY CONNECTIONS

Cambridge University, U.K., made pendulum observations at the National Gravity Base Station, Melbourne A, in 1967 as part of measurements on the Western Pacific Calibration Line (WPCL), (Browne & Honkasalo, 1970). The unfortunate illness of Mr B.C. Browne at Singapore prevented repeat observations being made in Melbourne prior to final swings in Teddington, U.K. This weakened the ties between Australia and other countries and also the direct tie Teddington - Melbourne.

The Geographical Survey Institute (GSI) of Japan made pendulum ties between Tokyo and Sydney and Canberra in 1967 and between Tokyo and Brisbane during 1970. The BMR set of GSI pattern pendulums were swung side by side with the GSI set at Sydney and Canberra during the 1967 work. The BMR set of pendulums continue to give unsatisfactory results. New pendulums with extremely low profile knife edges (Caw, 1969) have been constructed by NSL and new solid-state timing equipment has been designed and built by BMR. The improved apparatus is now being tested.

Gravity meter ties to Australia by overseas organisations were made by the Royal Thai Survey Corps during 1967 and by the United States Hydrographic Office as part of Project Magnet.

During 1967 BMR made a three-meter tie between the Australia/TPNG gravity network and Honiara, British Solomon Islands.

During 1969 BMR made a ladder sequence of observations along most of the WPCL and the most northern part of the North American Calibration Line between Sydney, Australia and Point Barrow, Alaska. Ladder sequences to the north and south of Tokyo gave measurements on the Japanese Calibration Line between Sapporo and Kumamoto. Four La Coste meters were used - three BMR meters and one loaned by the Antarctic Division of the Commonwealth Department of Supply. Two of the meters require only linear scale factor correction to give gravity intervals in very good agreement with the mean result of the four La Coste meters used on the WPCL by the United States Air Force (USAF) in 1965. The behaviour of the other two meters was not so consistent and their results are considered to be less reliable. Cooke (in press) analyses the results of this work together with measurements on the ACL during 1970 (see chapter 4).

4. AUSTRALIAN NATIONAL GRAVITY NETWORK

The history of the establishment of the Australian National Gravity Network (ANGN) up to June 1965 is given by Dooley (1965a). Two dates are of particular significance - 1950/51 which saw the establishment of the Cambridge pendulum stations throughout Australia (Dooley et al., 1961), and 1962 when the values at these stations were revised by Dooley (1965b) on the basis of gravity meter and pendulum ties up to that date.

During 1964/70 the ANGN was considerably strengthened by a series of Isogal regional surveys using groups of gravity meters. The base stations of the present ANGN and the traverses of these surveys are shown in Plate 2.

The ANGN places heavy reliance on the Australian Calibration Line (ACL), a north-south chain of base stations which follows the east coast of Australia for most of its length (see Plate 2.) On the Australian mainland the east-west traverses carry the east coast values across Australia, while north-south traverses through the centre of Australia and along the west coast provide links for distribution of loop misclosures.

The 1962 values at Melbourne, Cairns, and Darwin were considered to be particularly good, being based on several pendulum measurements as well as gravity meter ties. The 1962 value of 979 979.00 mgal at the National Gravity Base Station (NGBS) at Melbourne, has been accepted by BMR and is still retained as the datum for the ANGN. The mean milligal defined by the average given by the two intervals Melbourne-Cairns and Melbourne-Darwin, as calculated from the 1962 values, has been accepted as the "mean Australian milligal". Values for these two intervals were calculated from the 1965 USAF/BMR observations on the WPCL & ACL (see Chapter 4) using calibration tables obtained at the La Coste & Romberg factory. The mean intervals for the five La Coste meters required a correction factor of 0.9997 to give the best fit to the intervals expressed in mean Australian milligals. Datum values relative to NGBS for the ACL between Melbourne and Cairns and a value for Darwin were calculated from the USAF/BMR observations using this correction factor.

Most of the east-west traverses were flown in 1964-65 (Barlow, 1969, Plate 3). Forty-seven of the Cambridge pendulum stations established during 1950/51 were re-occupied. The mean intervals, as determined by the three or four meters, and the relevant east coast datum for each east-west traverse were used to calculate values at the base stations of the ANGN referred to as the "May 1965 Isogal values".

For each Cambridge pendulum station the new Isogal value was compared with that given by the 1950 pendulum measurement (result computed without magnetic correction). The difference was plotted against observed gravity value. The regression line is parallel to, and close to, the observed gravity axis, giving the important result that the mean Australian milligal, as defined above, is compatible with the mean milligal defined by this set of 47 Cambridge pendulum measurements.

During 1967 the remaining east-west traverses on the Australian mainland were completed and north-south traverses were flown through the centre of Australia and along the west coast. It has been estimated that the standard error in the gravity value at a station relative to the east-west traverse passing through that station is 0.1 mgal, and that the standard error in the gravity value at a station relative to the network as a whole is 0.2 mgal.

The Australian network was extended to cover the whole of the Territory of Papua and New Guinea (TPNG) during 1967 by reading a series of Isogal-type traverses, although the rugged terrain of the inland parts of TPNG and extraordinarily large gravity anomalies throughout the whole area precluded the design of a set of Isogal lines of equal observed gravity value (see Plate 2). The TPNG Isogal network was extended to Munda and Honiara in the British Solomons Islands Protectorate.

During 1966, the Dominion Observatory of Canada made observations along the ACL between Melbourne and Cairns using two La Coste meters. The results do not appear to be as consistent as those of the USAF/BMR meters, and no account has been taken of them as yet.

BMR made a multi-meter run on the ACL during 1970 to strengthen the intervals between Melbourne and Cairns and to extend the chain to its full length - Hobart (Tasmania) to Mount Hagen and Laiagam (TPNG). Three observers made concurrent readings on nine gravity meters - 3 La Coste & Romberg, 4 Worden, and 2 Sharpe Canadian meters. A chartered aircraft was used to transport the team, which included an observer and gravity meter from the Geological Survey of New South Wales, (NSW). Full drift control was obtained by repeat observations in the order ABAB for each interval. Although many of the gravity intervals were beyond the limited (120 mgal) range of the Sharpes, all intervals were within small dial (240 mgal) range of the Wordens and could, of course, also be measured by the La Costes. The accurate intervals established by this group of seven (or nine) meters will be taken into account in the next adjustment of the ANGN. This work also established correction factors to be applied to the calibration factors of the BMR La Coste meters. These will permit calculation of results expressed in mean Australian milligals for those intervals along the WPCL and Japanese Calibration Line which were measured by BMR during 1969 (See Chapter 4).

Other valuable results of the 1969 measurements on the ACL were the re-determination by nine meters of the seven gravity meter calibration ranges located on the ACL, and the accurate determination of the interrelationship between the "Australian calibration range milligal", as defined by the accepted intervals on the gravity meter calibration ranges, and the mean Australian milligal. These appear to be compatible to within 0.02%.

After publication of the May 1965 Isogal values it is proposed to adjust the ANGN over the whole of Australia and TPNG. This adjustment, which will take several years, will take into account all ties that have been made in Australia both between Isogal places and between the base and excentres at each place.

5. CALIBRATION AND PERFORMANCE CHARACTERISTICS OF GRAVITY METERS

The establishment of eight local gravity meter calibration ranges throughout Australia by BMR during 1960/61 has been described by Barlow (1967). A gravity meter calibration range was established at Canberra in 1965. Results obtained during multi-meter control surveys indicated that the provisional value of 52.72 mgal ascribed to this range was in error. A re-determination made in 1968 with six meters (Milsom & Nik Mohamed, 1969) gave the value 52.76 mgal. An adjustment of several hundredths of a milligal will need to be made to the accepted value of the Hobart Calibration Range, which was re-determined during the 1970 measurements on the ACL. During these measurements re-determinations were also made of the calibration ranges at Canberra, Sydney, Brisbane, and Townsville in terms of the Melbourne range; the values of these ranges are within the limits of accuracy specified by Barlow (1967). The 1970ACL measurements also established a new local gravity meter calibration range at Port Moresby. All gravity meters used in Australia during the period under review have been calibrated on at least one of the ranges to facilitate integration of results.

The establishment of the ACL has made possible the calibration of geodetic meters in terms of the mean Australian milligal (for definition see Chapter 4) and the intercomparison of geodetic and exploration meters. The ACL consists of 25 base stations with a maximum gravity interval of 203 mgal, the difference in the gravity values at the two ends of the line being 2946 mgal. Commercial air transport is available between most of the stations, although several would need to be overflown, so that regular airline flights can be used only when calibrating geodetic meters. The seven local calibration ranges which are located on the line provide short-range calibration facilities.

Measurements made with geodetic gravity meters on the ACL and WPCL during recent years enable the Australian calibration standards to be compared with intervals on the WPCL, and hence with international calibration standards. As far as can be assessed at this stage, the Australian and international standards agree to within 1 part in 3000.

Repeated calibration runs, together with multi-meter control surveys, in which several different types of meters are read concurrently, have continued to give useful information regarding the performance characteristics of gravity meters. Discrepancies of 0.1 - 0.2 mgal are revealed by this work and require investigation (Barlow, 1970). Shortage of staff has prevented BMR from carrying out further laboratory tests on the performance characteristics of gravity meters, particularly tests on erratic behaviour induced by vibration and possibly other factors.

6. GRAVITY COVERAGE IN AUSTRALIA AND THE TERRITORY OF PAPUA & NEW GUINEA

The distribution of gravity stations in Australia and TPNG as at June 1970 is shown in Plate 3, which may be compared with the distribution as at December 1966 given by Barlow (1968).

The gravity coverage of the continent of Australia has been further accelerated by increasing the area covered annually by BMR reconnaissance gravity surveys, which have a station density of 1 station per 130 square km and use helicopter transport. During the period under review a total area of more than 3 million square km was surveyed, and 80 percent of the continent of Australia is now covered by at least reconnaissance gravity observations.

Many important contributions to the gravity coverage of Australia have been made by private exploration companies mostly operating under the Petroleum Search Subsidy Acts, under which approved oil-search geophysical surveys are subsidised by the Commonwealth. Some companies have used helicopters to obtain reconnaissance coverage in areas where there was little or no gravity data. For example, an area of about 200,000 square km in the north-east corner of South Australia (SA) has been covered by subsidised BMR-pattern surveys with at least 1 station per 42 square km.

Important contributions have also been made by State Mines Departments (notably those of SA and NSW) and by Universities (notably that of Tasmania). During the period under review, the SA Mines Department added 700,000 square km to the area already covered by them at 1 station per 42 square km, using both road and helicopter transport. They also made regional road traverses and conducted detailed surveys in several areas of SA. The Geological Survey of NSW (Mines Department) has made regional road traverses and conducted detailed surveys in NSW. The Geology Department of the University of Tasmania has completed the reconnaissance coverage of that State (partly by helicopter) and conducted some detailed surveys.

During 1966-68 regional coverage was obtained over the south-eastern portion of the mainland of TPNG, and the coverage extends farther to the south-east, stations being established by helicopter on all islands and all reefs exposed at low tide. Landing sites, suitable even for a helicopter, are difficult to find in many parts of both the onshore and offshore areas, and stations could not always be established on an 11-km grid. Similar regional coverage was obtained during 1969 over New Britain, New Ireland, and the islands off the east coast of New Ireland. During 1968 a special effort was made to obtain reconnaissance gravity coverage of the Sepik River area with stations on a 6-7 km grid. Although most readings were obtained by the conventional helicopter gravity technique, the hover-site method was tested in the Sepik swamp, using a remote-reading underwater gravity meter lowered from a hovering Jet Ranger helicopter; this work showed that the new technique had promise but required further development (Darby et al., 1969).

Plate 4 shows the gravity coverage of Australia and TPNG as at June 1970. The classification of the types of coverage has been changed from that used in earlier National Reports (e.g. Plate 1 in Dooley, 1965a). This change was necessary because BMR now uses the metric system and because of the improved coverage of Australia. Since June 1970, BMR and the SA Mines Department have completed the coverage of SA at 1 station per 42 square km. The western part of the State was covered by a BMR contract survey, the specifications of which were amended to give the denser coverage. The SA Mines Department co-operated in the supervision of this contract, and itself completed the required coverage in the remaining area in the eastern part of the State.

It is expected that the reconnaissance gravity survey of mainland Australia will be completed by 1972/73.

7. GRAVITY MEASUREMENTS AT SEA

During the period 1965 to June 1970 BMR covered 0.8 million square km of the continental shelf of Australia by contract marine geophysical surveys to the north-west of the continent of Australia - see Plates 3 and 4. These surveys were carried out primarily to extend the reconnaissance gravity coverage of the mainland over the continental shelf, and to obtain seismic reflection data. Continuous recordings were made along traverses spaced 16 km (9 nautical miles) apart at a ship speed of about 18 km per hour (10 knots), this speed being a compromise between the requirements of the gravity and seismic systems. These surveys have gradually incorporated other geophysical methods for relatively small additional costs. Feasibility tests of geophysical methods not previously used on surveys in Australia and experience with advanced navigational techniques have made a large contribution to improving the methods of operation, and to the geophysical coverage of offshore Australia.

During the second half of 1970 a further BMR survey covered 0.4 million square km of the continental shelves of mainland TPNG and the Bismarck Archipelago with a similar reconnaissance pattern. Traverses were also read at a spacing 37 km (20 nautical miles) across the deeper waters of the Bismarck Sea and the northern part of the Coral Sea with isolated traverses in the Solomon Sea to provide regional gravity data for crustal studies and other purposes over an area of 0.3 million square km.

BMR will commence an extensive marine survey in 1971 to provide regional coverage of the whole of the continental shelf and slope of mainland Australia with the exception of the Gulf of Carpentaria and the Great Barrier Reef. Subsequent surveys will cover these areas and intensify the coverage of the remainder of the continental shelf to reconnaissance standard.

Hawaii Institute of Geophysics made surface gravity meter observations along traverses to the north of TPNG and in waters around the Bismarck Archipelago in the Royal Navy vessel "HMS Dampier" during 1965. The US Coast & Geodetic Survey read a gravity traverse down the west coast of Australia, across the Great Australian Bight, along the south-east coast of Australia, and across the Tasman Sea in the vessel "USCGSS Oceanographer" during 1967; Australian observers participated in this cruise.

Hawaii Institute of Geophysics in co-operation with BMR and the University of Queensland made gravity observations east of mainland TPNG in the research vessel "Mahi". The Soviet Geophysical Committee of the Academy of Sciences of the USSR made gravity observations east of Australia during 1970/71 in the research vessel "Vitiaz".

Lamont-Doherty Geological Observatory of Columbia University (LGO) read gravity traverses in the Coral Sea between the Australian mainland and TPNG. Observations were made on the research vessels "Conrad" and "Vema" and on the National Science Foundation vessel "USNS Eltanin". LGO also read regional gravity traverses to the south of Australia on "USNS Eltinin". The University of NSW participated with LGO in the gravity work in both of these areas, and joint reports are in preparation.

8. AUTOMATIC COMPUTING AND COMPILATION OF GRAVITY DATA - GRAVITY MAPS OF AUSTRALIA

BMR has an extensive suite of gravity programmes which are run on the CDC 3600 computer at the Commonwealth Scientific & Industrial Research Organisation (CSIRO) Computer Centre at Canberra. Other organisations involved in gravity work also make use of automatic data processing (ADP). SA Department of Mines use a programme, developed on their behalf by Australian Mineral

Development Laboratories, for the distribution of closure errors for helicopter networks, and for subsequent reduction of gravity results. The University of Tasmania uses an Elliot 503 computer to periodically update and provide data from a master file of principal facts of all gravity stations in Tasmania. The University of New South Wales makes extensive use of ADP for the calculation of isostatic anomalies and geodetic parameters.

The basic BMR gravity reduction programme corrects gravity field observations for tidal effects and meter drift and converts measured intervals to milligal equivalents; makes least-squares adjustment of the gravity network onto base station values (the network can contain up to 400 nodes and 1600 links); computes height differences from field and base barometer observations, correcting for atmospheric parameters, and makes a least-squares adjustment of the height network to fixed elevations at benchmarks; and writes the basic principal facts for each gravity station on magnetic tape. This programme, and peripherals to retrieve principal facts and calculate free-air and Bouguer anomalies have been described by Bellamy et al., (in preparation). Various other programmes have been written to assist in the visual presentation and interpretation of gravity, for example by the automatic plotting and contouring of gravity maps.

The compilation of all available gravity data in Australia and its Territories and presentation of gravity maps of Australia are functions of BMR. The establishment of an accurate network of base stations by the Isogal project and the establishment of gravity meter calibration ranges have made an accurate compilation of all gravity data in Australia at least feasible. ADP has provided the means whereby the huge volume of data can be handled.

About 500,000 gravity stations have been observed in Australia, and the principal facts for about 100,000 of these have been put on the magnetic tape. About half of this information has been released to the Aeronautical Chart and Information Center (ACIC), St Louis, through the Hawaii Institute of Geophysics (HIG). HIG has compiled other Australian data supplied by BMR to approximately the same datum and forwarded it to the ACIC. All of these data are held in the Department of Defence (DOD) Gravity Library, USA and are available internationally from there.

Eventually all usable gravity data will be recomputed to modern standards and stored on magnetic tape. The output from this compilation will be used to prepare an accurate free-air anomaly map of Australia and Bouguer anomaly maps, each computed for a particular density. The data will be in a readily usable form suitable for various geodetic and structural investigations.

Because of the delay necessary in the production of an accurate compilation, and because a less rigorous integration provides data in a form suitable for many purposes, BMR has compiled and published several editions of a preliminary Bouguer anomaly map of Australia. The base map of the Tectonic Map of

Australia (1 inch = 40 miles or 1:2,534,400) was used for the compilation of computed Bouguer anomalies to facilitate a direct comparison between Bouguer anomalies and known regional geological structure. The third edition of this map incorporated data available at the end of 1967, and a reduced version of the mainland portion of this map (1 inch = 270 miles or about 1:17,000,000) is presented in Plate 1. Substantial areas of Australia were covered in 1968 and 1969 (compare Plates 1 and 4) and the remaining areas of the State of South Australia were covered during 1970.

9. GRAVITY MEASUREMENTS IN ANTARCTICA

Two gravity meter ties have been made between Australia and Antarctica by the Antarctic Division of the Commonwealth Department of Supply. The tie Melbourne-Christchurch-McMurdo-Byrd is considered a useful international tie as the two gravity meters have been calibrated over an equivalent interval of the WPCL. A weak tie between Melbourne and Wilkes with a La Coste & Romberg gravity meter was obtained by Antarctic Division from observations made before and after ship transportation of the meter to and from a two year survey in Antarctica.

BMR geologists used helicopters to make a few poorly distributed gravity observations during geological work near the Amery Ice Shelf in the 1968/69 summer and in the Prince Charles Mountains during the 1969/70 summer. During this work a few stations were established near Mawson.

During the past nine years, gravity observations have been made by BMR and Antarctic Division as part of glaciological investigations of the Law Ice Dome (previously known as the Wilkes Ice Dome). Stations at 1.6-km (1-mile) intervals have been observed on a regular 16 km grid of traverses over an area of 7000 square km. Irregularly spaced traverses extend the gravity coverage over a further 5000 square km (Allen & Whitworth, 1968). The gravity technique has proved useful in measuring ice thickness and also ice accumulation, as the gravity meter can detect vertical shifts of the ice surface more quickly and more accurately than levelling surveys.

10. EARTH TIDE RECORDING

Although some progress was made towards the development of recording gravity meters, no usable records of the tidal variation of gravity have been made in Australia.

In 1968, work recommenced on the modification of a North American remote-reading (underwater) meter to enable it to record tidal variations of gravity. This meter had been used experimentally for this purpose intermittently during the period 1960-64 but tests carried out in 1968 showed that the earlier gravity records would be unreliable because of inadequate temperature records. Temperature control and temperature recording, both for the meter and for the associated electronics (which have been largely rebuilt) have been greatly improved. Long-term drift in the gravity and temperature records are under investigation at present.

No attempt has been made to bring back into service the Heiland gravity meter which was modified for use as a recording tidal gravity meter by Burch (1965). It is hoped that the North American and Heiland meters can both be made sufficiently accurate and reliable that side-by-side operation of the two meters will verify observed tidal variations.

The Department of Geophysics of the University of New England, Armidale is establishing an earth-tidal facility to be known as the Cooney Observatory in hand-made 80 year old mine-workings near the University. The first instruments to be installed will be tensioned-wire strain meters, a novel temperature and pressure compensated quartz strain meter and a two-component laser interferometer strain meter. Environmental data will be fully recorded. BMR will co-operate in the project and provide a pair of Verbaandert-Melchior quartz horizontal pendulums. The installation of recording gravity meters is envisaged.

11. RESEARCH IN PHYSICAL GEODESY

The programme of research in physical geodesy commenced by Professor R. S. Mather at the South Australian Institute of Technology has been continued by him at the University of NSW from February 1966. In the period 1966-67, trial computations for the geoid were made by Mather (1968) from a combination of surface gravimetry and satellite data for a test region in South Australia. The geoidal determinations were extended to the whole of the Australian mainland in 1968 (Mather, 1969a), and carried a step further when the gravimetric and astro-geodetic geoids for Australia were compared after allowing for translation of reference systems. These tests indicated errors in the gravimetric solution, primarily owing to incompatibility between the different gravity data sets used in the solution (Mather & Fryer, 1970).

A homogeneous data set was prepared in 1969 and the resulting 1970 free-air geoid was computed for Australia (Mather, 1970). The accuracy of the gravimetric geoid compared very favourable with that of an astrogeodetic geoid based on a station density of 1 station per 10,000 square km. The 1970 data set, which is of acceptable accuracy for first-order geodetic determinations, was used to determine the location of the Australian Geodetic Datum (AGD) in Earth Space (Mather, 1971).

A research group at the University of NSW is associated with Professor Mather in current studies of various problems in physical geodesy which were brought to light by previous work. One project is the investigation of the nature of systematic errors in gravimetric solutions of the geoid (Mather, 1969b). This is a joint venture with the Royal Australian Army Survey Corps, financial support being provided by the Nuffield Foundation. A second project is a study of the exact nature of surface deflections of the vertical. A third project being planned is an analytical study of the nature of geoid undulations.

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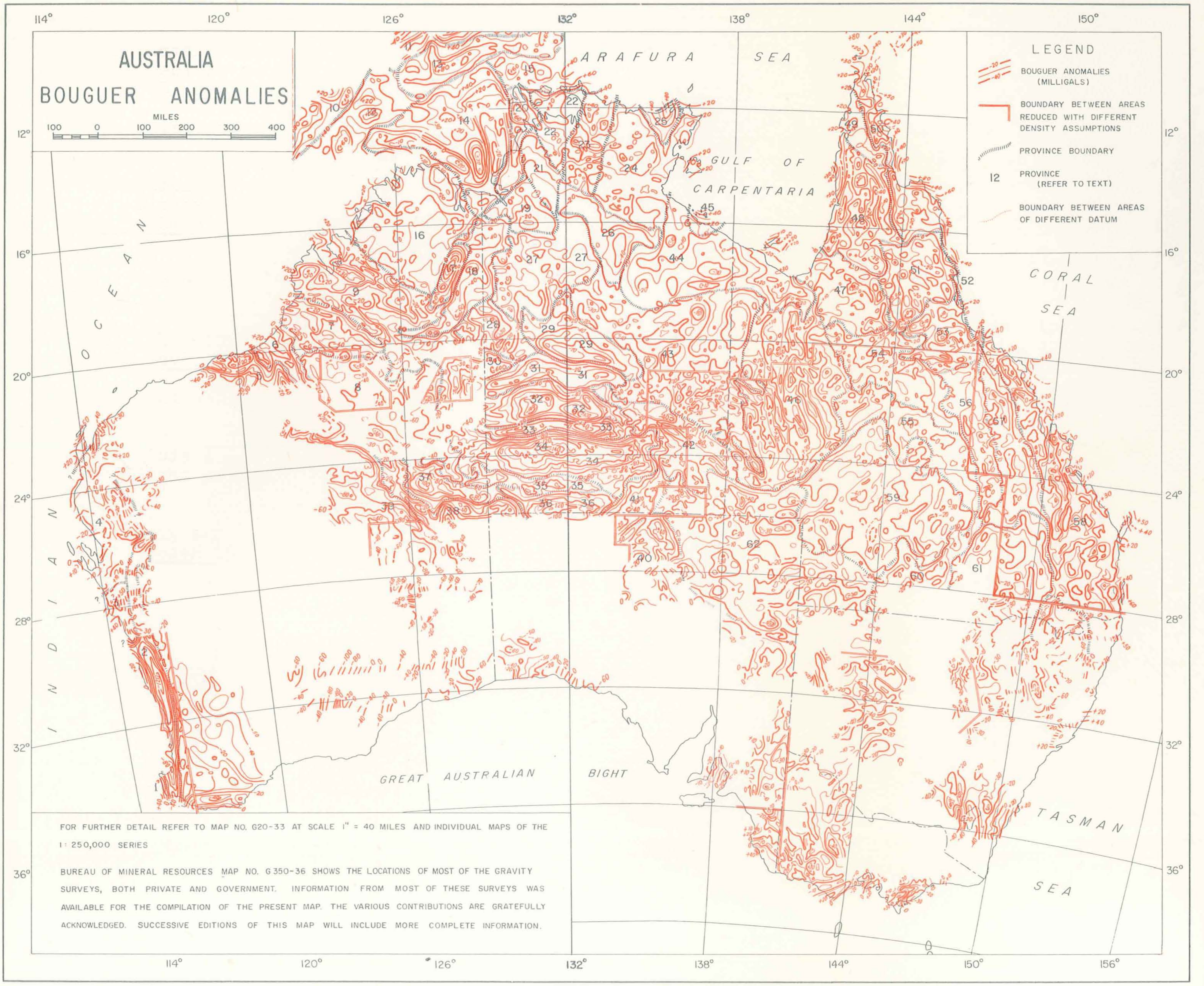

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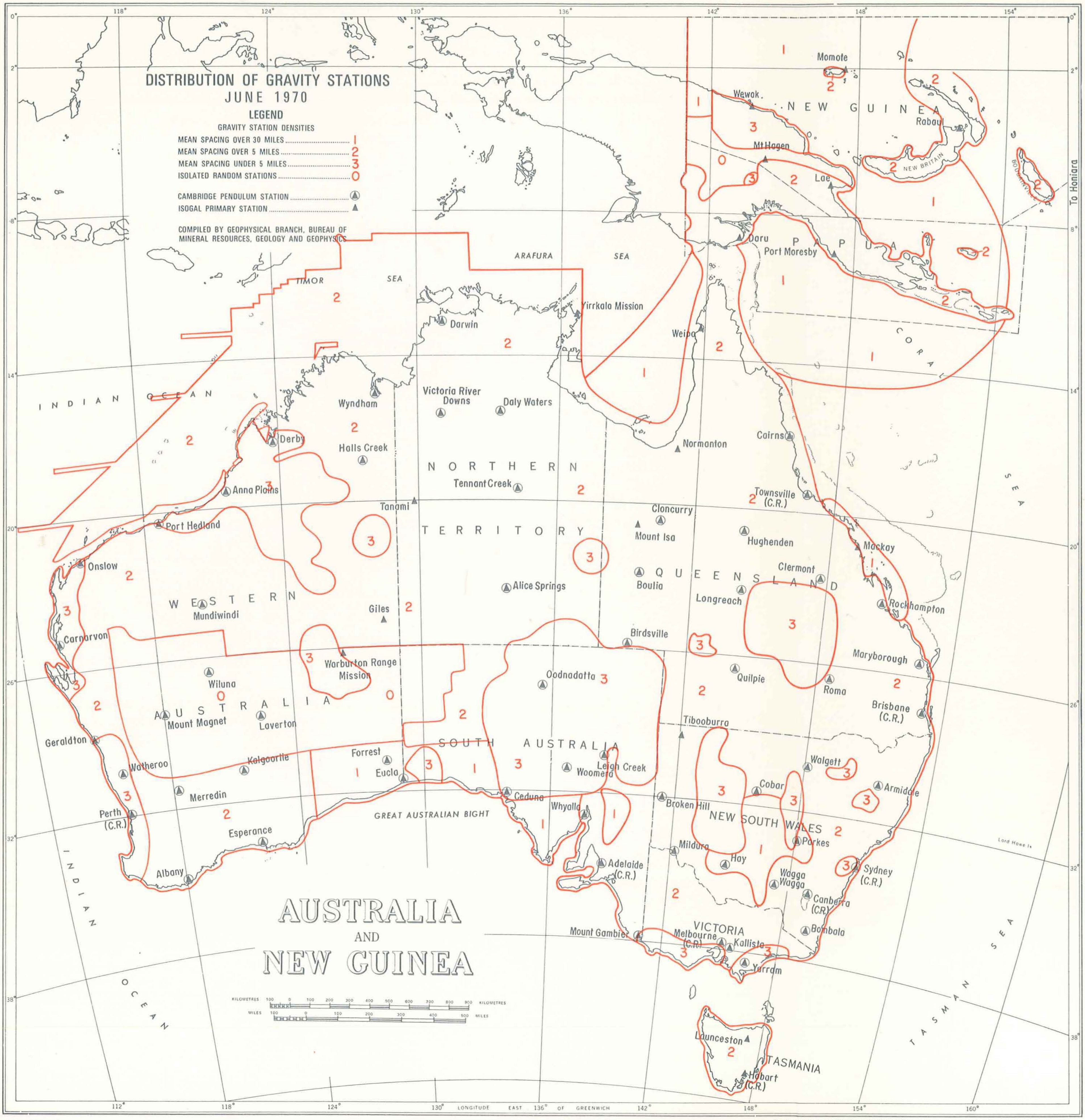

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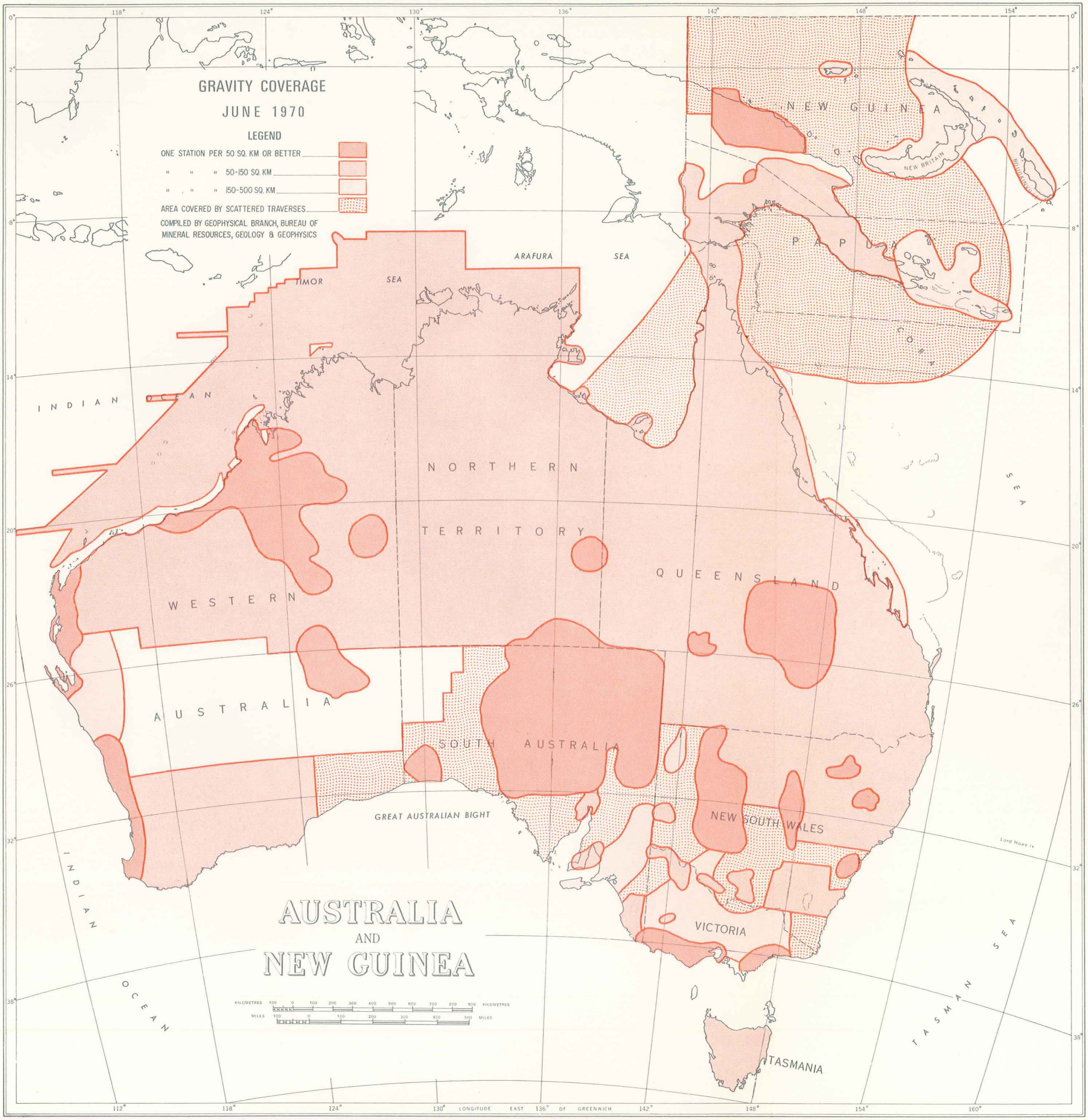

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