COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES
GEOLOGY AND GEOPHYSICS

RECORDS:

NATIONAL REPORT ON GRAVITY IN AUSTRALIA, JANUARY 1963 TO DECEMBER 1966

by

B.C. BARLOW

15928/65

RECORD NO. 1968/21

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SUMMARY

Gravity coverage in Australia has steadily increased between January 1963 and December 1966. More than one-third of the continent has now been covered by reconnaissance gravity surveys. Further gravity measurements have been made in the Territory of Papua & New Guinea, in Antarctica, on ocean islands, and on the continental shelf.

An absolute determination of gravity is in progress, and international ties have been strengthened by pendulum and gravity meter observations. The National Gravity Network has been greatly strengthened by the "Isogal survey" and observations along the Australian Calibration Line. Local calibration ranges have now been established at nine centres. A preliminary gravity map of Australia has been prepared and is being revised as a continuing project.

Automatic computing is being used increasingly in processing and interpreting gravity data. Research in physical geodesy has been carried out at several centres. Studies of the performance of gravity meters have shown some unexpected results.

NOTE

This report was prepared for presentation at the Fourteenth General Assembly of the International Association of Geodesy to be held in Switzerland between 25 September and 7 October 1967. It forms Part IV of the National Report of the Commonwealth of Australia.

COMMONWEALTH OF AUSTRALIA

NATIONAL REPORT ON GRAVIMETRY

FOR THE PERIOD 1963 - 1966

1. INTRODUCTION

The following report gives an account of gravity work in Australia and Australian Territories between 1st January 1963 and 31st December 1966. It incorporates the report prepared for the meeting of the International Gravity Commission at Paris in September 1965 (Dooley, 1965a) and brings up-to-date the report prepared by Langron (1966a) for the Thirteenth General Assembly of the International Association of Geodesy.

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

2. ABSOLUTE DETERMINATION OF GRAVITY

Apparatus for an absolute determination of gravity is being constructed at the National Standards Laboratory, Sydney. The method will be free rise and fall in vacuum of a metal corner reflector through horizontal planes defined interferometrically, the vertical separation of the planes being measured by optical multiplication or laser techniques. An accuracy of one part in ten million is south.

3. CONNECTIONS TO STATIONS OF THE FIRST ORDER WORLD GRAVITY NETWORK AND OTHER INTERNATIONAL BASES

Connections between Australia and stations of the First Order World Gravity Network (FOWGN) have been further strengthened during the period.

The results of a pendulum tie between Tokyo and Melbourne using BMR's GSI-pattern pendulums showed discrepancy of about 2 1/2 milligals from previously published values (Langron, 1966b). Subsequent observations with this pendulum apparatus on the Australian Calibration Line (ACL) revealed even more serious discrepancies. Examination of the knife-edges and agate bearing plates

indicated faults thought to be the main sources of error. The pendulums and swinging chamber were returned to Sokkisha of Japan for re-working and are expected back early in 1967.

Observers from the United States Air Force made gravity observations with four La Coste & Romberg gravity meters on the ACL along the east coast of Australia in 1965 as part of a double run on the Western Pacific Calibration Line (WPCL). In Australia, they were accompanied by a BMR observer with a fifth La Coste meter. Observations were made across the southern part of Australia during 1966 by the USAF using the same four meters.

The Dominion Observatory of Canada made observations in Australia as part of a double run on the WPCL. In addition to observations on the ACL, readings were obtained on a traverse through the centre of Australia.

Further international ties by La Coste meters have been made as part of the "Project Magnet" conducted by the United States Naval Hydrographic Office. La Coste gravity meter ties between Tokyo and various points in Australia were made in 1964 by the United States Army Map Service, Far East.

4. NATIONAL GRAVITY BASE STATION AND NETWORK

The First Order World Gravity Station at Melbourne has been the National Gravity Base Station for seventeen years. Although control of the building in which this station is located has passed out of the hands of BMR, access to the site can still be arranged. The problem of selecting a new National Base has therefore not yet arisen (see Dooley, 1965a).

In order to establish a more accurate national reference network, a series of surveys known collectively as the "Isogal Project" was commenced in 1964. The principle is to survey a set of traverses roughly east-west across Australia, each traverse approximately following an "isogal" of observed gravity values, thus minimising uncertainties due to calibration problems. Each traverse has as its observed gravity datum a station of the north-south ACL. At least three dissimilar meters are used to measure gravity intervals between base stations and between each base and its excentres. The distance between base stations is usually 100 to 150 miles, and drift control is obtained by repeated direct flights using a chartered aircraft.

Most of the east-west traverses were flown during 1964 (Barlow, in preparation) with minor extensions to the network in 1965 and 1966. The results obtained by the United States Air Force using four La Coste meters in 1965 have been adjusted by a slight change in mean calibration factor and then accepted as providing datum values for the "May 1965 Isogal values" for the network. Results to date indicate a standard error of 0.1 milligal in the gravity value at a station relative to its east-west traverse and a standard error of 0.2 milligal in that value relative to the

network as a whole. Forty-seven Cambridge pendulum stations have been re-occupied so far, and the new observed gravity values indicate that the new "mean Australian milligal" is consistent with that defined by the Cambridge pendulum results (results computed without magnetic correction).

Pendulum observations on the ACL during 1964 with BMR's GSI-pattern pendulums gave results which are inconsistent and disagree with accepted gravity intervals. The results of this work been rejected as far as network values are concerned.

The status of the Isogal project as at December 1966 is shown in Plate 3.

5. CALIBRATION 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 new range was established near Canberra in 1965.

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.

An Australian Calibration Line (ACL), generally along the east coast of Australia, has been defined; determination of the gravity intervals between stations is proceeding with the co-operation of international observers. During 1963-66 observations with seven La Coste meters have greatly improved the accuracy of earlier measurements made with the Cambridge pendulums and various gravity meters.

A "mean Australian milligal" has been defined from the average of the gravity intervals Melbourne - Darwin and Melbourne - Cairns based on gravity values computed by Dooley (1965b). Results of USAF measurements indicate that this milligal is consistent within a few parts in 10,000 with the milligal defined by the local gravity meter calibration ranges and with the European milligal.

Erratic results have been obtained when repeated measurements of gravity intervals were made with groups of meters during the Isogal project. At present these effects are tentatively ascribed to environmental effects at the gravity stations, e.g. vibration which has been observed to cause a significant change in the rest position of the beam of quartz-type gravity meters. It is now thought that vibration may be also the cause of the apparent erratic variations in calibration factor previously reported by Barlow (1967).

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

The gravity coverage of the continent has been further accelerated by increasing the area covered annually by BMR helicopter gravity surveys. A steady increase has occurred also in the extent of gravity surveys conducted by private oil search companies, many of which have also used helicopter transport to speed up their surveys.

Plate 1 shows the distribution of gravity stations in Australia and the Territory of Papua & New Guinea (TPNG) as at December 1966. Although most of Australia has at least some regional coverage, several large areas in South Australia and southern Western Australia have only isolated random stations.

Plate 2 shows the total reconnaissance gravity coverage of Australia and TPNG as at December 1966. Reconnaissance coverage is defined here as meaning at least one station per 50 square miles (or mean station spacing not more than 7 miles).

By far the largest contribution in area to this coverage has been the reconnaissance helicopter gravity surveys of BMR. This work was done initially by BMR itself, using chartered helicopters, but since 1963 the whole survey has been let out annually on contract. During the period 1963-66 more than 750,000 square miles were covered and the annual coverage is now approximately 250,000 square miles. Station spacing is roughly on a 7-mile grid. Heights are obtained by looped barometric observations adjusted to a network of spirit-level traverses. Positions are obtained from aerial photographs.

Many contributions to the gravity coverage have been made by private oil-search companies. Under the Petroleum Search Subsidy Acts approved surveys are subsidised by the Commonwealth, which may then publish the results six months after the completion of the survey. In addition, many companies have willingly released station readings on a regional scale from unsubsidised surveys.

Important contributions have also been made by State Governments and Universities. For example the University of Tasmania has carried out surveys in Tasmania and also in TPNG where they co-operated with the United States Army Map Service, BMR, and the Division of National Mapping in helicopter gravity surveys.

A contract marine gravity (and seismic) survey was carried out for BMR during 1965 over part of the continental shelf off Wyndham in north-west Australia. Observations were made with a La Coste & Romberg surface-ship gravity meter and controlled by periodic observations with a La Coste & Romberg underwater gravity meter (Smith, 1966). A gravity survey of St. Vincent's Gulf, South Australia was made by Beach Petroleum N.L. (Sprigg & Stackler,

1965). A diving bell containing a normal land gravity meter and an observer was lowered to the sea bottom in depths as great as 150 feet.

7. COMPILATION OF GRAVITY DATA IN AUSTRALIA

Geodetic investigations and crustal studies require the integration of gravity surveys to a common datum and common milligal value. The compilation of all available gravity data in Australia and presentation of gravity maps of Australia are functions of BMR.

The accurate integration of existing gravity work with current and future gravity surveys is a long-term project, as a large amount of existing data has to be reprocessed to fit it to the present-day accurate network values and to values provided by ties between the modern surveys and the earlier gravity work. Automatic data processing is being used to handle the data which are being compiled on magnetic tape. An essential part of this work was the introduction of an eight-figure station numbering system within which it is proposed every gravity station in Australia will be uniquely numbered. The results of all modern gravity surveys are being reduced using automatic data processing, and so are immediately ready for compilation. The suite of computer programmes developed by BMR in conjunction with the Computer Research Section of Monash University for the automatic reduction of gravity surveys on a CDC 3600 computer are described by Lodwick and Bellamy (in preparation). The output from this compilation will be used to prepare a free-air anomaly map of Australia and several Bouguer anomaly maps for various densities. The data will be in an easily usable form for various geodetic and structural investigations.

Because of the delay necessary in the production of an accurate compilation, and because a less rigorous integration will provide data in a suitable form for many purposes, BMR has compiled a preliminary Bouger anomaly map of Australia (Shirley, in preparation). All major gravity surveys in Australia have been approximately adjusted to common datum but no attempt has been made to recompute individual surveys to a common density. The map is presented at a scale of 40 miles to 1 inch on the same projection as the Tectonic Map of Australia, and is available as a transparent overlay. The contour interval is 5 milligals where sufficient data are available. The first edition of the map was issued in November 1965. Further additions have since been made to the map, and the second edition will be issued early in 1967.

Mean anomalies for 15-minute and 1-degree squares have been calculated for a large part of Australia but have not yet been published.

8. GRAVITY MEASUREMENTS IN ANTARCTICA AND ON OCEANIC ISLANDS

During the period 1963-65 gravity measurements with quartz-type meters were made in Antarctica in association with seismic traverses for ice thickness determination. Gravity ties were made during transport of the meters between Australia and Antarctica. Langron (1966c) has made a study of all the Australian gravity measurements between Australia and Antarctica. The adjusted values of the main Antarctic base stations have an accuracy no better than $\pm$ 5 to 10 milligals because of calibration and drift uncertainties and temperature effects.

In 1966 the Australian National Antarctic Research Expedition made a gravity tie between Melbourne, Christchurch, and McMurdo using two La Coste & Romberg gravity meters, air transport being provided by the United States of America.

Gravity meter ties have been made to Australian Territorial Islands including Lord Howe Island, Nauru, Ocean Island, Christmas Island, and Cocos Island.

9. EARTH TIDE RECORDING

An attempt was made to record earth tides at the old Melbourne Observatory using a North American underwater gravity meter and a modified Heiland gravity meter. Numerous breaks in the continuity of the records during 1963 and 1964 render these virtually unusable. The programme was temporarily discontinued when the Geophysical Branch moved in 1965 from Melbourne to Canberra, where a suitable site is not yet available.

10. RESEARCH IN PHYSICAL GEODESY

A project "Orientation of the Australian National Spheroid" is being sponsored by the Australian Research Grants Committee and carried out by the University of New South Wales. It is proposed to calculate deflections of the vertical and geoid-spheroid separations along several chains of Laplace stations. Additional gravity stations close to each Laplace station are to be observed, but use will be made of existing gravity data held by BMR for the outer zones of each calculation.

In the first half of the period under review, this work was carried out by the South Australian Institute of Technology.

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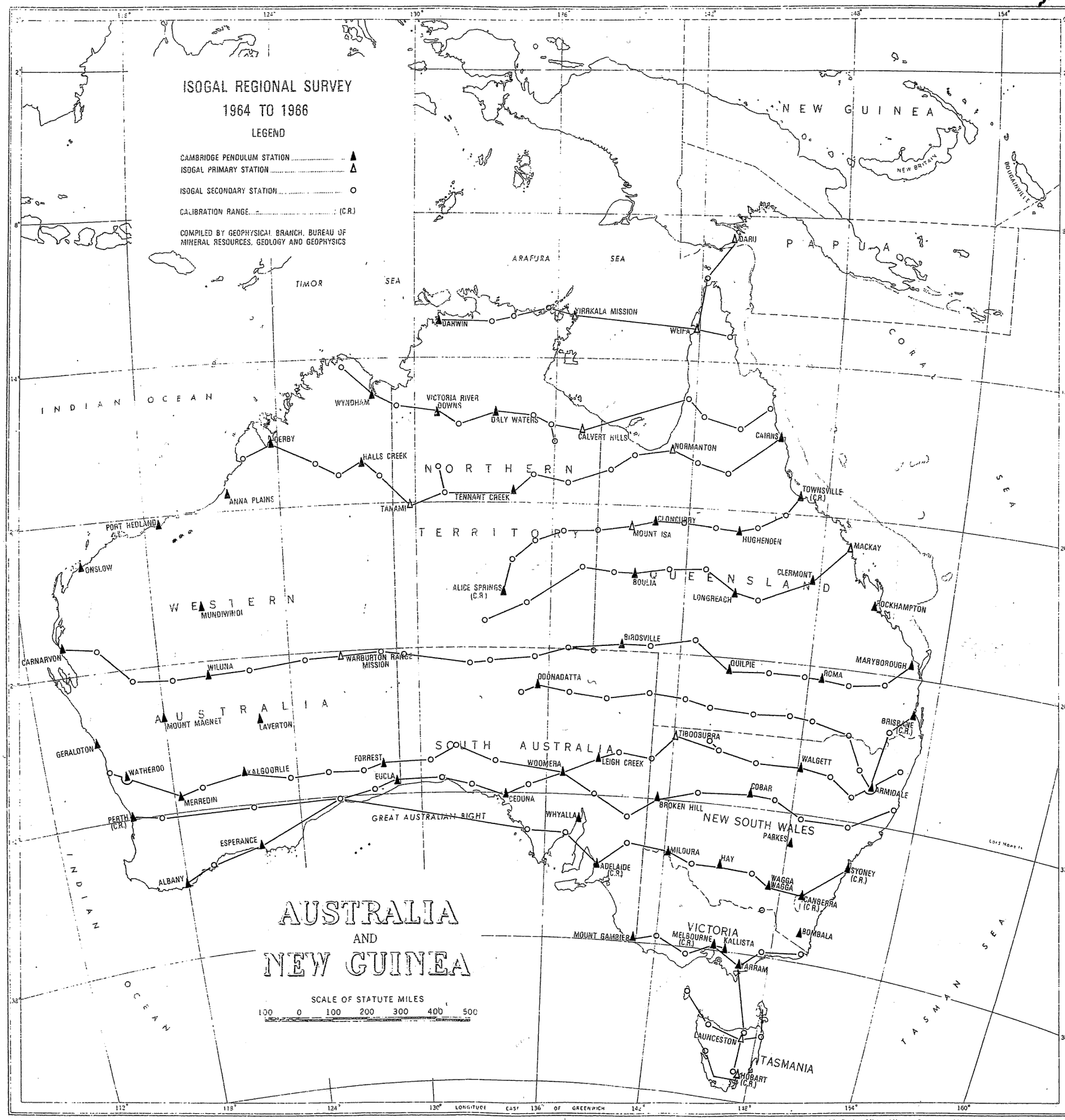

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