COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

1959, No. 97

NATIONAL REPORT

ON

GRAVITY IN AUSTRALIA

AND

AUSTRALIAN TERRITORIES,

MAY 1959

by

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1. INTRODUCTION.

The Bureau of Mineral Resources, Geology and Geophysics, of the Commonwealth Department of National Development, has as one of its functions the carrying out of gravity surveys both for exploration and regional purposes, and has been concerned with establishing a national gravity reference system. This report has therefore been prepared in the Geophysical Section of the Bureau.

2. CONNEXIONS TO STATIONS OF THE FIRST ORDER SURVEY AND TO OTHER INTERNATIONAL BASE STATIONS.

Many gravity connexions have been made between Australia and overseas countries since 1950. The initial reference framework in Australia was established by the Bureau of Mineral Resources, Geology and Geophysics (B.M.R.) with the Cambridge pendulums in 1950-51, at 59 stations distributed over the Australian mainland (Plate 1). A report on these observations is at present in press (Dooley, McCarthy, Maddern. Keating and Williams, 1960).

In 1950 C. Muckenfuss of the Woods Hole Oceanographic Institution, made observations at many stations in Australia with a Worden gravity meter. About 25 of these observations were made either at B.M.R. pendulum stations, or at adjacent stations which have since been connected by gravity meter to pendulum stations. Other gravity meter observations were made by P. Stahl in 1952-53 en route to Antarctica, and W.E. Bonini in 1954. The relations between these and the pendulum stations are discussed by Dooley et al. (1960).

The Cambridge pendulum station at the B.M.R. Geophysical Laboratory in Footscray, a suburb of Melbourne, is the National Gravity Base Station, (N.G.B.S.) and has been designated as a station of the first order network. Table 1 lists the international connexions to N.G.B.S. Also listed are international connexions to some other Australian stations. These have been included in Table 1 only where the N.G.B.S. or an adjacent station was not visited during the survey. Many of the observers listed in Table 1 occupied several other stations during their visits to Australia. Lists of these, with values where available, are given in Table 2.

The gravity-meter ties carried out in 1959 from Sydney-Tokyo, Cairns-Johannesburg, and Melbourne-Auckland, used B.M.R. Worden meters 140 and 169, and Australian National University (Canberra) Worden 201. These were flown by kind co-operation of QANTAS Airways in the care of the pilot, and delivered at the terminal airports to observers, who made the readings and returned the meters to the pilot. The connecting stations were chosen to be within small-dial range of the Worden, so as to eliminate errors due to resetting and calibration of the large dials. Worden 140 showed very uniform drift in these measurements, but the drift of Worden 201 was too irregular for useful results to be obtained.

3. COMPILATION OF GRAVITY DATA IN AUSTRALIA.

In 1957 the Bureau of Mineral Resources invited oil companies, State Governments, Universities, and other institutions which had carried out gravity work in Australia, to contribute data on a regional basis for incorporation in a gravity map of Australia. This request met with favourable reponse from all the organisations approached, and some went to considerable trouble to prepare the data in a suitable form. A provisional Bouguer anomaly map which includes this information has been compiled.

Plate 2 shows the density of data available at present, as requested in the International Gravimetric Commission circular of 27th January 1959. Plate 3 shows provisional contours of the mean Bouguer anomalies for one-degree squares. Plate 4 shows Bouguer anomaly contours drawn from the figures on plate 3.

In calculating the mean anomalies of the one-degree squares, equal weight has been given to equal areas rather than to equal number of stations. Thus, the mean of a cluster of observations in one corner of a square would be weighted equally with each of three or four stations distributed over the remainder of the square, if that were all the data available. Where the only observations available are concentrated near one side or one corner of a square the mean value was positioned near that side or corner of the square on the map, instead of in the centre.

It is proposed to compile similar maps for free air anomalies (which have already been calculated) and for isostatic anomalies; very few isostatic reductions have yet been made. The 59 pendulum stations of the 1950-51 survey have been reduced for Hayford theory with the thicknesses of 56.9Km., 80Km., 96Km., 113.7Km., and for Airy theory with thicknesses of 20Km., 30Km., 40Km., and 60 Km.. (Dooley et al., 1960). A few stations have been calculated for Hayford 113.7Km., only, in the Carnarvon Basin, W.A., and in the vicinity of Cairns, Queensland.

Most of the Bouguer anomalies used have not been corrected for topographic effects. However, over most of Australia these effects are small because of the rather flat and low topography.

4. CALIBRATION.

The gravity values as determined by the Cambridge pendulums showed a small systematic difference with latitude from the observations of Bonini. Bonini s gravity meters were calibrated against the Gulf pendulums in North America. It was presumed that the difference was due to magnetic effects on the Cambridge pendulums, and a correction (about 0.7 parts in 1000) was made to allow for this. The resulting values have been related to the adopted value for N.G.B.S. (Melbourne) and have been provisionally adopted as working values for datum and calibration of gravity meters used in surveys in Australia.

The adopted values show no systematic difference from the subsequent pendulum measurements with the Gulf pendulums, although irregular differences of less than 1 milligal occur.

The estimated average standard error of the Cambridge pendulum measurements relative to N.G.B.S. is $\pm$ 0.6 milligal. Thus a calibration based on two adjacent pendulum stations could be considerably in error. To improve the accuracy, it is proposed to carry out gravity meter surveys based on accurate looping procedures between the pendulum stations. This will be done so that the one gravity meter is used over say 15 to 20 pendulum stations well distributed in latitude. and in a short period of time so that the calibration factor will not change substantially. Least-squares adjustment will enable an accurate calibration factor to be determined for the gravity meter and adjustments can then be made to the values at the pendulum stations, in view of the higher accuracy of the gravity meter for differences between stations.

The first stage of this survey will commence shortly with gravity meter loops between Melbourne and Cairns in the eastern portion of Australia. Tentatively the stations along the east coast (Hobart-Melbourne-Canberra-Sydney-Brisbane-Maryborough-Rockhampton-Townsville-Cairns) are regarded as a calibration chain. They are connected by frequent air services and cover a gravity range approximately from 980.45 to 978.5. The range could be extended to 978.2 or 978.3 by including Darwin, Thursday Island or Port Moresby.

A smaller calibration range is used between N.G.B.S. (Melbourne)and Kallista, with an intermediate station at Ferntree Gully (about 5 miles from Kallista). The following values have been provisionally adopted, as the result of agreement between the Cambridge pendulum measurements and measurements by overseas visitors:-

N.G.B.S. - Kallista	69.9 milligals
Ferntree Gully-Kallista	55.6 "

5. GRAVITY MEASUREMENTS AT SEA.

In 1956, the Bureau of Mineral Resources co-operated with Columba University in carrying out a submarine gravity survey in the south-west Pacific Ocean. H.M. submarine "Telemachus" was made available for this purpose by the Royal Navy and Royal Australian Navy. Vening Meinesz pendulum equipment of the Columbia University was used and the route taken was Sydney-Wellington-Auckland-Tonga-Fiji-Norfolk Island-Sydney, including several traverses across the Kermadec-Tonga Trench.

The Bureau of Mineral Resources has purchased an underwater gravity meter (North American) and this has been used for off-shore observations in Port Phillip Bay, Victoria; along the north coast of Australia from Cape York to Darwin and Wyndham in the Great Barrier Reef area of Queensland; and in the Gulf of Papua in New Guinea.

6. GRAVITY MEASUREMENTS IN ANTARCTICA.

Several ties have been made by Worden gravity meters during the annual relief expeditions to the Australian National Antarctic Research Expedition stations at Macquarie Island, Heard Island and Mawson. Readings have been made also at several landing points along the coast of Antarctica. The location of these gravity observations is shown in Plate 5 Comparisons with measurements made by Expeditions Polaires Francaises have been made at Macquarie Island, Dumont d'Urville, and Kerguelen Is., and a tie has been made to the Russian pendulum station at Mirny.

These results have not yet been completed, owing to doubts about the calibration of the gravity meters, temperature effects, and irregularities in drift. However, preliminary investigations indicate an agreement to within 2-3 milligals of the French and Russian values. Pendulum observations at say Mawson would be highly desirable.

During the 1957 and 1958 expeditions, a Worden gravity meter (No.169) was used in conjunction with seismic reflection traverses extending about 400 miles inland from Mawson, for determination of ice thickness (Plate 6). Preliminary results of the 1957 traverse were presented to the I.U.G.G. in Moscow (Goodspeed, 1958), and reduction of the 1958 results should be completed shortly.

7. PLANS FOR FUTURE DEVELOPMENT OF NATIONAL GRAVITY SURVEY.

Plans for improvement of the gravity coverage of Australia may be classed under several projects.

(a) Obtaining coverage of unobserved and remote areas. It is considered that some observations, even if widely spaced and not of the highest accuracy, would be valuable; it is planned to fill in some of the gaps on the map by making readings at landing points of light aircraft.

Many cattle or sheep stations in the outback area of Australia are served by commerical aircraft which carry passengers, mail and goods, and visit the stations once per week or once per fortnight. A survey has recently been carried out using the facilities provided by these aircraft, in western Queensland, Northern Territory, and the north-eastern part of Western Australia. Approximately 120 stations were established in 6 weeks.

Many other stations which are not served by regular airlines maintain landing strips suitable for use of light aircraft, mainly in connexion with the Royal Flying Doctor Service which provides medical facilities in the sparsely inhabited areas. It is planned to make gravity observations at these stations using one of the Bureau s light aircraft for transport.

A helicopter was used for gravity and geological observations in the Canning Desert area of Western Australia in 1957, and further work with helicopters is planned during 1959 in western Queensland.

The limitations of accuracy in all measurements by airborne parties will be in the measurement of altitudes of the stations. Only barometric methods can be used for this purpose, and most gravity measurements will be made many miles from the nearest place where control observations can be made.

(b) Accurate surveying of loops between pendulum stations, as outlined in Section 3 above.

(c) More intensive coverage on a regional basis - stations with mean spacing 20-30 Km. - and filling in areas between existing surveys for oil and for other economic purposes.

It is expected that coverage of the State of Victoria should be completed early in 1960.

(d) Extension of observations to neighbouring islands and territories, including Tasmania and Papua-New Guinea; and (when suitable arrangements can be made for a submarine and equipment) further observations in adjacent ocean areas.

(e) Local surveys around selected sites for determinations of geoid undulations and deflections of the vertical. No definite plans for this work have been made yet.

8. REFERENCES.

DOOLEY, J.C., McCARTHY, E., MADDERN, C.A. KEATING, W.D. and WILLIAMS, L.W. 1960 - Pendulum measurements of gravity in Australia 1950-51, Bur.Min.Resour.Aust.Bull.46 (in press).

GOODSPEED, M.J., 1958 - Preliminary report on ice-thickness measurements at Mawson 1957-58. Bur.Min.Resour.Aust.Rec. 1958/27 (unpublished).

WOOLARD, G.P., HARDING, N.C., MUCKENFUSS, C. BONINI, W.E., and BLACK, W.A. 1952 - World-wide gravity measurements conducted during the period June 1949 - January 1952. Woods Hole Oceanographic Inst. Ref. No.52-59 (unpublished manuscript).

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Mines Administration Pty.Ltd.
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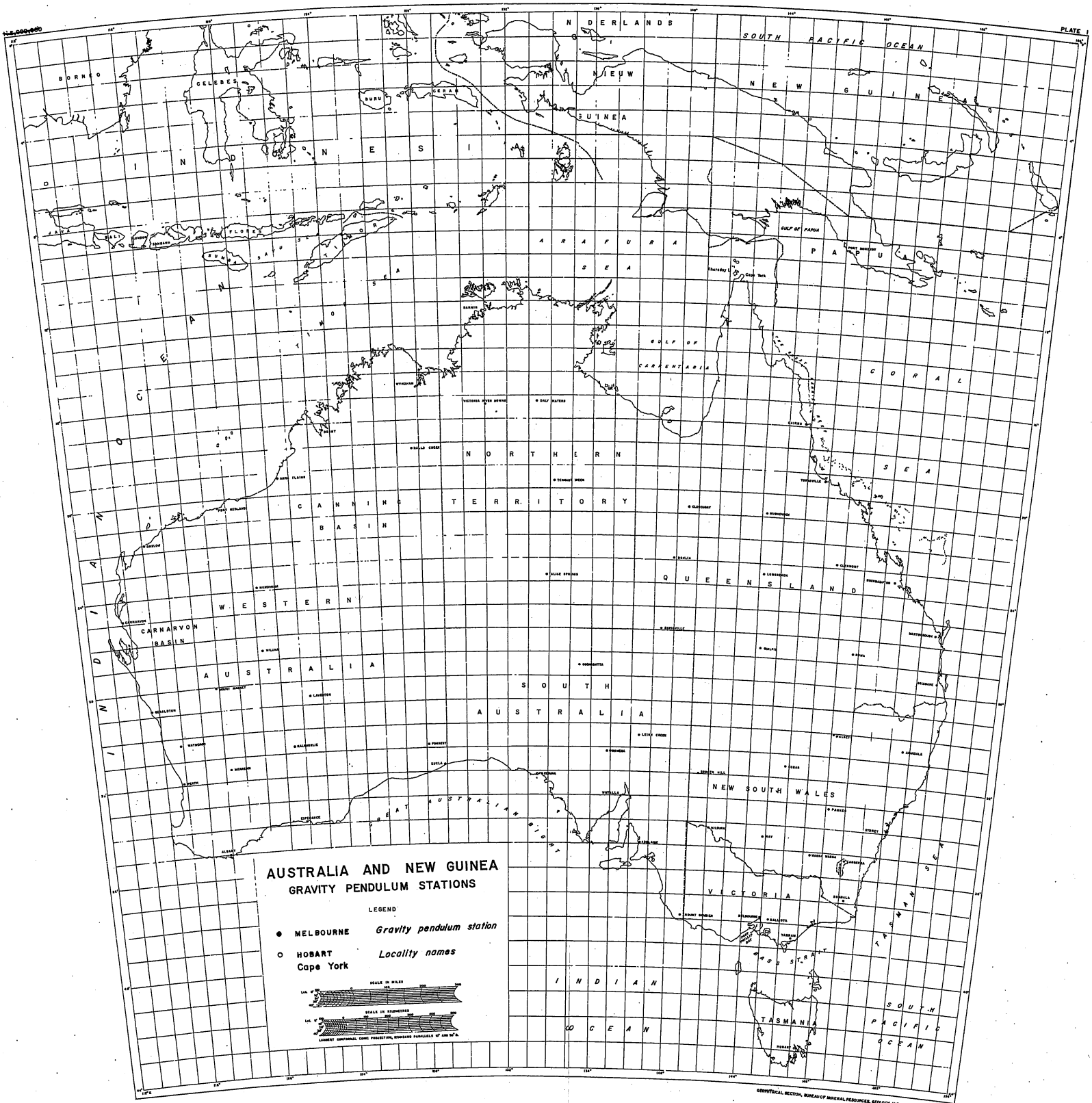
West Australian Petroleum Pty.Ltd.
Westralian Oil Ltd.



GEOPHYSICAL SECTION, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS 669-402
TO ACCOMPANY RECORDS 1969, No. 97

PLATE 2

AUSTRALIA AND NEW GUINEA
DISTRIBUTION OF GRAVITY STATIONS
MARCH, 1959

LEGEND

1 Mean spacing over 50 km
2 " " " 10 "
3 " " under 10 "
} Gravity station densities

0 Isolated random stations

• Pendulum stations (Cambridge)

SCALE IN MILES

SCALE IN KILOMETRES

LAMBERT CONFORMAL CONIC PROJECTION, STANDARD PARALLELS 10° AND 30° S.

NEDERLANDS NIEUW GUINEA

SOUTH PACIFIC OCEAN

NEW GUINEA

BORNEO

CELEBES

BURU

CERAM

INDONESIA

JAVA

BALI

LOMBOK

SUMBAWA

FLORES

SUMBA

TIMOR

SAVU SEA

ARAFURA SEA

PAPUA

TIMOR SEA

GULF OF CARPENTARIA

CORAL SEA

INDIAN OCEAN

NORTHERN TERRITORY

WESTERN AUSTRALIA

SOUTH AUSTRALIA

QUEENSLAND

NEW SOUTH WALES

VICTORIA

TASMANIA

BASS STRAIT

TASMAN SEA

SOUTH PACIFIC OCEAN

GREAT AUSTRALIAN BIGHT

DARWIN
WYNDHAM
VICTORIA RIVER DOWNS
DALY WATERS
DERBY
HALLS CREEK
ANNA PLAINS
TENNANT CREEK
PORT HEDLAND
ONSLOW
CARNARVON
MUNDIWINDI
WILUNA
ALICE SPRINGS
CLONCURRY
HUGHENDEN
CAIRNS
TOWNSVILLE
BOULIA
LONGREACH
CLERMONT
ROCKHAMPTON
BIRDSVILLE
QUILPIE
ROMA
MARYBOROUGH
BRISBANE
GODNADATTA
MOUNT MAGNET
LAVERTON
GERALDTON
WATHEROO
KALGOORLIE
MERREDIN
PERTH
FORREST
EUCLA
ESPERANCE
ALBANY
WOOMERA
LEIGH CREEK
CEDUNA
WHYALLA
BROKEN HILL
ADELAIDE
COBAR
WALGETT
ARMIDALE
PARKES
SYDNEY
WAGGA WAGGA
CANBERRA
MILDURA
HAY
BOMBALA
MELBOURNE
MOUNT GAMBIER
KALLISTA
YARRAM
HOBART

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AUSTRALIA AND NEW GUINEA

BOUGUER ANOMALIES

AVERAGE VALUES IN MILLIGALS FOR 1° SQUARES

● *Gravity pendulum station*

○ *City or town*

SCALE IN MILES

SCALE IN KILOMETRES

LAMBERT CONFORMAL CONIC PROJECTION, STANDARD PARALLELS 10 AND 30 S.

GEOPHYSICAL SECTION, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G69-411
TO ACCOMPANY RECORDS 1970, No 97

PLATE 4

AUSTRALIA AND NEW GUINEA
BOUGUER ANOMALY CONTOURS
(BASED ON AVERAGE VALUES FOR 1° SQUARES)

LEGEND

- Gravity pendulum station
- Contour in milligals
- " " " (doubtful)
- City or town
- Gravity high
- " low

$\sigma = 2.67\ gr/cm^3$

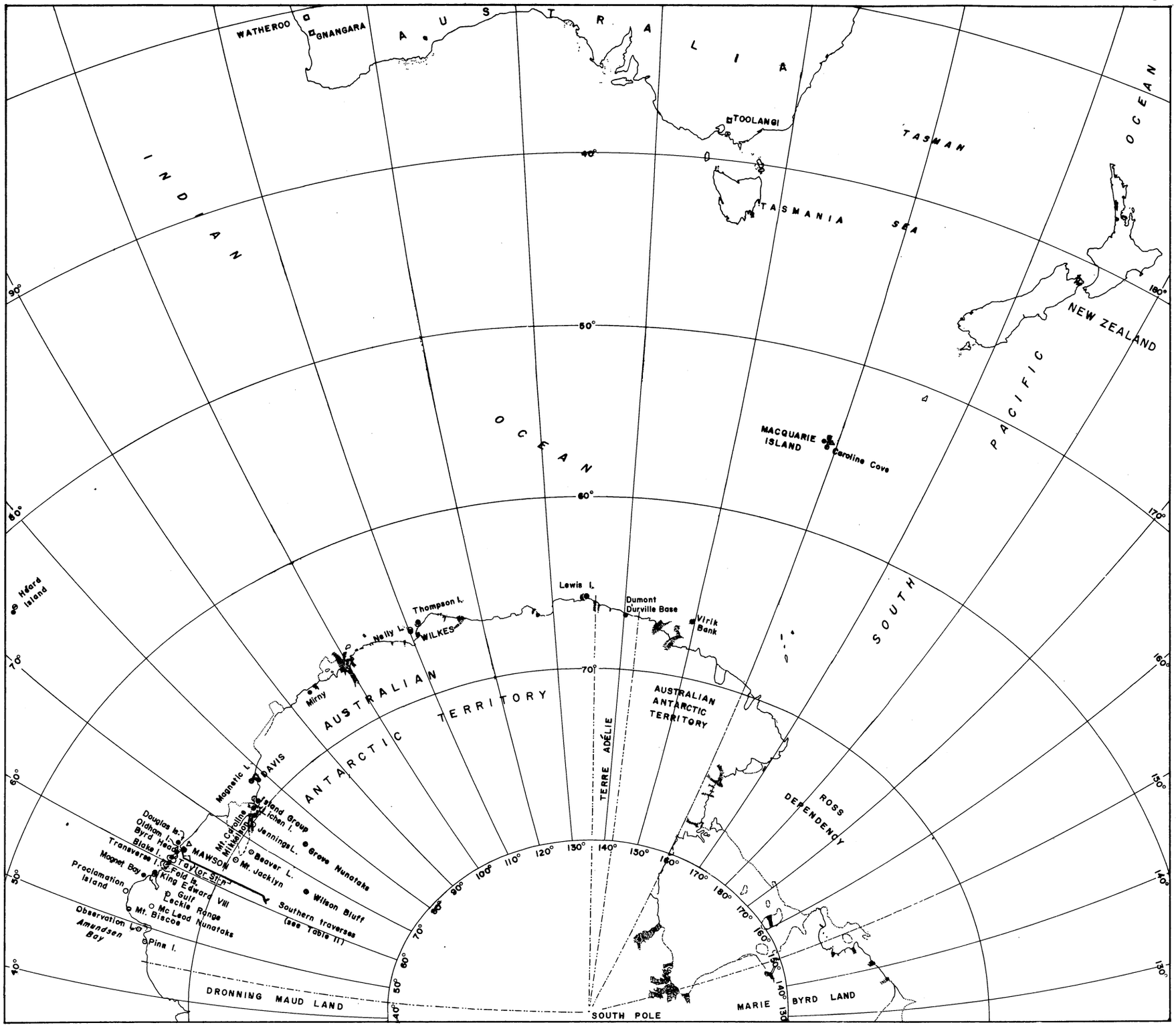
Contour interval 10 milligals

SCALE IN MILES

SCALE IN KILOMETRES

LAMBERT CONFORMAL CONIC PROJECTION, STANDARD PARALLELS 10° AND 30° S.

GEOPHYSICAL SECTION, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS G69-404
TO ACCOMPANY RECORDS 1939, No 97



LEGEND

- ● GRAVITY STATION
- ○ FIELD MAGNETIC STATION
- □ MAGNETIC OBSERVATORY
- △ SEISMIC OBSERVATORY

SCALE IN MILES

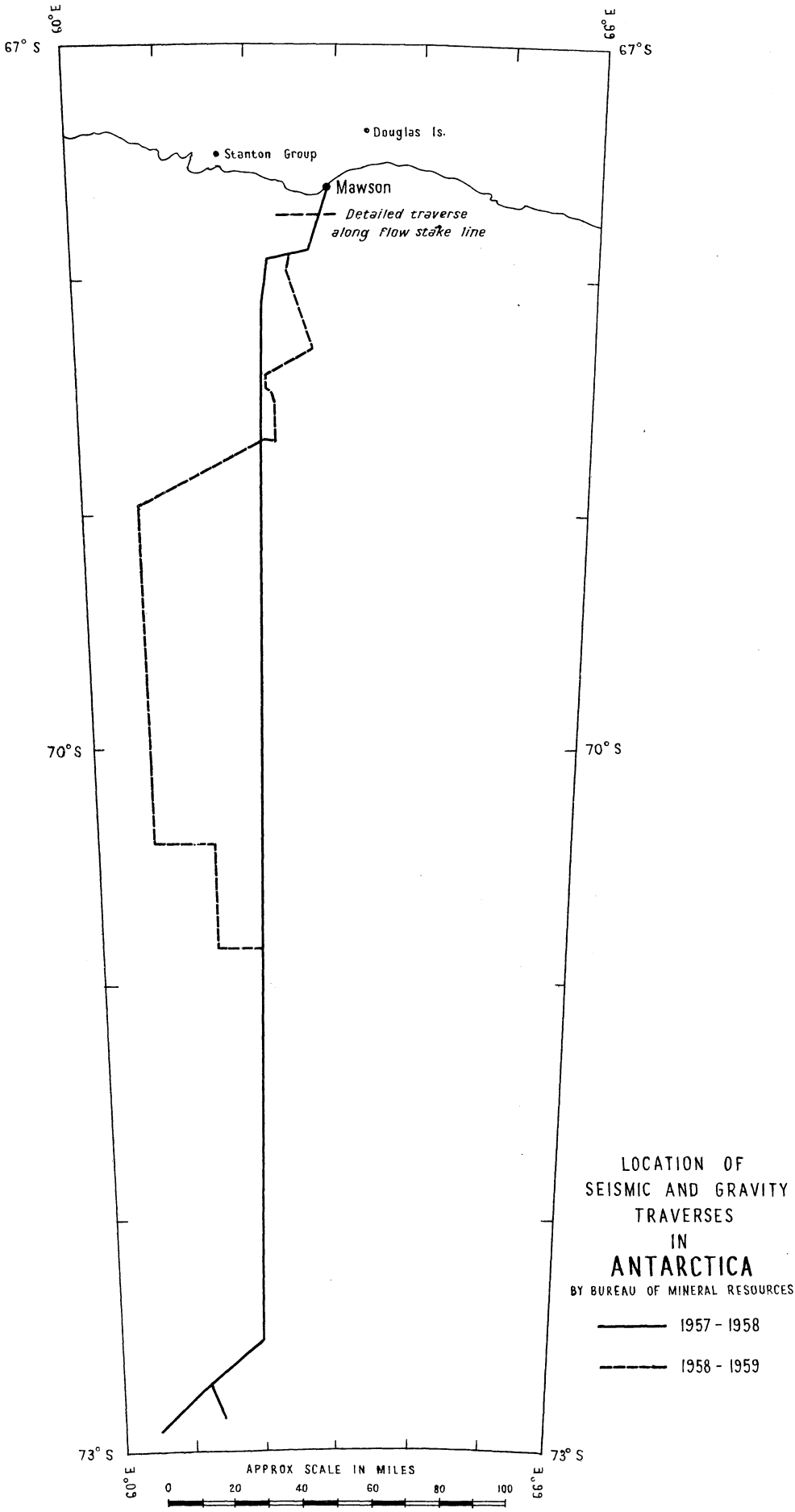
100 0 100 200 300 400 500 600 700 800

AUSTRALIAN GRAVITY MEASUREMENTS IN ANTARCTICA

TO JUNE 1958

Geophysical Section, Bureau of Mineral Resources, Geology & Geophysics G 265-8

TO ACCOMPANY RECORDS 1959, No 97



LOCATION OF
SEISMIC AND GRAVITY
TRAVERSES
IN
ANTARCTICA
BY BUREAU OF MINERAL RESOURCES

1957 - 1958

1958 - 1959

GEOPHYSICAL SECTION, BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS. G265-9

To Accompany Records 1959, N°97

TABLE 1 - INTERNATIONAL GRAVITY TIES TO AUSTRALIAN STATIONS

Institution	Observer	Date	Instruments	Connecting base station	Adopted gravity at base	Station observed	Observed gravity	Gravimeter connection to P.S.	Inferred gravity at P.S.	Remarks
National base station, Footscray, Melbourne.										
BMR	McCarthy et al	1950-1	Cambridge pends. (screened)	Cambridge	981,268.5	NGBS	979,977.8	-	-	
WHOI	Muckenfuss	1950	Worden 10e	Washington Commerce Base	980,119.0	NGBS	979,981.0	-	-	
EPF	Stahl	1952-3	Western 42EQ	Paris Observatory	980,943.0	NGBS	979,980.8	-	-	Final values communicated by P.E.Victor 1957, Sept.19
WHOI	Bonini	1954	Worden 10f) " 147)	Washington CIW Geophys. Lab.	980,100.7	NGBS	979,980.1	-	-	Results communicated by G.P. Woollard, 1956, June 8.
EPF	Martin	1955-6	Western 47	Paris Observatory	980,943.0	NGBS				No separate result given but believed to confirm Stahl's measurements.
WHOI	Rose	1957	Gulf pendulum	Madison	980,368.9	adjacent to NGBS	979,979.5	0	979,979.5	Communicated by G.P. Woollard 24th Sept. 1958.
		1957	Worden	Wisconsin	"	"	979,980.1	0	978,980.1	Provisional value only.
WHOI	Sparkman	1958	La Coste geodetic			NGBS				Results not yet available.
WHOI	Laudon	1958	Worden			NGBS				
GSI	Inoue	1959	GSI pendulum	Kyoto	979,721.5	NGBS				"
BMR,ANU & DSIR	Flavelle, Reilly	1959	Wordens 140 169 201	Auckland "A"	979,948.8	NGBS " 	979,979.8 979,979.8 			
Other international ties.										
LGO	Traphagen	1956	Vening Meinesz pendulums	LGO New York	980,258.4	Neutral Bay,Sydney	979,687	-0.5	979,686.5	
WHOI	Iverson	1958	Gulf pendulums	Madison	980,368.9	PS,Sydney	979,685.5			Communicated by Woollard, 24th Sept., 1958.
BMR,ANU & GSI	Goodspeed Okuda et al	1959	Wordens 140 169 201	Hakone (Japan)	979,723 " "	PS,Sydney " " " "	979,685.7 979,685.8 -			 201 drifts irregular
BMR,ANU & BPI	Goodspeed, Hales	1959	Wordens 140 201	Johannesburg (Bernard Price Institute)	978,549.1	PS,Cairns " "	978,500.0 -			 201 drifts irregular
MGT	da Cunha Porto	1956	Worden	Dili (Timor)		PS,Darwin	-			

ABBREVIATIONS USED IN TABLE 1

B.M.R. - Bureau of Mineral Resources, Geology & Geophysics, Australia
E.P.F. - Expeditions Polaires Francaises
A.N.U. - Australian National University, Canberra.
L.G.O. - Lamont Geological Observatory, Columbia University, U.S.A.
M.G.T. - Missao Geografica de Timor
N.G.B.S. - National gravity base station, Melbourne.
W.H.O.I. - Woods Hole Oceanographic Institute, U.S.A.
G.S.I. - Geographical Survey Institute, Japan.
D.S.I.R. - Dept. of Scientific and Industrial Research, New Zealand.
B.P.I. - Bernard Price Institute of Geophysical Research, Johannesburg, S.A.
P.S. - Pendulum station established by BMR with Cambridge pendulums.

TABLE 2.

Other stations occupied by international observers 1956-59.

(a) Gulf pendulums	Rose 1957	Iverson 1958
Sydney	979,686.0	
Brisbane	979,168.7 (+0.5)	979.169.3 (+0.5)
Townsville	979.622.8 (-0.7)	979,623.8 (-0.7)
Cairns	978,498.5	978.499.8
Darwin	978,313.8 (+2.2)	978.314.0 (+2.2)

Figures in brackets are corrections in milligals to be applied to these observations for comparison with Cambridge pendulum stations (BMR) where the two stations do not coincide.

(b) Gravity meters

Rose 1957	Sparkman 1958	Laudon 1958
Wagga	Sydney	Canberra
Maryborough	Brisbane	Sydney
Rockhampton	Darwin	Brisbane
Clermont	(and others)	Rockhampton
(in addition to pendulum stations listed above)		Townsville
		Cairns
		Darwin
		Adelaide
		Alice Spring
		Tennant Creek