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GRAVITY METER MEASUREMENTS ON THE WESTERN PACIFIC JAPANESE, AND AUSTRALIAN CALIBRATION LINES, 1969-70

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SUMMARY

Observers from the Bureau of Mineral Resources have completed gravity measurements for the establishment of an Australian Calibration Line, with a range of about 2950 mgal. This Line consists of 25 stations extending in latitude from Hobart, Tasmania, to Laiagam, New Guinea. Six quartz gravity meters and three La Coste-Romberg geodetic gravity meters were used. The quartz meter results have been reduced to mean observed gravity values relative to an excentre of the Australian absolute gravity measurement site, and on the scale established in Australia by the Cambridge pendulums. Scale correction factors to be applied to maker's calibration tables are determined for two of the La Coste-Romberg meters by comparison with this set of values. Corrected La Coste-Romberg values are then averaged with the quartz meter values to adopt standard gravity values.

The La-Coste-Romberg meter correction factors also permit the reduction to Australian scale and datum of 1969 gravity measurements on the Western Pacific Calibration Line, and in Japan, by a Bureau of Mineral Resources party with four La Coste-Romberg meters. Adopted values are based on the results from two of these meters. A scale difference of -0.535 mgal/gal is derived for these gravity values with respect to United States Air Force gravity meter measurements in 1964-65.

1. INTRODUCTION

The international gravity measurements described in this paper were made in six weeks during September-November 1969. Two observers from the Bureau of Mineral Resources (BMR) each used two of the La Coste-Romberg geodetic gravity meters G20, G101, G104, G132. Commercial air transport was used for all the main intervals except in Japan, where railway and ferry were used. The locations of measurements are shown in Figure 1; two or more stations were read if possible in each location. The ladder system of measurement was used for the gravity intervals between these locations (A B C .... N .... C B A). Stations of the Western Pacific Calibration Line (WPCL) read by a United States Air Force gravity team in 1964-65 (Whalen, 1966) were used extensively to facilitate scale comparison of the results. Additional work was programmed for Japan to provide material for a scale comparison of the Japanese and Australian gravity networks. Brief details of all stations occupied are included in Table 1. Diagrams of new stations established during the survey, and of excentres on the WPCL not used during surveys by other organisations, are included as Figure 5. Detailed diagrams and photographs of all stations will be included in the report by Cooke (in preparation (a)).

A BMR party carried out the Australian gravity measurements included here during five weeks in May-June 1970 (Cooke, in preparation (b)). Three observers each used three of the nine gravity meters, which were: La Coste-Romberg geodetic gravity meters G20, G101, G132; Worden 200 mgal range quartz meters W140, W169, W260, W548; and Sharpe Canadian 100 mgal range quartz meters S130, S145. The Sharpe meters could not be used for all intervals because of their small range, but all intervals were within the range of the Worden meters. A chartered light aircraft provided transport for the complete survey. Each interval was measured in a single day with full drift control (ABAB). Locations of all gravity measurements are shown in Figure 2 and brief station details are provided in Table 1.

The chief object of this work was to provide the means for adjusting the Australian gravity scale and datum to the world standard. The Australian measurements were to permit the determination of scale correction factors to the La Coste-Romberg meter original calibration tables, in terms of the Australian milligal. This would allow the international measurements to be reduced to the Australian standard. Adjustment to the world standard can then be done when a standard set of gravity values is adopted internationally for Western Pacific Calibration Line stations.

2. ESTABLISHMENT OF THE AUSTRALIAN CALIBRATION LINE

The Australian gravity standard is defined by the results (without magnetic correction) of 1950-51 Cambridge pendulum measurements at 58 stations in Australia, relative to the Australian National Gravity Base Station, Melbourne (Dooley, et al 1961, Dooley, 1965). The adopted value for this latter station is that derived by Cook (1957). An extensive network of accurate base stations, the 'Isogal' network (Barlow, in preparation), has since been established on this original framework by multi-gravimeter surveys. Milsom (in press) extended this network to include the Territory of Papua and New Guinea (TPNG). A system of local gravity meter calibration ranges, with intervals in the range 55-60 mgal, also makes the Australian standard widely accessible (Barlow, 1967).

Six of these calibration ranges were at locations on the Australian Calibration Line (ACL) (see Fig. 2), and all instruments were used on each of these ranges during the survey. In addition, a new calibration range was established at Port Moresby. A single calibration factor for each quartz meter was found to be satisfactory throughout the survey.

The calibration of a La-Coste-Romberg (LCR) gravity meter is not determined from range measurements in this way, as the calibration factor is not constant over the gravity range of the instrument. The calibration is stable (however see below for G20 results), and a table of factors to be used with each individual meter is supplied by the manufacturer. A linear adjustment may be applied to this table to ensure that measured intervals are on any desired scale.

Quartz meter intervals calculated with these adopted factors, and LCR meter intervals at maker's calibration, are listed in Table 2. All readings were corrected for earth tide variations, using tables published by the European Association of Exploration Geophysicists (EAEG), prior to calculation of gravity intervals. For details of all analyses carried out on ACL results see Cooke (in preparation (b)).

Mean intervals from the four Worden meters were calculated, and the residuals for all six quartz meters were examined. Residuals from W169 strongly indicated that its calibration factor varied with the size of the interval being measured (all intervals, whether large or small, were measured on the quartz meters with the centre of each instrument's range set to correspond approximately with the mean observed gravity value for that interval). High intervals measured consistently lower than the mean, although agreement, naturally, was good at about 55 mgal, the average calibration range interval. As no such indication has previously been observed for this meter it was thought better to reject its results for all ties other than the five closest to calibration range intervals. A few results from other meters were rejected on the ground of abnormal residuals. Averages of W140, W260, and W548 results were than used to derive values of observed gravity for all stations, based on an adopted value for the station at Sydney, which is the most reliable value relative to the Australian National Gravity Base Station in Melbourne. This Sydney station is an excentre of the site of a recent absolute gravity measurement (Gibbings et al, 1970).

Eight of the original Cambridge pendulum stations are located on the ACL either directly or via nearby excentres (see Fig. 2). Because of the large scatter in the pendulum results (standard deviation 0.6 mgal) a scale difference between the pendulum gravity values and the quartz meter average values would be difficult to detect. However the much more precise Isogal values for these eight stations (Barlow, in preparation) were found to represent accurately the correct scale (the average scale of the original 59 pendulum values), so these were used as substitute for the pendulum values in this test. A minor adjustment (x 1.000025) to the quartz meter average values was found to be necessary to bring them to agreement, on average, with these Isogal values, and hence with the correct scale. This represented a discrepancy between the network milligal and the calibration range milligal. However it was so small that no adjustment can meaningfully be made to the calibration range intervals. The adjusted set of quartz meter station values (the "quartz set") became the basis for investigation of the LCR meter values.

LCR meter G101 gave very bad results almost throughout the survey; high and erratic drifts were experienced, and the repeatability of interval measurement was generally very poor. Its results were rejected completely. G20 and G132 on the other hand behaved excellently. Values of observed gravity for all stations were derived independently from the results of each of these meters ("G20 set", and "G132 set"), based on the Sydney station. Absence of a G20 interval Melbourne-Moorabbin (resulting from a drop in meter temperature) meant that Tasmanian station values in G20 set were calculated relative to an assumed value at Moorabbin. Differences between these sets and the quartz set are shown in Figure 3 (A and B).

Examination of these plots reveals unexpected features. Both show the points for Canberra and Lae removed from the general trend. Major differences exist between measurements by the Worden meters and the La Coste-Romberg meters of intervals involving these stations, such that the differences compensate in summing the intervals measured on each side of the anomalous stations. This suggests the presence of a peculiar effect at these stations which affects the two types of meter differently. Intervals Lae-Port Moresby and Lae-Menyamya were each measured twice, so that the effect was manifest at Lae in two readings on each of four days.

Linear regression lines were fitted by the method of least squares to plots A and B for several different cases, which are detailed in Fig. 3. In all cases the anomalous points for Canberra and Lae were omitted. Since a major objective was to determine LCR meter scale correction factors (SCF) to allow reduction of the international measurements, the most important case used only that portion of the gravity range which was common to both surveys, namely Port Moresby to Hobart (omitting the section beyond the discontinuity Melbourne-Moorabbin in the case of G20). The slopes derived from these latter cases were adopted, the appropriate SCF was applied to the values in G20 set and G132 set (0.999870 and 0.999890 respectively) and a mean LCR value was computed for each station Melbourne-Laiagam. Stations Lae to Laiagam were included here, although the SCF are apparently inappropriate in this range, because a plot of the differences between G20 set and G132 set (Figure 4A) shows that the two meters are mutually consistent on average over the whole range Melbourne-Laiagam. The standard deviation (SD) of these differences after SCF adjustment is about 0.035 mgal. An apparent change in trend occurs beyond the Melbourne-Moorabbin discontinuity.

Although the repeatability of interval measurement is much better with a LCR meter than with a quartz meter (SD approximately 0.02 mgal and 0.05 mgal respectively), significant differences are often found between intervals measured by two or more LCR meters (see Table 2; also table of calibration range measurements in Cooke, in preparation (b)), which are not accounted for by different SCF. Apparently calibration anomalies exist in some parts of a LCR meter range which are not detected during factory calibration; this can be seen in the wavelike character of the ACL difference plot in Fig. 4A, and of meter difference plots published by Ernberg and Hollensbe (1964). Thus the uncertainty in a single LCR meter interval measurement is not much different from that in a quartz meter interval. Consequently, equal weight was given to LCR and quartz meter results in adopting the final ACL station values. These are listed in Table 1, and were derived as follows:

Stations Melbourne - Port Moresby (except Canberra); the weighted average of mean LCR values and quartz set values. The SD of differences between the two groups was 0.035 mgal.

Stations Canberra, and Lae-Laiagam; mean LCR values and quartz set values were seriously discrepant, so both were retained pending further work to clarify the situation.

Stations Moorabbin-Hobart; the weighted average of G132 values with quartz set values.

3. INTERNATIONAL MEASUREMENTS

The main inter-city gravity intervals measured during the international survey are listed in Table 3, and local excentre intervals in Table 4. These are computed at the maker's calibration scale for each meter. The pairs of values for each interval of Table 3 represent the measurements on the outward and return legs. Original readings were tide-corrected using EAEG tables. Usually two or more readings were made at each main station with at least an overnight time interval between, so that a partial drift curve could be constructed for each station. Where these drifts were similar at consecutive stations, allowance was made for drift in calculating the interval; if the drifts were of opposite sign, intervals were calculated from actual readings.

Examination of Table 3 shows that the quality of the four instruments was not uniform, as indicated, for instance, by repeatability of values on outward and return legs. G104 and G132 were excellent in this respect and their drift characteristics were very good throughout. G20 was fair in both respects, but G101 was relatively poor; a number of drift tares occurred and in other respects its behaviour was suspect. Although G101 was better than it was during the ACL survey, its poor quality results, and the difficulty in deciding rejectable values without knowing its SCF, led to rejection of its results. Details of overall drift, and other analyses carried out on the international measurements, are to be found in Cooke (in preparation (a)).

The intervals measured by G20, G104, and G132 were used separately to derive sets of gravity values for all stations, based on Sydney V, which was also the base for ACL values. Plots of the differences (G20-G132) and (G104-G132) appear in Fig. 4A and Fig. 3C respectively. A serious discrepancy in the behaviour of the difference (G20-G132) between the ACL and international surveys is apparent. Comparison of G20 and G132 results separately with an independent set of values (United States Air Force 1964-65 results, including both WPCL and ACL stations - see Whalen (1966) and Table 1) shows that all the discrepancy lies in G20 results. These were consequently rejected from use in adopting international gravity values. Control over G20 was much closer during the ACL survey and there is no reason to suspect its ACL results.

The SCF for G132 (0.999890) is consistent for both ACL and international surveys, and correspondence between G104 and G132 is very close (Fig. 3C). It seems satisfactory to determine a SCF for G104 by comparison with G132 results. The slopes of linear least squares regression lines calculated for (G104-G132) over the ranges Singapore-Sapporo (the approximate range for which the SCF for G132 was determined) and Singapore-Point Barrow are insignificantly different. Combination of this scale difference with the SCF for G132 gives the SCF for G104 (0.999785) over the range Singapore-Sapporo, and it seems reasonable to use the same figure for the Alaskan stations.

The adopted gravity values for the international stations are listed in Table 1. They are calculated as the means of G104 and G132 values each adjusted by the appropriate SCF. The standard deviation of the difference between these adjusted values is 0.03 mgal.

4. SCALE COMPARISON OF BMR AND OTHER GRAVITY VALUES

A United States Air Force (USAF) team made international measurements with four LCR meters in 1964-65 (Whalen, 1966). Stations of the WPCL and ACL were included in this work. The American results were based on Frankfurt P, with a scale derived by the calibration of one LCR meter (G43) against the 1961 Gulf pendulum results on the North American Calibration Line. USAF station values are given in Table 1, together with the differences from BMR values, adjusted to a common excentre where necessary. The differences are plotted in Fig. 4B and correspondence between the USAF and BMR results is seen to be excellent. The differences for the excentres at each location were averaged, in order to weight each location equally in the least squares calculation of the scale difference, and a scale difference of 0.535 mgal/gal was determined.

Comparisons at Canberra support the LCR meter gravity value rather than the quartz meter value of the discrepant results obtained by BMR (see Fig. 4B). The large discrepancy observed at Hong Kong M cannot be explained; although the station was not marked and some of its surroundings had been altered, enough remained to identify the site with reasonable confidence.

5. ACKNOWLEDGEMENTS

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LCR meter G104 was borrowed from Antarctic Division, Department of Supply, Melbourne, and Sharpe meter 130 was borrowed from the Geological Survey of New South Wales.

Very many individuals assisted the progress of both surveys. Special thanks are due to T. Seto, H. Ishii, and other members of the First Geodetic Section, Geographical Survey Institute, Ministry of Construction, Tokyo and to M. Manansala, Chief Geophysicist, Bureau of Coast and Geodetic Survey, Manila. The United States Air Force allowed access to a number of bases, and accommodation at Point Barrow was provided by the Arctic Research Laboratory. Previously unpublished station reference letters used in this report were provided by Professor C. Morelli, President of Special Study Group No. 5 of the International Association of Geodesy.

Useful discussions were held with B.C. Barlow at all stages of the work. The Director, Bureau of Mineral Resources, authorized this publication.

Bureau of Mineral Resources, Geology and Geophysics,

Canberra,

Australia,

1970 October.

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TABLE 1

ADOPTED GRAVITY VALUES AND STATION DESCRIPTIONS

Australian Calibration Line

UNADJ.

Station	BMR 1970	USAF 1965	ADJ	Difference		Brief Site Description
Hobart	980,449.20 mgal					BMR disc 6491.0160 outside entrance to TAA terminal, Llanherne airport
Launceston	980,275.84					BMR disc 6491.0171 outside Ansett cargo depot, Launceston airport
Flinders Is	980,204.71					BMR disc 6491.9140 in terminal porch, Flinders Is airport
Moorabbin	980,001.83					BMR disc 7090.9401 in Australian Air Charterer' hangar, Moorabbin airport
Melbourne	979,961.16	962.08* (05)	962.16 ✓	0.90*	1.00	BMR station 7090.0101 outside TAA terminal, Essendon airport
Albury	979,765.58	~~766.44*~~	766.53	0.86*	0.95	BMR disc 6793.1136 TAA terminal porch, Albury airport
Canberra	979,(620.64),(620.43)$	621.11* (38)	621.47 ✓	0.74 .85* (74)	0.83	BMR disc 6893.0104 in bus parking bay, Ansett terminal, Canberra airport
Sydney V (Base)	979,698.78	697.54 .59	699.68	0	0.90	BMR disc 6891.0105 in porch, old international terminal, Sydney airport
Williamtown	979,582.29					BMR disc 7090.9402 under flood-light outside terminal, Williamtown airport
Kempsey J	979,426.48	427.02	427.10	0.54	0.62	BMR disc 6491.9111 outside terminal, Kempsey airport
Grafton K	979,329.43	329.99	330.06	0.56	0.63	BMR disc 6491.9110 outside terminal, Grafton airport
Brisbane J	979,159.62	160.16	160.22	0.54	0.60	BMR disc 6491.0147 outside TAA terminal, Brisbane airport
Maryborough A	979,021.48	021.91	021.96	0.43	0.48	BMR disc 5099.9948 in hangar, Maryborough airport
Rockhampton K	978,874.22	874.61	874.66	0.39	0.44	BMR disc 6499.0149 in fire station, Rockhampton airport
Mackay J	978,734.17	734.43	734.46	0.26	0.29	BMR disc 6491.0161 outside terminal, Mackay airport
Townsville	978,624.06	624.26* (624.237)	624.27	0.18*	0.21	BMR disc 7090.0151 outside terminal, Townsville airport
Cairns A	978,500.65	500.79	500.81	0.14	0.16	BMR disc 5099.9952 in Anset workshop, Cairns airport
Cooktown	978,442.33					BMR disc 7090.1072 outside terminal, Cooktown airport
Iron Range	978,346.32					BMR disc 6600.0025 in terminal porch, Iron Range airport
Thursday Is	978,244.47					BMR disc 6691.1001 outside terminal, Horn Is airport
Port Moresby	978,212.68					BMR disc 6791.0476 outside DCA offices, Port Moresby airport
Lae	978,(010.88),(011.17)$					BMR disc 6791.0177 terminal porch, Lae airport
Menyamya	977,(831.68),(831.81)$					BMR disc 6791.9035 in grass hut, Menyamya airstrip
Mt Hagen	977,(678.04),(678.21)$					BMR disc 6791.0178 outside terminal, Mt Hagen airport
Laiagam	977,(503.52),(503.68)$					BMR disc 6791.9029 outside post office, Laiagam airport

* differences adjusted to a common excentre

$ first value derived from La Coste meters, second value from quartz meters. At other stations, agreement is good and mean value is tabulated.

WPCL and Japan

Station	BMR 1969	USAF 1965	Difference	Brief Site Description
Sydney A	979,685.78 mgal	686.56 686.54	0.78	Basement room B37, National Standards Laboratory, Sydney University
Sydney N	979,666.98	667.73	0.75	Fuller's Bridge picnic shelter, Lane Cove National Park
Sydney O	979,608.01	608.74	0.73	Cul-de-sac, Illaura Avenue, Wahroonga
Sydney S	979,689.52			Outside Entrance 3, north-west corner, old international terminal, Sydney airport
Sydney W (Base)	979,698.78			Entrance porch, south-east corner, old international terminal, Sydney airport
Darwin A	978,314.07	314.10	0.03	Assay laboratory, Bureau of Mineral Resources, Wood St, Darwin
Darwin J	978,315.45	315.47	0.02	Check-in area, terminal building, Darwin airport
Darwin K	978,315.45			Entrance porch, international terminal, Darwin airport
Singapore A	978,081.30	081.23	-0.07	Map room F, Dept of Geography, University of Singapore
Singapore B	978,080.69	080.58	-0.11	Beneath Raffles Bust, entrance hall, Singapore National Museum
Singapore J	978,081.47	081.36	-0.11	Verandah, People's Association, old Kallang airport terminal
Singapore O	978,080.07	079.98	-0.09	Beneath commemorative plaque, Paya Lebar Airport terminal entrance
Manila B	978,362.34	362.38	0.04	Magnetic observatory office, Muntinlupa
Manila K	978,376.43	376.50	0.07	Outside old KLM operations building (now abandoned), Manila Airport
Manila L	978,373.09	373.13	0.04	Quarantine section, international terminal, Manila Airport
Hong Kong A	978,766.66	766.93	0.27	Basement room B10, US Consulate, Garden Rd, Victoria
Hong Kong B	978,770.21	770.45	0.24	Seismograph vault, Royal Observatory, Kowloon
Hong Kong L	978,771.94	772.24	0.30	Outside main ground level entrance, Kai Tak Airport terminal
Hong Kong M	978,775.50	772.85	-2.65	Lobby, Grand Hotel, Carnarvon Rd. Kowloon
Hong Kong N	978,768.81	769.08	0.27	Verandah, Royal Observatory, Kowloon
Hong Kong T	978,771.93			New Station on footpath precisely at western corner, Kai Tak Airport terminal building
Taipei B	978,964.54	964.85	0.31	Room 110, Physics building, National Taiwan University
Taipei J	978,973.86	974.11	0.25	Compass rose, lobby floor, MATS terminal, Taipei Airport
Taipei L	978,972.60			New Station at foot of innermost pillar, loading entrance, Taipei Airport terminal

WPCL and Japan (Contd)

Station	EMR 1969	USAF 1965	Difference	Brief Site Description
Kadena J	979,134.10	134.57	0.47	Lobby, MATS terminal, Kadena AFB
Kadena O	979,122.49			New Station in passenger transit lounge, Naha Airport terminal
Tokyo B	979,802,52	803.40	0.88	Basement gravity room, Earthquake Research Institute, Tokyo University
Tokyo C	979,777.03	777.86	0.83	Basement gravity room, Geographical Survey Institute, Meguro
Tokyo D	979,723.16			Outside library, Fujiya Hotel, Hakone
Tokyo N	979,771.94	772.75	0.81	Corner of check-in lobby, Haneda Airport
Tokyo R	979,787.82	788.65	0.83	Porch, MATS terminal, Tachikawa AFB
Anchorage J	981,936.37	938.28	1.91	Outside west entrance, building 32-235, Elmendorf AFB
Anchorage N	981,918.63	920.57	1.94	Passenger lounge, Anchorage Airport terminal
Anchorage Q	981,938.04			Front office, Barton's Air Service, Merrill Field
Anchorage R	981,748.99			Flat-topped rock, outside military site above ski bowl (US Geological Survey station)
Fairbanks C	982,244.33			Loading platform, rear of Geophysical Institute, University of Alaska
Fairbanks E	982,247.64			Ski room 1, Patty Building, University of Alaska
Fairbanks K	982,244.63	246.75	2.12	Passenger lounge, Fairbanks Airport terminal
Fairbanks M	982,216.15			Loading platform, building T-1221, Eielson AFB
Point Barrow A	982,697.65			Furnace room, building 251, Arctic Research Laboratory
Sapporo 1	980,489.44			Gravity house in grounds, University of Hokkaido
Sapporo K	980,440.03	441.28	1.25	Near gift shop, Chitose Airport terminal
Mizusawa 1	980,160.21			Gravity house in grounds of International Latitude Observatory
Mizusawa 2	980,161.53			Basement gravity room, International Latitude Observatory
Kakioka	979,979.69			Gravity house of Kakioka Magnetic Observatory
Kyoto A	979,721.09			Basement gravity room, new Geological and Mineralogical Institute, Kyoto University
Kyoto C	979,721.61			Basement gravity room, Geophysical Institute, Kyoto University
Kumamoto 1	979,565.64			Entrance, Faculty of Education, University of Kumamoto
Kumamoto 2	979,565.00			Entrance porch, Faculty of Science, University of Kumamoto

TABLE 2

ACL INTERVALS

Tie $	G20	G101	G132	W140	W169	W260	W548	S130	S145
1	173.355	173.45	173.380	173.41	R (173.56)	173.30	173.37		
2	71.155	71.07	71.170	71.14	71.10	71.14	71.07	R 71.24	71.14
3	202.790	203.10	202.925	202.92	R 202.71	202.87	202.81		
4	(40.65)	40.75	40.665	40.64	40.65	40.67	40.66	40.60	40.71
5	195.530	(195.98)	195.575	195.64	R 195.48	195.61	195.57		
6	144.985	145.98	144.965	145.11	R 144.95	145.12	145.15		
7	-78.145	-(78.31)	-78.155	-78.34	-78.36	-78.32	-78.40	R-78.23*	R-78.16
8	116.535	116.88	116.530	116.49	R 116.42	116.39	116.57		
	116.520	116.66	116.505	116.46	R 116.44	116.49	116.45	116.57	
9	155.840	156.26	155.850	155.80	R 155.60*	155.77	155.82		
10	97.025	97.26	97.000	97.05	R 96.96	97.12	97.03	97.14	97.06
11	169.860	169.97	169.795	169.76	R 169.62	R 169.64	169.83		
	169.855	170.05	169.800	169.78	R 169.62	169.83	R 169.64		
12	138.170	138.63	138.185	138.15	R 137.98	138.15	138.11		
13	147.245	147.30	147.255	147.21	R 147.20	147.26	147.31		
14	140.055	140.19	140.095	140.10	R 139.84*	140.00	140.03		
15	110.145	110.19	(110.075)	110.10	R 110.06	110.10	110.19	110.15	
16	123.430	123.60	123.460	123.42	R 123.20	(123.39)	123.33		
17	58.295	58.36	58.345	58.36	58.25	58.34	58.30	58.33	58.34
18	96.075	96.04	96.030	96.00	R 95.90	R 95.80*	95.99	95.99	(95.99)
19	101.860	101.90	101.910	101.81	R 101.77	101.86	101.82	101.84	(101.87)
20	31.780	31.83	31.765	31.79	31.85	31.82	31.80	31.82	31.80
21	201.765	201.86	201.805	201.59	R 201:47	201.45	201.53		
	201.810	201.81	201.830	201.57	R 201.39	201.53	201.48		
22	179.275	179.16	179.175	R 179.15	R 179.21	179.31	179.37		
	179.275	179.18	179.175	179.27	R 179.42	179.41	179.44		
23	153.675	153.67	153.635	153.55	R 153.49*	153.58	153.65		
24	174.505	174.60	174.565	174.52	R 174.49	174.52	174.55		
	2945.86	2949.15	2946.002						
Calibration factors	Maker's table	Maker's table	Maker's table	0.10195	0.10103	0.10880	0.10947	0.11662	0.10645

$ Ties are numbered as shown in Figure 2

* Tare suspected

( ) 2:1 tie

R Value rejected

TABLE 3

MAIN INTERVALS WPCL AND JAPAN

Station	G20	G101	G104	G132
Sydney V	1383.210 1383.185	1383.020 1383.630	1383.640 1383.630	1383.495 1383.465
Darwin K	235.235 235.310	235.310 235.365	235.385 235.420	235.425 235.375
Singapore O	293.005 292.980	293.045 293.010	293.070 293.055	293.055 293.035
Manila L	398.810 398.715	398.780 398.805	398.945 398.935	398.840 398.940
Hong Kong L	200.730 200.665	200.670 200.585	200.685 200.710	200.695 200.695
Taipei L	149.965 149.890	149.850 149.895	149.935 149.935	149.875 149.890
Kadena O	649.365 649.310	649.675 649.145	649.595	649.535 649.505
Tokyo N	2146.325 2146.495	2147.035	2147.130 2147.145	2146.950 2146.920
Anchorage N	326.040 326.110	326.035 325.930	326.115 326.055	326.030 326.030
Fairbanks K	452.980 453.110	453.470 453.035	453.110 453.190	453.095 452.985
Point Barrow A				
Sapporo 1	329.090	$(327.990)*	329.265	329.300
Mizusawa 1	383.115 383.060	$ 384.770 384.690	383.260 383.260	383.230 383.225
Tokyo C	55.390 55.385	55.395 55.480	55.435 55.450	55.400 55.435
Kyoto C	156.630 156.630	156.655 156.685	156.670 156.675	156.580 156.595
Kumamoto 1				

* Tare suspected

$ Intervals relative to Mizusawa 2

TABLE 4

EXCENTRE INTERVALS WPCL AND JAPAN

Stations		G20	G101	G104	G132
Sydney	V-S	0.275	0.245	0.260	0.260
	A-V	-13.025	-12.940	-13.000	-12.985
	A-N	18.790	18.830	18.810	18.785
	A-O	77.770	77.790	77.800	77.770
Darwin	K-J	0.010	0.015	-0.030	0.005
	K-A	1.390	1.390	1.360	1.380
Singapore	O-J	-1.405	-	-1.400	-1.390
	O-B	-0.625	-(0.570)*	-0.620	-0.615
	O-A	-1.250	-(1.185)*	-1.235	-1.220
Manila	L-K	-3.310	-3.275	-3.365	-3.325
	L-B	10.785	10.715	10.725	10.760
Hong Kong	L-T	0.015	0.010	0.020	0.005
	L-M	-3.545	-3.580	-3.570	-3.550
	L-N	3.115	3.060	3.145	3.115
	L-B	1.710	1.710	1.740	1.740
	N-A	2.150	2.170	2.140	2.160
Taipei	L-J	-1.245	-(1.230)*	-1.250	-1.275
	L-B	8.090	(8.030)*	8.055	8.050
Kadena	O-J	-11.610	-11.605	-11.605	-11.620
Tokyo	N-C	-5.160	-5.180	-5.075	-5.115
	C-B	-25.515	-25.470	-25.475	-25.500
	C-R	-10.815	-10.775	-10.785	-10.790
	C-Kak	-202.620	-202.735	-202.710	-202.670
	C-D	53.850	(53.925)*	53.895	53.865
Sapporo	1-K	49.450	(49.390)*	49.410	49.425
Mizusawa	1-2	-1.315	-	-1.315	-1.315
Kyoto	C-A	0.505	0.505	0.530	0.540
Kumamoto	1-2	0.635	0.655	0.645	0.620
Anchorage	N-J	-17.770	-17.625	-17.775	-17.710
	N-R	169.585	169.655	169.675	169.660
	N-Q	-19.405	-19.415	-19.420	-19.400
Fairbanks	K-C	0.275	0.240	0.305	0.315
	K-E	-2.995	-2.985	-3.020	-2.990
	K-M	28.495	28.440	28.515	28.455

* Tare known or suspected

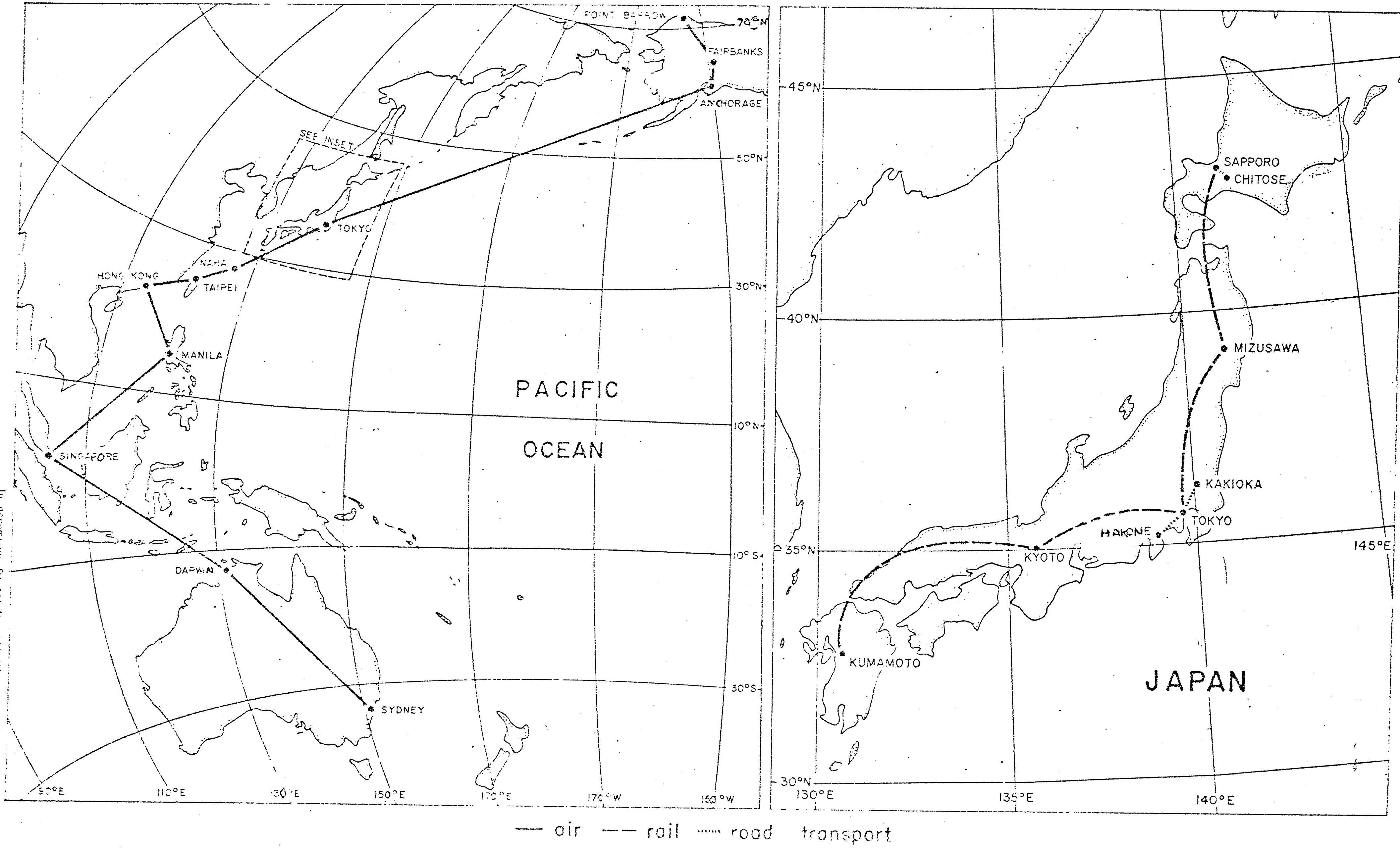
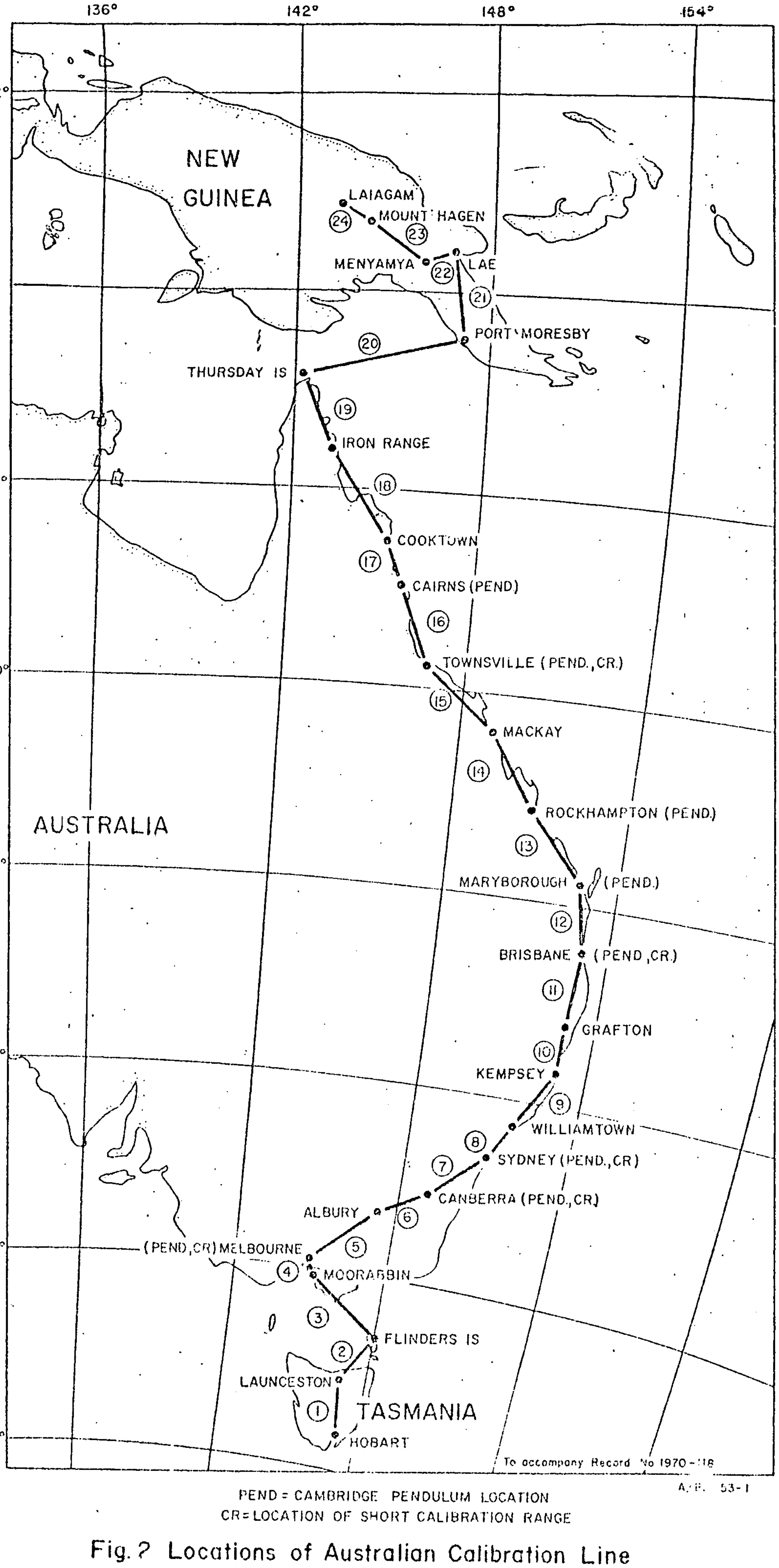


Fig. 1 Locations of international gravity measurements

To accompany Record No. 1970-118

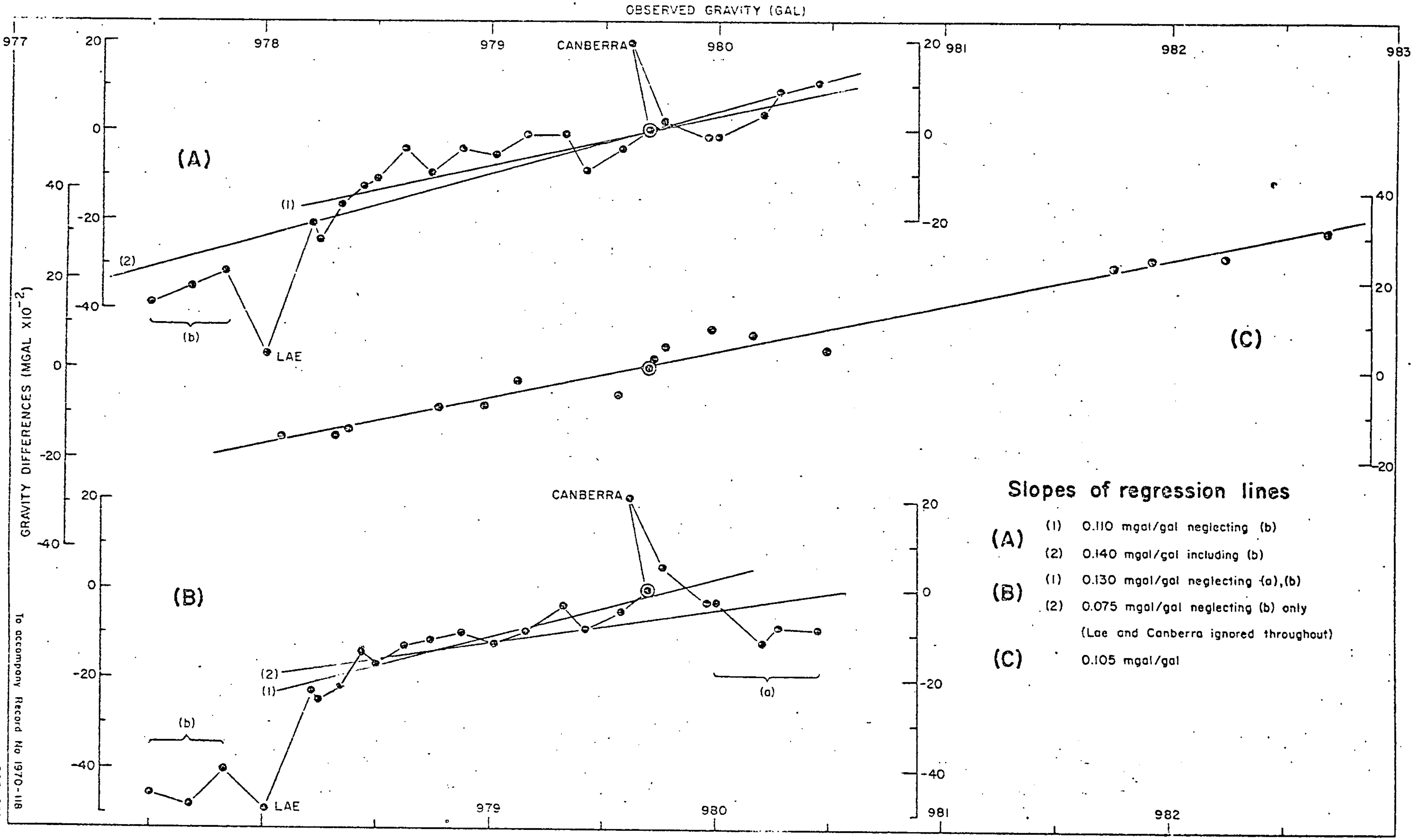
W/B2-3-1



PEND = CAMBRIDGE PENDULUM LOCATION
CR = LOCATION OF SHORT CALIBRATION RANGE

Fig. 2 Locations of Australian Calibration Line stations and key to tie numbers

Fig. 3 Differences in observed gravity



◎ BASE STATION (SYDNEY V) (A) (G132-MEAN QUARTZ) ACL (B) (G 20-MEAN QUARTZ) ACL (C) (G 104-G 132) WPCL

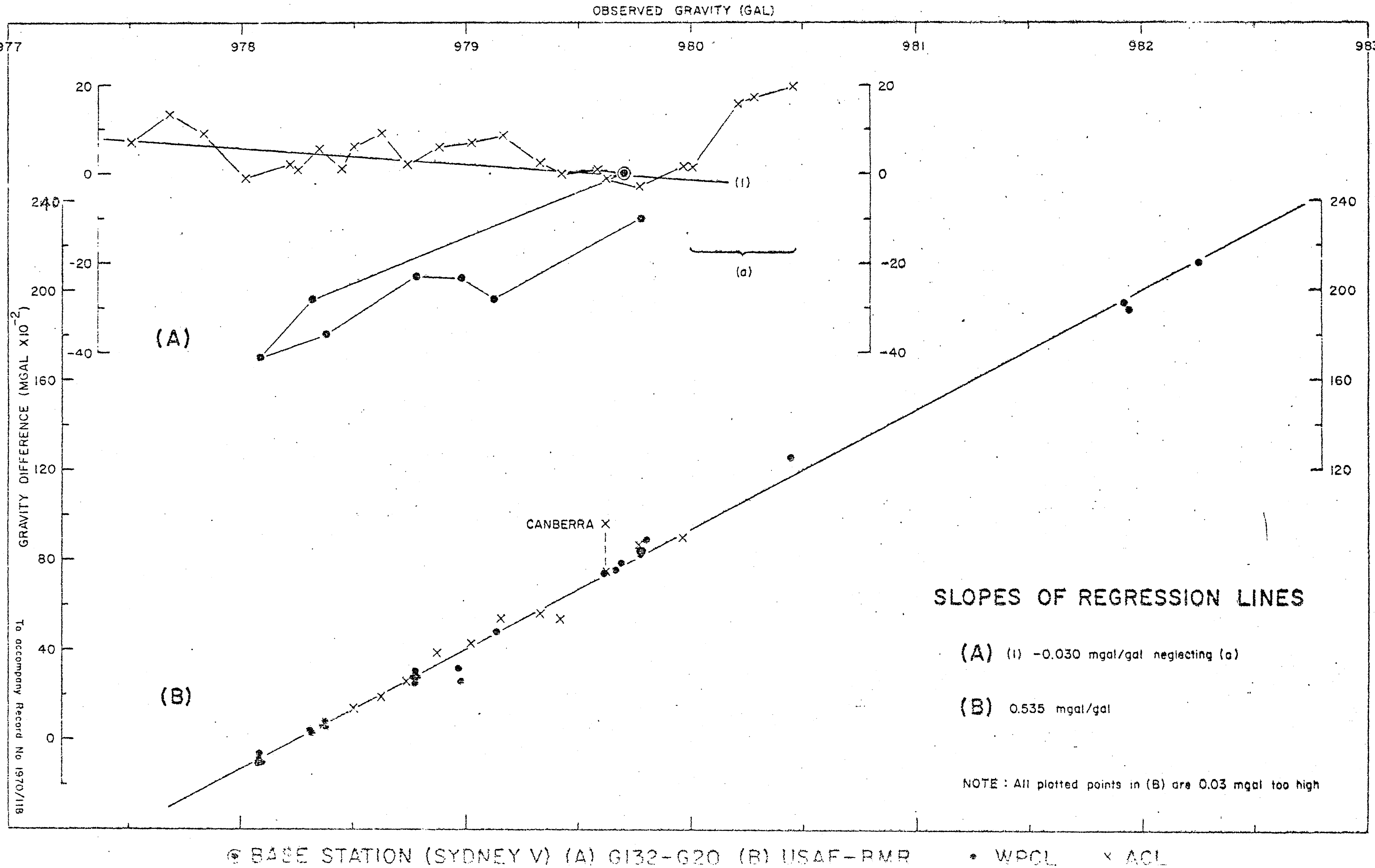


Fig.4 Differences in observed gravity

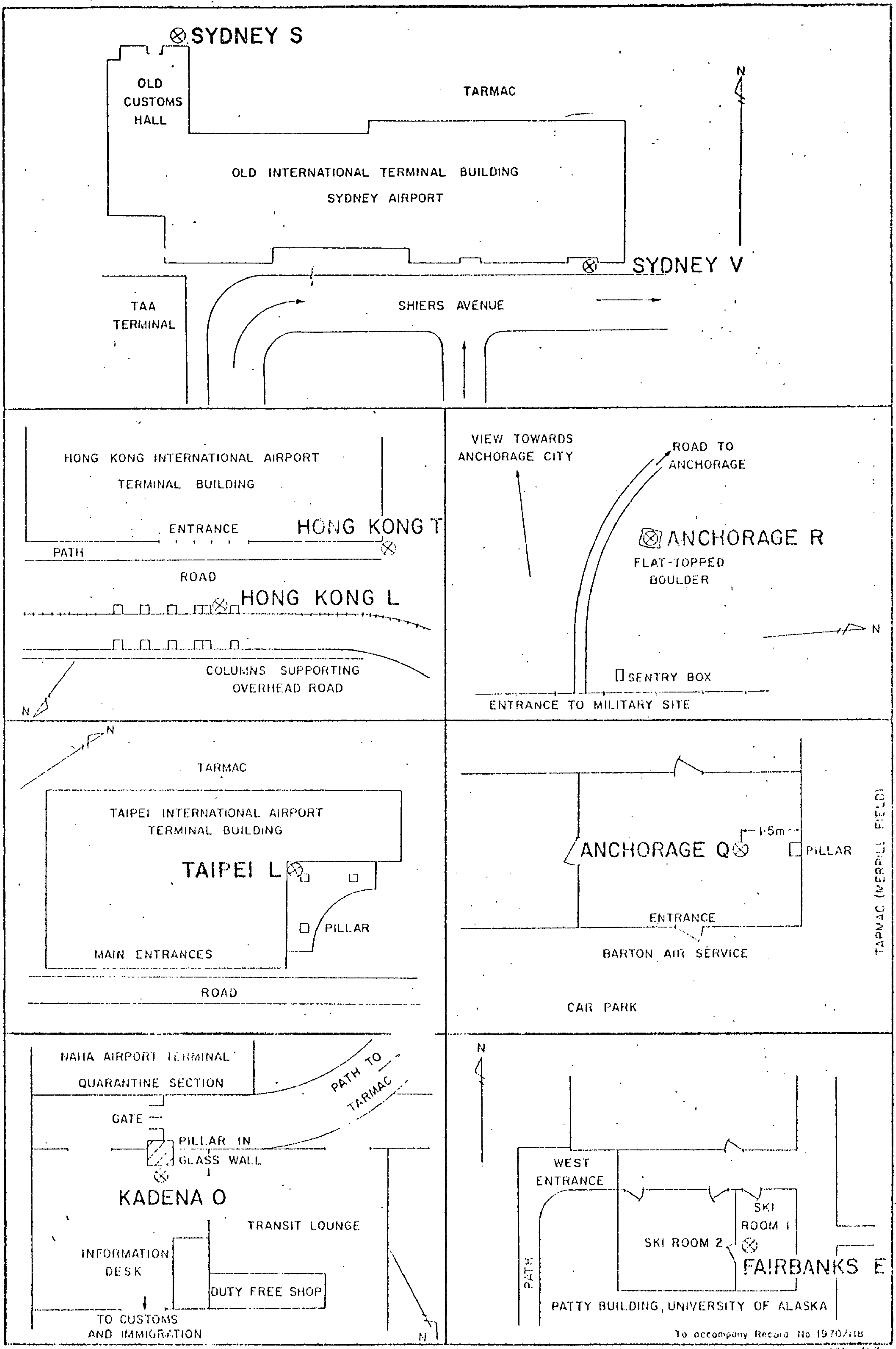


Fig.5 Previously unpublished station descriptions