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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1969 / 31

Revision of the Gravity Meter Calibration Range Interval,

Canberra 1968

by

J.S. Milsom and Nik Mohamed

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ILLUSTRATIONS

SUMMARY

Results obtained during the 1967 Isogal gravity surveys in Australia and Papua-New Guinea indicated that the accepted value of the interval of the Canberra calibration range was in error. A special determination of the relation between the Canberra and the Melbourne ranges was made in January 1968 by two observers using six gravity meters. This work resulted in the adoption of a new value of 54.76 milligals for the interval of the Canberra range.

1. INTRODUCTION

During 1960 and 1961 the Bureau of Mineral Resources established calibration ranges for gravity meters in all Australian State capitals and also at Townsville and Alice Springs (Barlow, 1967). The intervals for these ranges, in each case between 50 and 60 milligals, are based on a value of 55.69 milligals for the original Melbourne calibration range between Ferntree Gully and the Kallista pendulum station. This value was adopted after analysis of a large amount of pendulum and gravity meter data (Dooley, 1965). The Kallista/Ferntree Gully range is no longer used, but the present Melbourne range, which is very close by, has been tied to it with an estimated accuracy of ± .01 milligal.

In 1965 the Geophysical Branch of BMR was transferred from Melbourne to Canberra, and a site for a calibration range was selected in the Canberra area (Plate 1). At the time, the range was read using four meters, and a value of 54.72 milligals was adopted, this being the mean of all the readings.

More recent work, and in particular a number of difficulties that have arisen in reducing the results of the Australian and the New Guinea 1967 Isogal surveys, suggested that this mean value was too low. As described below, an investigation of all calibrations carried out in Canberra and Melbourne in the period 1965-67 was made, and this indicated an interval of 54.76 milligals. The uncertainty was still large, however, and it was decided to send to Melbourne as many meters as practicable, to attempt to determine the value of the Canberra range with an accuracy of ±0.01 milligal. Such an accuracy is highly desirable since the majority of meter calibrations are now made in Canberra.

2. CANBERRA RANGE RESULTS 1965-67

The method used in determining the intervals of calibration ranges outside Victoria has been fully described by Barlow (1967). In this method, in a single determination of the range, the calibration factor (K) of the meter used is described in terms of five parameters:

K_A,	the 'maximum possible value'	(maximum calibration factor ever determined in Melbourne)
K_a,	the 'maximum probable value'	(maximum calibration factor determined in Melbourne within one or two months of the measurement on the other range)
$\bar{K}$,	the 'most probable value'	(mean of all Melbourne determinations within two or three months of the measurement on the other range)
K_b,	the 'minimum probable value'	(similar to K_a)
K_B,	the 'minimum possible value'	(similar to K_A)

It was considered that if these parameters were measured for each determination, and if a sufficient number of determinations were made, then values of ranges outside Victoria could be obtained with a small and easily estimated possible error. For these parameters to be meaningful it is obviously necessary that there should be a large number of readings made on the Melbourne range. Unfortunately, owing to the removal of the Geophysical Branch to Canberra, the number of Melbourne calibration runs made since the establishment of the Canberra range has been quite small. A conventional graphical representation can be produced for 1965, for the three quartz meters Worden 140, Worden 61, and Sharpe 145 (Plate 2), but values for K_a and K_b cannot be obtained. The results of these determinations suggest a value for the Canberra range of the order of 54.76 milligals.

During 1966 no runs were made on the Melbourne range.

In 1967 one run was made on the Melbourne range with each of the meters Master Worden 548, Worden 169, and Worden 140. In this case the normal error estimates can only be made if the parameters are referred to the Canberra range, which was read a large number of times. In Plate 3, therefore, the value 54.72 milligals has been assumed for Canberra, and a value of 53.00 milligals is obtained for the Melbourne range. The accepted value of the Melbourne range is 53.04 milligals. Again, it appears that the Canberra range should have a value of about 54.76 milligals.

One of the meters used in the original determination of the Canberra range was La Coste G20. In the La Coste geodetic meters there is no reset device, the meter being operated over the whole of its range of some 7000 milligals by movements of a single very long micrometer screw. The calibration varies over the length of this screw, and a table is provided by the manufacturers with each meter giving the factor appropriate to each 100-milligal interval. Minor irregularities in the pitch of the screw result in changes of calibration factor over much shorter intervals than this, and for this reason La Coste meters are not normally used in BMR for the establishment of calibration ranges.

The Canberra range has now been read using a number of La Coste meters, and the results of these determinations (using the maker's calibration factors) are shown in Plate 4. These indicate a higher value of the interval, again of the order of 54.76 milligals. It will be noted that the highest value ever obtained with meter G20 is still lower than that obtained with any of the other meters.

3. INTENSIVE INVESTIGATION, JANUARY 1968

The results discussed above strongly suggested that the value of 54.72 milligals in use for the Canberra calibration range, was in error by about 0.04 milligal. The evidence was not, however, conclusive and, because of the current prime importance of the Canberra range, it was decided to conduct a special investigation, using all available quartz meters. These were Master Worden 548, Wordens 61, 169, and 260, Sharpe 145, and World-wide 35.

Barlow (1967) has discussed the causes of changes in calibration factor in quartz meters. Of those mentioned by him, two, the effects of ageing and internal pressure changes, were eliminated by carrying out the whole experiment within a very short space of time. The transportation effect, which has been found to be largest when the meter is taken to great heights in aircraft, was minimised by using a car for travel to and from Melbourne. There is little that can be done in practice to minimise the temperature effect, but fortunately this appears to be small for the 20°F range within which the work was carried out. It was hoped that the use of a number of meters would minimise errors due to purely erratic changes in calibration factor. Similarly, to minimise observer errors, two different observers were employed, and each observer read each meter on at least a 5-4 run (i.e. 5 readings made at the bottom station on the range and four at the top). To avoid observer fatigue and confusion between reading points on different meters, the observers read only two meters on any one run. The observers, J. Milsom and A. Volframs, had had considerable experience with most of the meters used when they made the New Guinea and Australian Isogal surveys in 1967.

It has also been found that errors may arise if a meter is not given time to settle down after a reset. A minimum of twelve hours was allowed for this.

The first readings in Canberra were made on 8 January and the meters were taken to Melbourne and reset on the following day. To eliminate possible errors due to irregularities in the measuring screws the meters were reset so that the dial readings at the bottom stations in Melbourne and Canberra were roughly the same.

Two complete (4-5 runs were made on the 10th and the remaining planned run on the morning of the 11th. Inspection of the drift curves showed that further work was desirable with some meters and a fourth (5-5) run was made in the afternoon. The party's return to Canberra was delayed by vehicle unserviceability until late on the 13th, when the meters were reset. Runs made on the 14th (5-6) and 15th (6-7 and 4-5) completed the work.

The results obtained are tabulated in the Appendix, shown graphically in Plate 5, and are briefly summarised below in Table 1:

<u>TABLE 1: Summary of results</u>

	Calibration factor		Canberra Range interval (milligals)	
	Volframs	Milsom	Volframs	Milsom
W61	0.0906(0)± (3)	0.0905(7)±(5)	54.71±.04	54.74±.05
W169	0.1011(2)± (4)	0.1011(0)±(4)	54.77±.04	54.74±.04
W260	0.1088(4)± (4)	0.1088(9)±(3)	54.77±.04	54.79±.03
MW548	0.1094(7)± (2)	0.1095(1)±(2)	54.75±.03	54.78±.03
S145	0.1066(6)± (3)	0.1066(7)±(2)	54.77±.03	54.76±.03
WW35	0.1155(3)± (2)	0.1155(0)±(2)	54.79±.02	54.78±.02

Certain systematic effects are immediately apparent, the most obvious being the consistently low values with Worden 61. In this case, one run, the second by Volframs in Canberra, gives a result definitely different from all other runs with this meter and this heavily influences the very low value shown above. However, even if this run is dismissed as an inexplicable random effect the W61 results remain low. This possibility results from the position of the reset screw and spring.

The errors shown in Plate 5, and in Table 1 and the Appendix, are actually the maximum deviations observed from any single determination within a run, from the mean of that run. It is not possible to apply rigorous statistical methods to the results, both because of their comparatively small number and because of the presence of unknown systematic effects. Barlow (1967), while recognising these limitations, has applied the concept of standard error (standard deviation) to the results for other calibration ranges. A standard error for the Canberra range can be similarly obtained. The mean of all the estimates in Plate 5 is 54.759 milligals. The standard error is about 0.01 milligal.

4. CONCLUSION

The value of 54.72 milligals formerly adopted for the Canberra calibration range is too low. A thorough investigation of the relationship between the Canberra and Melbourne ranges indicates that the best value for the Canberra range is 54.76 milligals with a standard error of about 0.01 milligal (Melbourne 53.04 $\pm$ 0.01 milligals).

5. REFERENCES

BARLOW, B.C. 1967 Gravity meter calibration ranges in Australia. Bur. Min. Resour. Aust. Rep. 122.

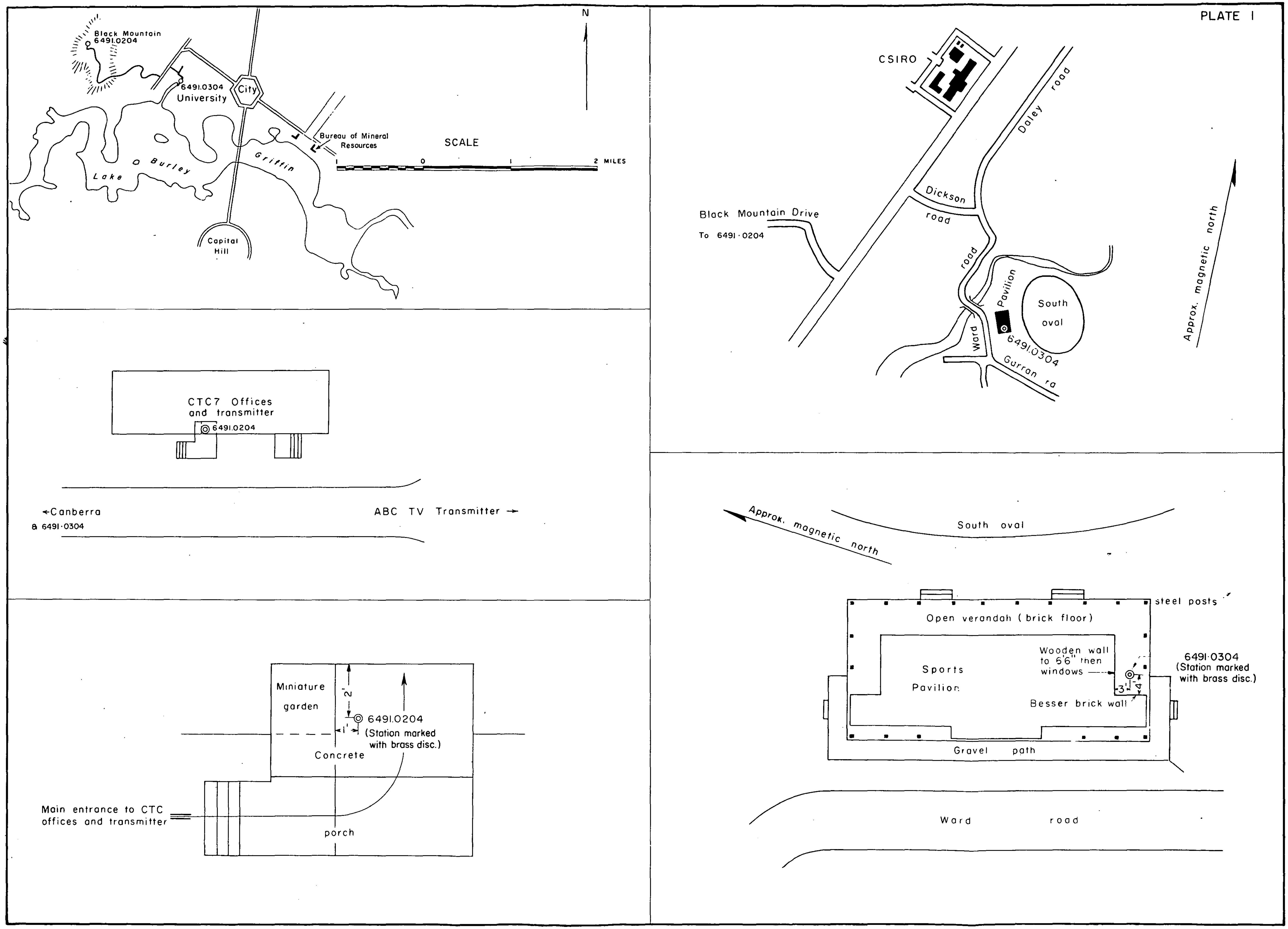
DOOLEY, J.C. 1965 Australian gravity network adjustment 1962. Bur. Min. Resour. Aust. Rep. 72.

RESULTS OF CANBERRA CALIBRATION RANGE INVESTIGATION 1968

APPENDIX

	W61	W169	W260	MW548	S145	WW35	OBSERVER	CODE
				d (scale division)				
CANBERRA 8 JAN 68	604.2 ± 0.3	541.7 ± 0.1	503.1 ± 0.2	500.1 ± 0.2	513.5 ± 0.1	474.3 ± 0.1	VOLFRAMS	d_1
	604.4 ± 0.2	541.7 ± 0.2	503.2 ± 0.2	500.3 ± 0.2	513.4 ± 0.2	474.2 ± 0.1	MILSOM	d_3
				K (milligals/scale division)				
MELBOURNE 10–11 JAN 68	0.0905 (7) ± (2)	0.1011 (2) ± (4)	0.1088 (6) ± (3)	0.1094 (7) ± (2)	0.1066 (6) ± (3)	0.1155 (3) ± (2)	VOLFRAMS	K_1
	0.0906 (4) ± (2)		0.1088 (2) ± (4)				VOLFRAMS	K_2
	0.0905 (7) ± (5)	0.1010 (9) ± (5)	0.1088 (9) ± (3)	0.1095 (1) ± (2)	0.1066 (7) ± (2)	0.1155 (1) ± (3)	MILSOM	K_3
		0.1011 (2) ± (3)				0.1154 (9) ± (2)	MILSOM	K_4
				d (scale division)				
CANBERRA 14–15 JAN 68	603.7 ± 0.1	541.4 ± 0.2	503.4 ± 0.2	500.1 ± 0.2	513.4 ± 0.1	474.2 ± 0.2	VOLFRAMS	d_2
	604.4 ± 0.3	541.3 ± 0.1	503.2 ± 0.1	500.2 ± 0.2	513.3 ± 0.3	474.4 ± 0.2	MILSOM	d_4
				Canberra range interval (= d x K)				
	54.72 (2) ± .04	54.77 (7) ± .03	54.76 (7) ± 0.3	54.74 (6) ± 0.3	54.77 (0) ± .03	54.79 (6) ± .02		K_1d_1
	54.76 (5) ± .04		54.74 (7) ± .04					K_2d_1
	54.67 (7) ± 0.02	54.74 (6) ± .03	54.76 (1) ± .03	54.74 (6) ± .03	54.75 (9) ± 0.02	54.78 (4) ± .03		K_1d_2
	54.71 (9) ± .02		54.74 (0) ± .03					K_2d_2
	54.74 (1) ± .04	54.76 (0) ± 0.04	54.79 (3) ± .03	54.78 (8) ± .03	54.76 (4) ± .03	54.77 (5) ± .03		K_3d_3
		54.77 (7) ± 0.04				54.76 (5) ± .02		K_4d_3
	54.74 (0) ± .06	54.72 (0) ± .03	54.79 (3) ± .02	54.77 (7) ± .03	54.75 (4) ± .04	54.79 (8) ± .03		K_3d_4
		54.73 (6) ± .03				54.78 (8) ± .03		K_4d_4
MEAN	54.72 (7)	54.75 (3)	54.76 (6)	54.76 (4)	54.76 (4)	54.78 (4)		

NOTE: The values of K and d used to obtain each value of the Canberra range interval are indicated in the 'Code' column.



Observed gravity interval

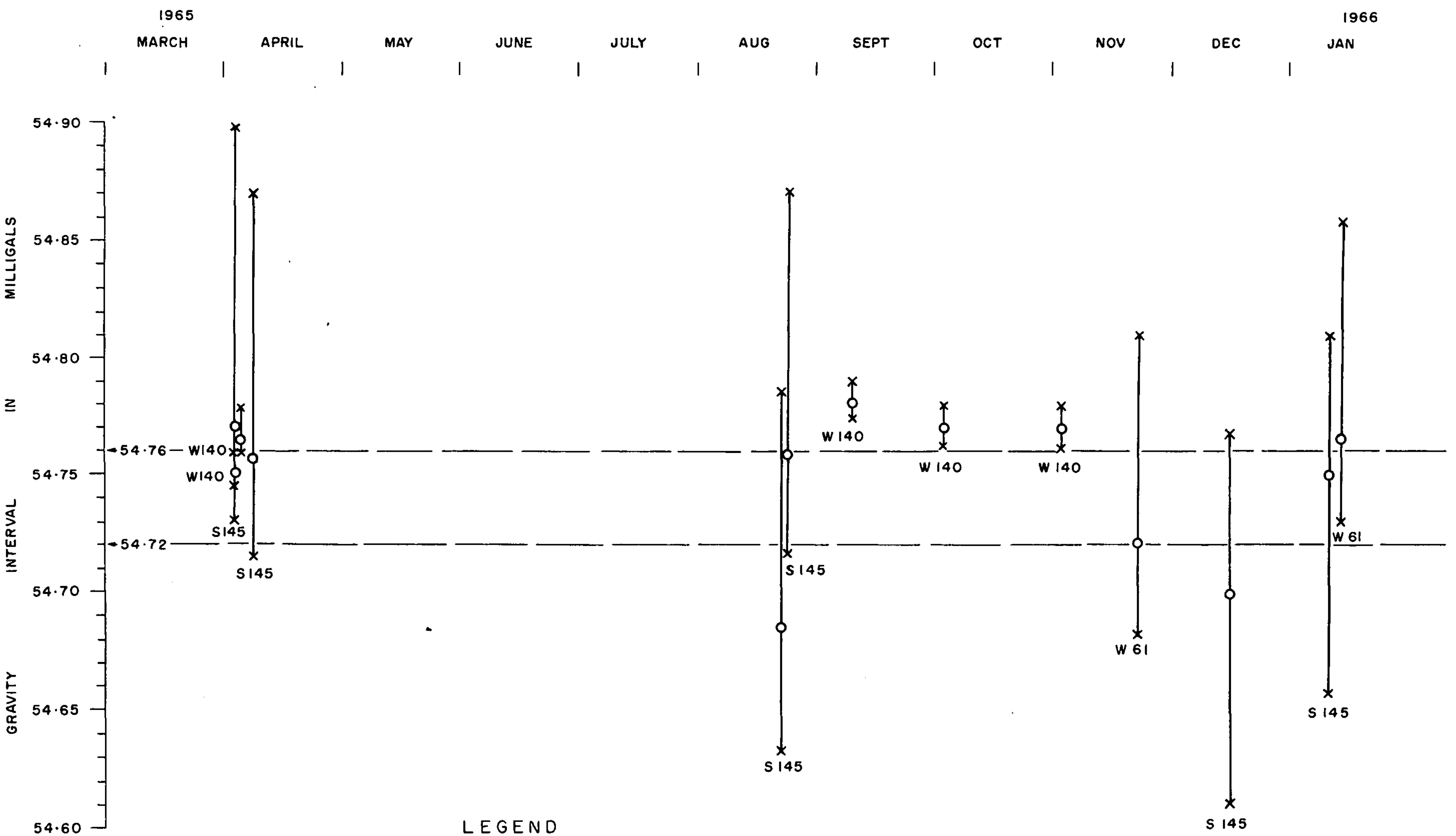
6491·0304 - 6491·0204 = 54·72 mgal (May, 1965)
6491·0304 - 6491·0204 = 54·76 mgal (Jan., 1968)
Station 6491·0304 previously referred to as CCS I
" 6491·0204 " " " " CCS 2

TO ACCOMPANY RECORD No. 1969/31

GRAVITY METER CALIBRATION RANGE

CANBERRA

G24-II



LEGEND

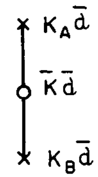
K Calibration factor of gravity meter (mgal/scale division)

K_A Maximum possible value of K

$\bar{K}$ Most probable value of K

K_B Minimum possible value of K

$\bar{d}$ Mean interval measured

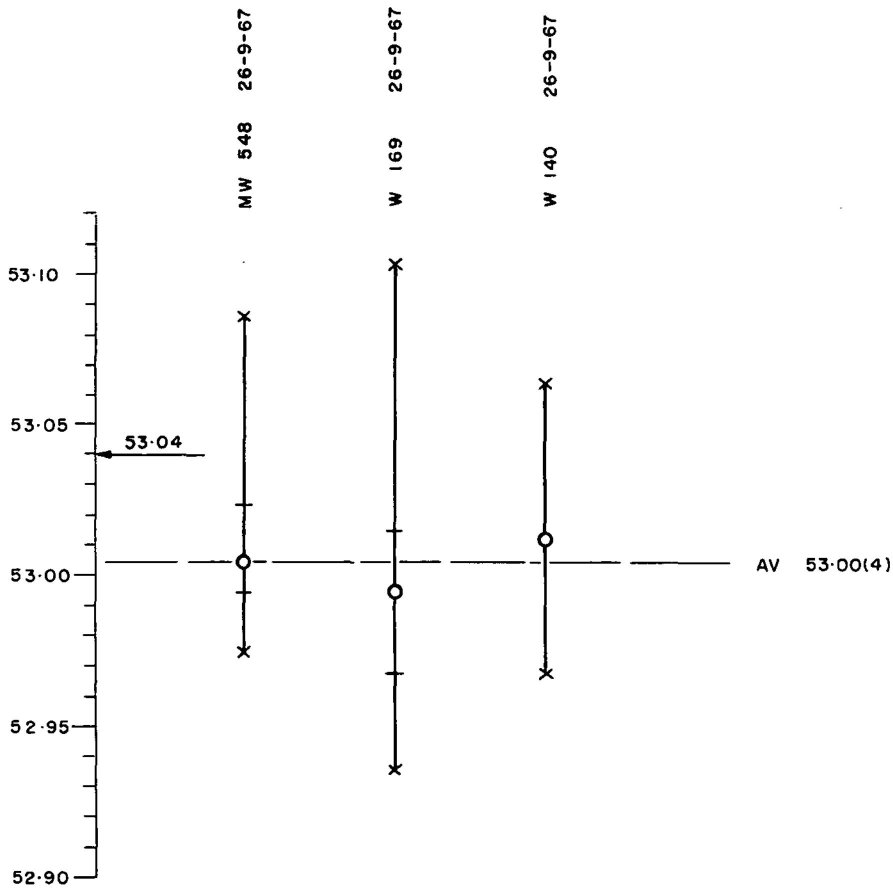


GRAPHICAL SUMMARY OF RESULTS CANBERRA CALIBRATION RANGE 1965

To accompany Record No.1969/31

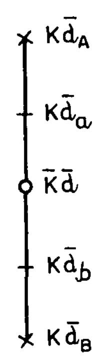
G 24-14

PLATE 2



LEGEND

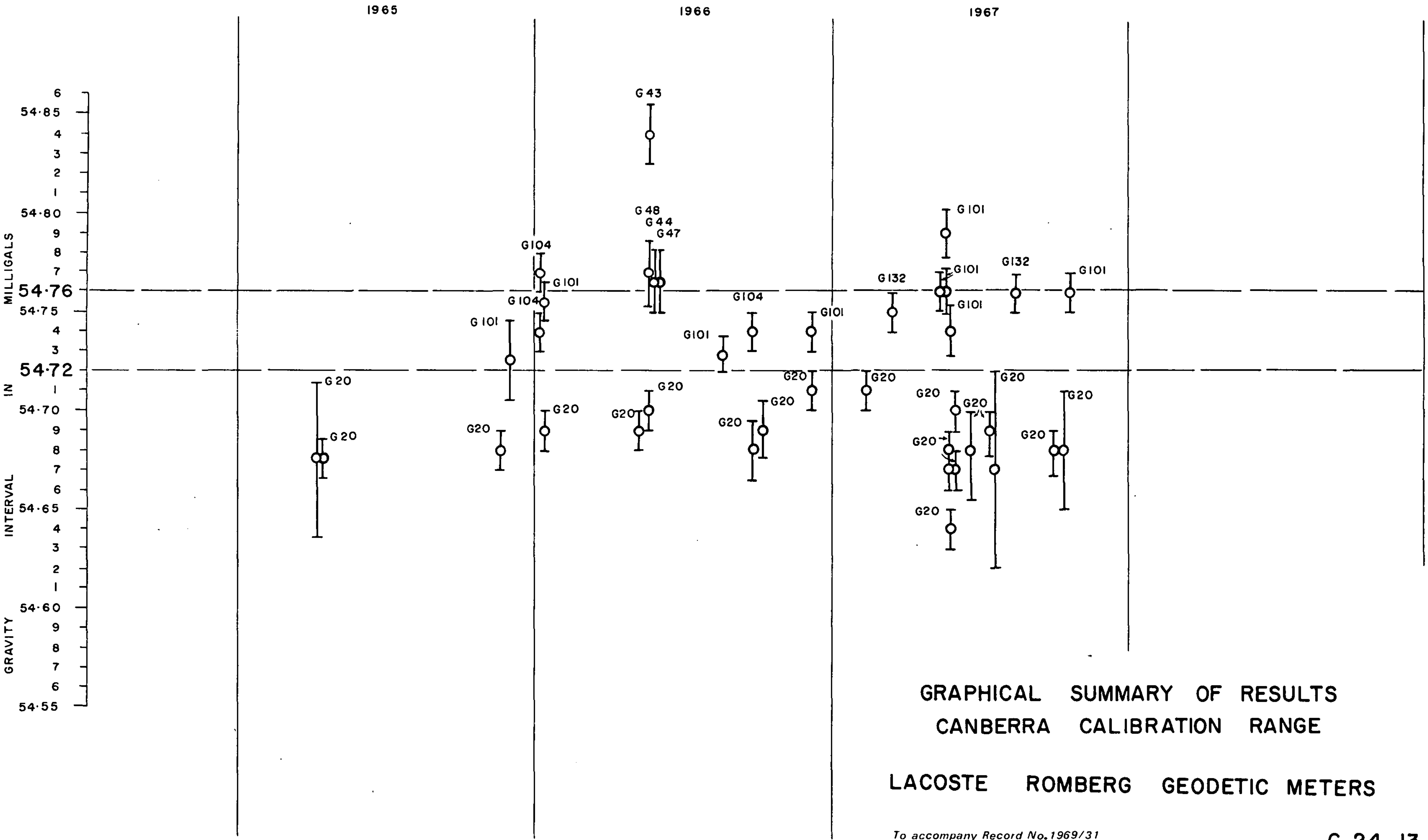
K	Calibration factor of gravity meter (milligal/scale division)
K_A	Maximum possible value of K
K_a	Maximum probable value of K
$\bar{K}$	Most probable value of K
K_b	Minimum probable value of K
K_B	Minimum possible value of K
$\bar{d}$	Mean value of d
d	Interval measured in scale division



GRAPHICAL SUMMARY OF RESULTS
MELBOURNE CALIBRATION RANGE 1967

To accompany Record No. 1969/31

G 24-15



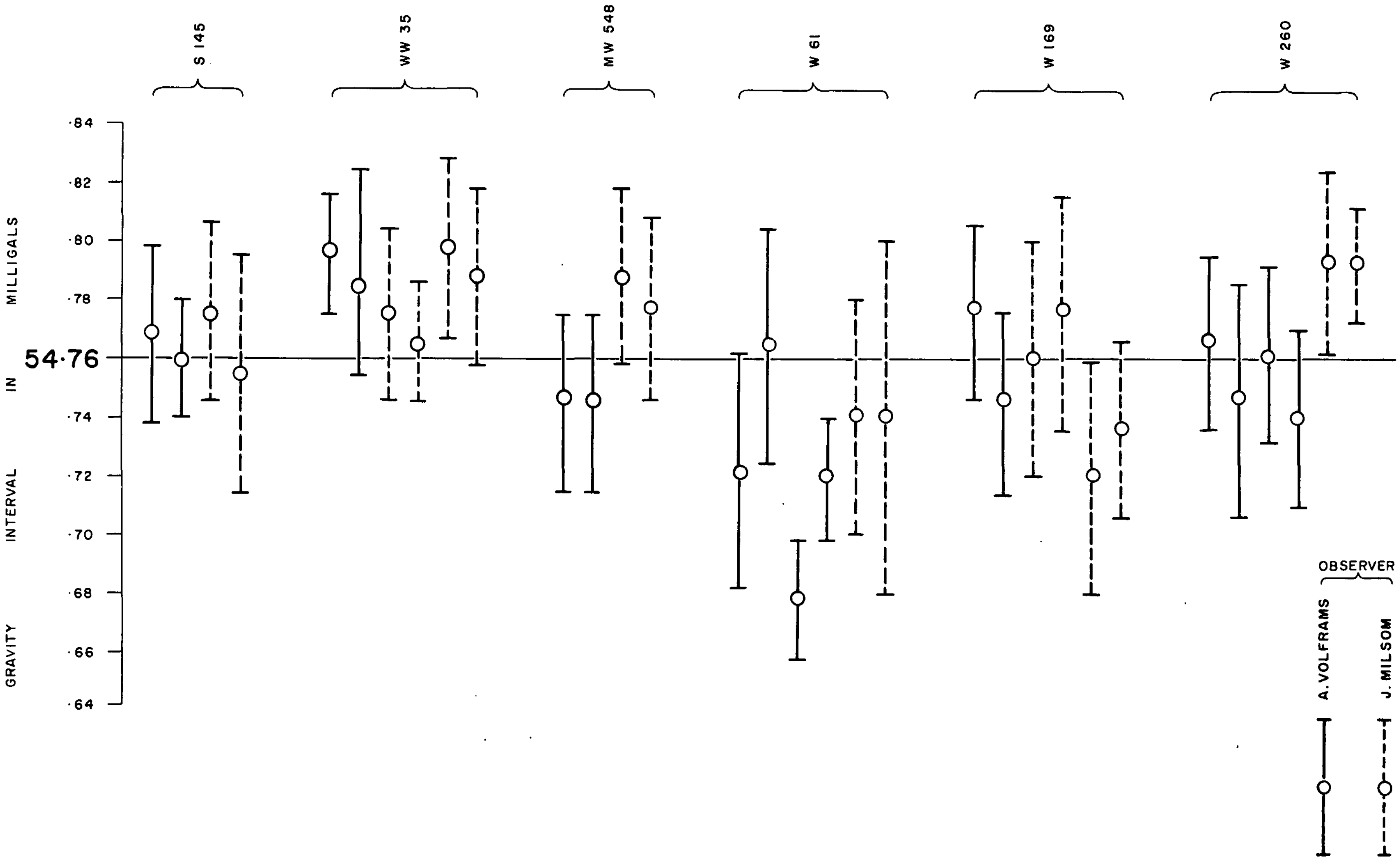
GRAPHICAL SUMMARY OF RESULTS
CANBERRA CALIBRATION RANGE

LACOSTE ROMBERG GEODETIC METERS

PLATE 4

To accompany Record No. 1969/31

G 24-13



CANBERRA CALIBRATION RANGE DETERMINATION
JANUARY 1968

To accompany Record No. 1969/31

G 24-12

PLATE 5