COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record No. 1970/89

Barometric Heighting — An Assessment of the Accuracy Achieved during Reconnaissance Gravity Surveys in Australia

by

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BAROMETRIC HEIGHTING - AN ASSESSMENT OF THE ACCURACY ACHIEVED DURING RECONNAISSANCE GRAVITY SURVEYS IN AUSTRALIA

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SUMMARY

The Bureau of Mineral Resources has currently completed a reconnaissance gravity survey of approximately 65% of Australia with a station density of approximately 1 per 50 square miles. The elevations for these stations have been obtained by barometric techniques. The results of these surveys indicate that erratic behaviour of the barometers and, at this stage, unknown (but probably climatic or mathematical) systematic variations contribute to the errors in the results. With the techniques employed on the reconnaissance gravity surveys it appears unlikely that the standard deviation of the adjustments to the survey network can be better than 3-4 feet. Trial surveys are recommended to investigate the possibility of using barometers reliably on more detailed surveys.

INTRODUCTION

The Bureau of Mineral Resources, Geology and Geophysics has currently completed a reconnaissance gravity survey of approximately 65% of Australia. Stations have been established at a density of approximately one per 50 square miles. The elevations for these stations have been obtained by barometric techniques. The survey techniques have undergone several modifications since the inception of this survey, but a fairly standard method has been in operation for the past few years. Figure 1 shows a typical flight plan for a standard 1:250,000 map sheet and it can be seen that a strong network is built up which is usually well controlled by accurate third order level bench marks.

From all these surveys a large amount of information has been accumulated as to the accuracy of barometric levelling techniques. Since 1965 the results of these surveys have been reduced by computer (Bellamy, Lodwick & Townsend, 1970) and large quantities of statistical data has been generated. This report presents some of the data, which have mainly been obtained from the 1968 survey (with which the author was most closely connected), but data are also included from the 1965, 1966 and 1967 surveys. The report is by no means comprehensive but it will indicate the expected accuracies that are likely to be obtained from such surveys.

The accuracy of the elevations on helicopter gravity surveys controls the accuracy of the final Bouguer anomalies. The statistics presented here indicate what this accuracy is likely to be. The formulae used in the height reductions have been discussed elsewhere (Bellamy & Lodwick, 1967) and are not repeated here.

NETWORK ACCURACY

As outlined previously each loop (Fig. 1) forms part of a network controlled by fixed heights. In the flying of a loop the cell centre and tie point must not be located on opposite sides of a bench mark traverse. Under these conditions areas (or segments) contained by bench mark traverses can be considered to be independent for computation purposes, and errors cannot be propagated into adjacent segments.

During computation each segment is computed three times through a least squares network adjustment phase:

(i) with only one fixed elevation in the network (this gives the internal standard deviation);

(ii) with half of the fixed elevations in the network;

(iii) with all fixed elevations in the network (this gives the external standard deviation).

In (ii) the differences between the computed values and the true values at the bench marks which were not fixed are used to compute the forecast standard deviation.

Table 1 gives the internal and external standard deviations together with the maximum adjustments. Also listed in Table 1 are the number of loops in each segment, the maximum elevation difference on one loop between cell centre and tie point, the average elevation difference of all loops, and the number of loops with elevation differences of over 500 feet.

In Figure 2 the average measured elevation difference is plotted against the internal and external standard deviations for each segment. It is seen that there is an increase in standard deviation with increase in mean elevation difference (except for segment D, which has a large percentage of loops with an elevation difference of over 500 feet). From this correlation it can be estimated that a standard deviation of less than 3 feet will not be very common even in relatively flat areas.

TABLE 1 1968 N.S.W.

Seg.	External S.D.		Internal S.D.		Mean Elev. diff. on Loop	No. Loops	Max. diff.	No. of loops with elev. over 500 ft
	SD	MA	SD	MA				
A	11.98	35.02	5.85	17.81	496	48	2868	17
B	20.80	56.71	10.33	32.93	965	88	4169	46
C	10.54	40.06	4.77	11.68	375	53	2021	13
D	18.72	44.06	14.34	39.37	633	39	1890	18
F	9.04	23.66	6.24	14.60	338	102	1943	24
G	7.86	17.92	4.42	11.78	53	62	225	0
H	6.45	19.77	4.21	11.10	57	97	285	0
I	5.64	14.91	5.11	12.65	61	59	270	0
J	4.48	12.33	2.46	7.13	74	36	220	0
K	5.37	12.68	2.53	5.28	38	35	149	0
L	5.50	18.63	4.08	18.71	76	85	289	0

ACCURACY BETWEEN BENCH MARKS

During the 1968 survey in New South Wales, Queensland, and Western Australia many loops contained more than one bench mark. Comparison of the measured elevation differences with the true elevation differences on these loops gives an estimate of the accuracy that can be expected in measured elevation intervals. These differences (sign ignored) are plotted as a histogram on Figure 3. Of these measured intervals, 72% are accurate to 7 feet or better and 86% are accurate to 10 feet or better.

The majority of the differences are plotted against the true elevation interval on Figure 4. No really significant conclusion emerges from this as the majority of the elevation intervals measured were comparatively small (less than 500 feet). However, there is a tendency for larger errors to be associated with larger elevation intervals.

INTERNAL STANDARD DEVIATION

As stated previously the internal standard deviation is obtained from the least squares adjustment of the network using only one fixed elevation. In most parts of Australia the elevation range in an individual segment is small, but in the coastal segments of the 1968 survey in New South Wales and Queensland a wide range in elevation was encountered (Table 1). Figure 5 shows the height of the bench marks above or below the fixed node and the difference between the computed and true elevations for these stations. It can be seen that there is a definite correlation between height interval and error.

BAROMETRIC DRIFTS

During the flying of a loop a base barometer is read at the commencement point of that loop. The difference in reading between the field and base barometers are compared at the beginning and end of each loop and the discrepancy between these two differences is called the barometric drift. Histograms of these drifts for the 1965, 1966, 1967, and 1968 surveys are presented in Figure 6 and the total drifts are presented in Figure 7 together with the normal distribution curve having the same mean and standard deviation. It can be seen that the standard deviation of these drifts is 5.64 feet. Any drifts in excess of 12 feet are rare and can generally be considered suspect misreadings or an indication of barometer malfunction.

DOUBLY READ ELEVATION INTERVALS

During the course of the more recent surveys stations have been established along the east and west margins of all 1:250,000 map sheets (Fig. 1). These stations are occupied twice on different days. The primary objective of these stations is to assist the Department of National Mapping topographic map series. However, the double occupation means that certain elevation intervals are measured twice. This gives an independent check on the repeatability of barometric height interval measurements. Figure 8 is a histogram of the differences between these doubly read elevation intervals.

BAROMETER PAIR DIFFERENCES

During a detailed gravity survey at Gosses Bluff in 1969 a pair of barometers were read simultaneously at each survey point. The differences in barometer readings at each point are shown in Figure 9 and it can be seen that there is a wide scatter in the differences. The largest would appear to be during the middle of the day (i.e. the time of maximum temperature), but the sample is not large enough and the results not consistent enough to confirm this. The differences commonly range over 0.30 millibars on any one day. This means that independent elevation differences measured by either of these barometers could differ by over 10 feet. This erratic behaviour of the barometers could account to a large extent for the barometric drift discussed earlier.

CONCLUSIONS

The main conclusions derived from the preceeding discussion are:

1. The erratic behaviour of barometer pairs causes both barometric 'drift' over a loop and also errors in elevation differences between stations.
2. There appears to be a linear relationship between the average elevation difference between tie points and the standard deviation of the adjustments to the network.
3. A systematic error of up to 100 feet occurs over areas with total elevation differences of 3000 feet.

The following are the more important statistics revealed:

1. The minimum standard deviation of the adjustments to a barometric network is 3-4 feet with an associated maximum adjustment of 9-12 feet.
2. Comparison with known elevation differences indicates that there is a mean error of about 6 feet.
3. The standard deviation of the barometric drifts is approximately 5.5 feet.
4. Elevation differences which are read twice have a mean difference of about 6 feet.

It is felt that in areas of low relief during stable weather conditions most of the observed errors in the network can be accounted for by the differential behaviour of the barometers with time. The response of the barometers both to abuse in the field and to temperature variations may be important in this regard.

In areas of high relief the physical characteristics of the barometers should remain the same (if the barometers are in good condition) and the factors which become important are:

(a) different weather patterns and associated pressure conditions between adjacent valleys and ranges;

(b) different temperature conditions between the base barometer and field barometer.

In rugged terrain it is probable that better results would be obtained if the elevation difference on loops were restricted to between 200 and 300 feet.

Over the majority of Australia mountainous conditions do not occur and so we expect and usually obtain elevations accurate to within 10 feet. This is accurate enough for a reconnaissance survey. In mountainous environments, however, the rapidly changing climatic conditions only permit an accuracy of about 40 feet.

It is important to emphasise that generally it is only the changing climatic conditions that cause the major inaccuracies (greater than 10 feet) in barometric levelling. This is exhibited in coastal vicinities where on-and off-shore breezes often cause systematic errors to occur in the barometric elevations.

RECOMMENDATION

It was concluded that the elevations obtained by barometric levelling are generally accurate enough for reconnaissance gravity surveys, but for more detailed surveys, when Bouguer anomaly features of less than 2 mgals could be important, the present system would be inadequate.

It is therefore recommended that experimental barometer surveys be conducted over known elevation ranges in

(a) flat inland areas

(b) mountainous areas

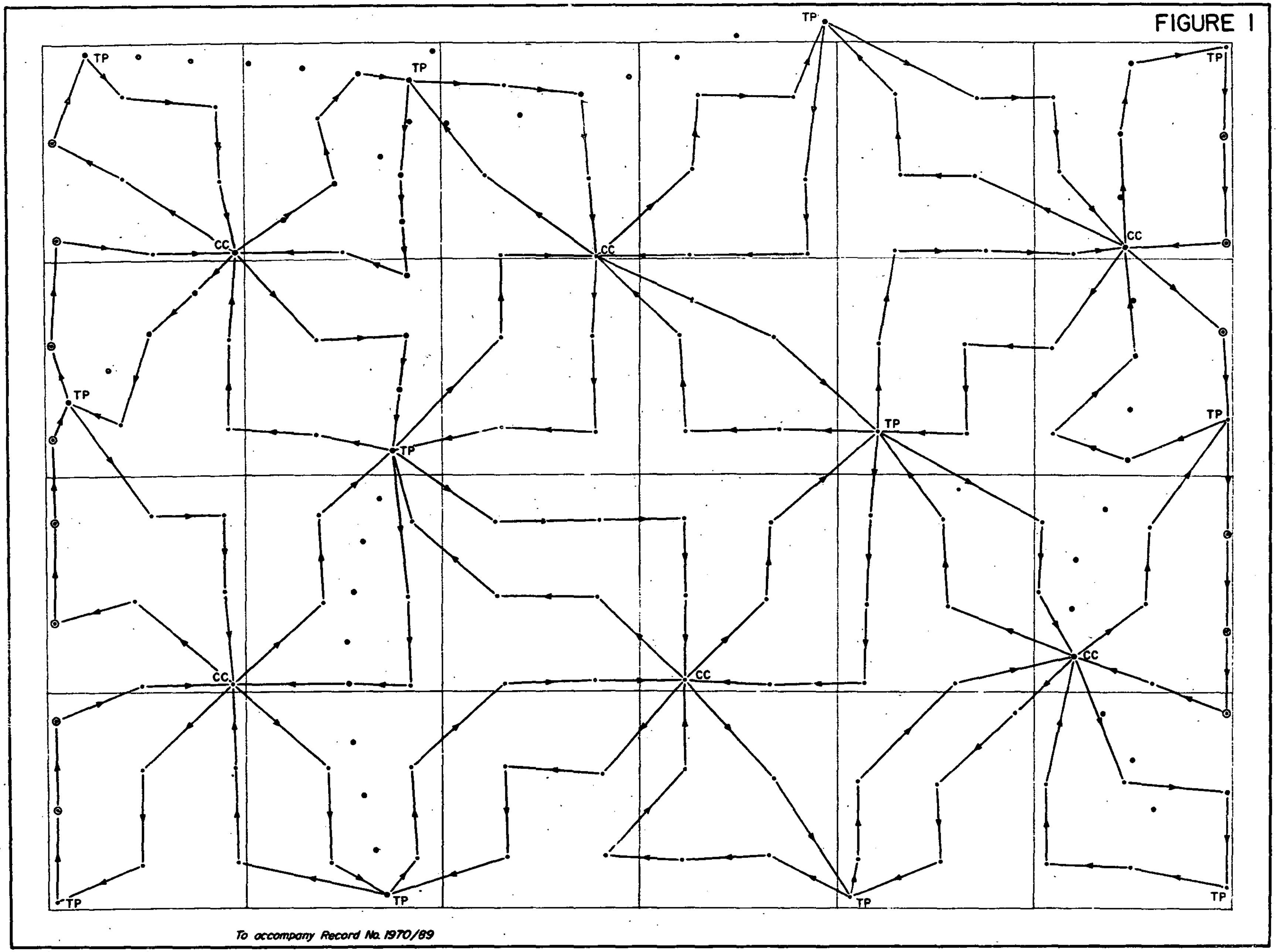
and (c) coastal area.

Combinations of multibase and multifield barometer techniques should be tried in an endeavour to improve the accuracy of the elevations. Recording of field temperatures will also be important. If a technique can be evolved to obtain accuracies of 2-3 feet it may be a more economical and faster way of conducting semi-detailed gravity surveys.

REFERENCES

BELLAMY, C.J., and LODWICK, G.D., 1967 - Reduction of barometric networks and field gravity surveys. Publ. Computer Centre, Monash Univ.

BELLAMY, C.J., LODWICK, G.D., and TOWNSEND, D.G., 1970 - BMR gravity reductions, storage and retrieval system. Bur. Miner. Resour. Aust. Rec. (in prep.). 1971-7(Rec.)



(Based on G65-195)

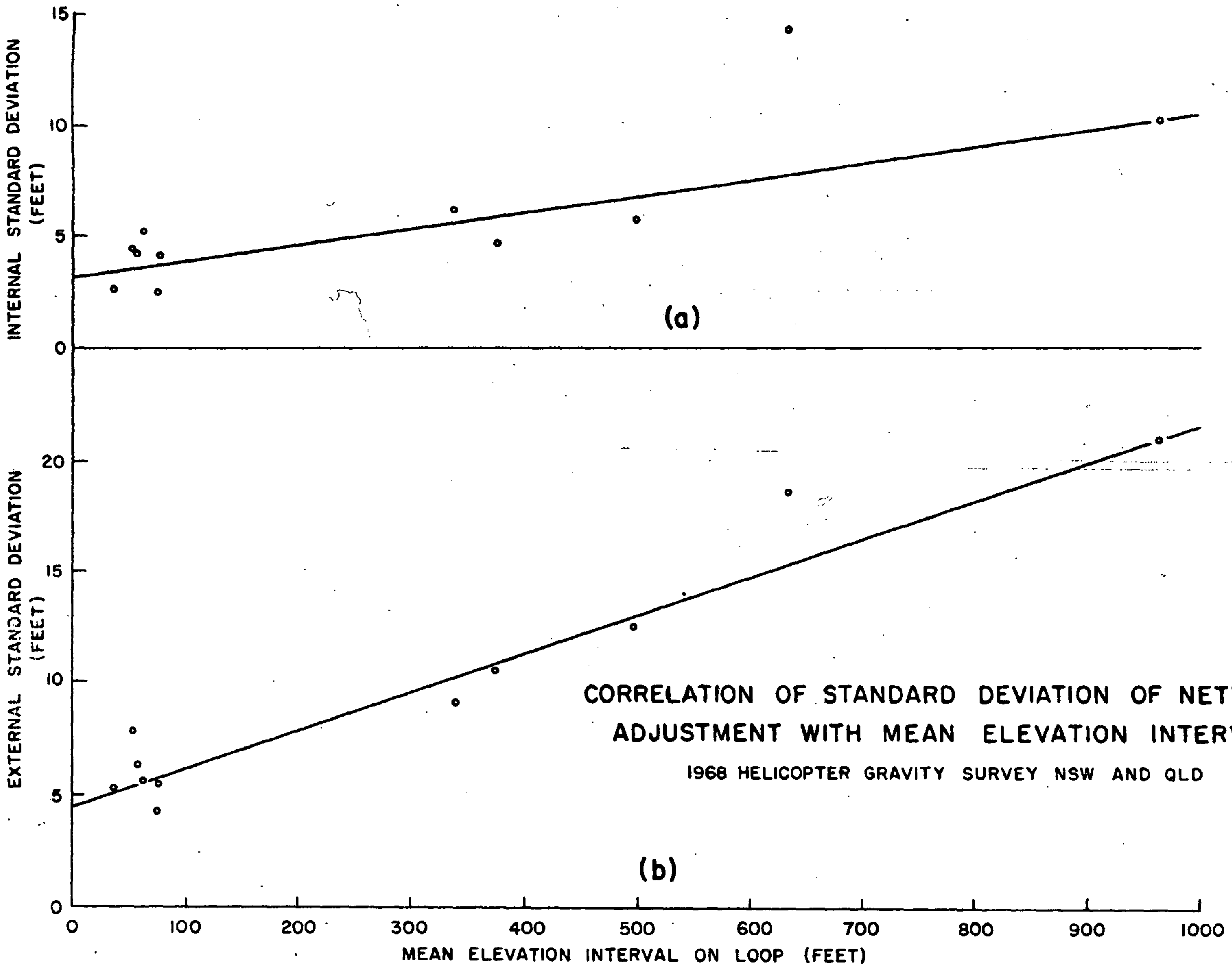
TYPICAL FLIGHT PLAN FOR 1:250,000 AREA

LEGEND

- • Bench mark
- · Gravity station
- CC Cell centre
- TP Tie point
- ⊚ Doubly read stations on sheet margin

G65-[redacted]

To accompany Record No. 1970/89



CORRELATION OF STANDARD DEVIATION OF NETWORK ADJUSTMENT WITH MEAN ELEVATION INTERVAL

1968 HELICOPTER GRAVITY SURVEY NSW AND QLD

G65-242A

FIGURE 2

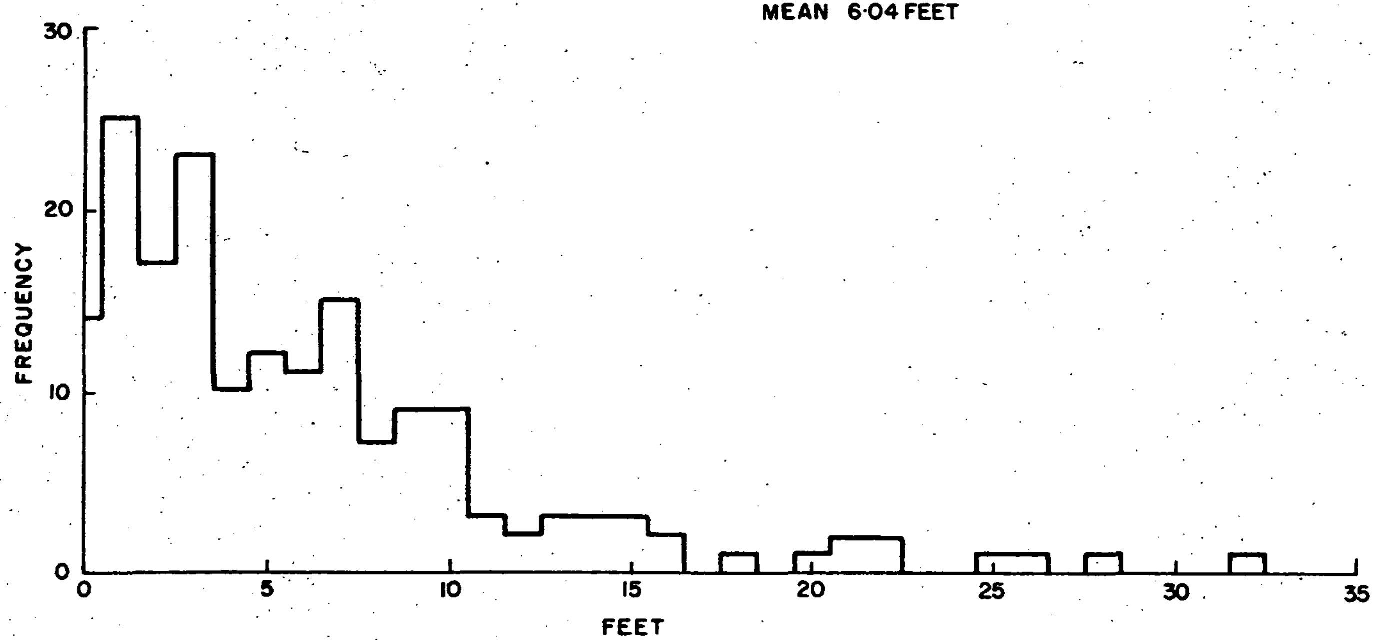
To accompany Record No. 1970/89

DIFFERENCES BETWEEN MEASURED AND KNOWN ELEVATION DIFERENCES ON ONE LOOP

1968 HELICOPTER GRAVITY SURVEY NSW, QLD, AND WA

178 OBSERVATIONS

MEAN 6·04 FEET



G65-240A

FIGURE 3

To accompany Record No. 1970/89

COMPARISON OF KNOWN AND MEASURED ELEVATION INTERVALS

1968 HELICOPTER GRAVITY SURVEY NSW, QLD, AND WA

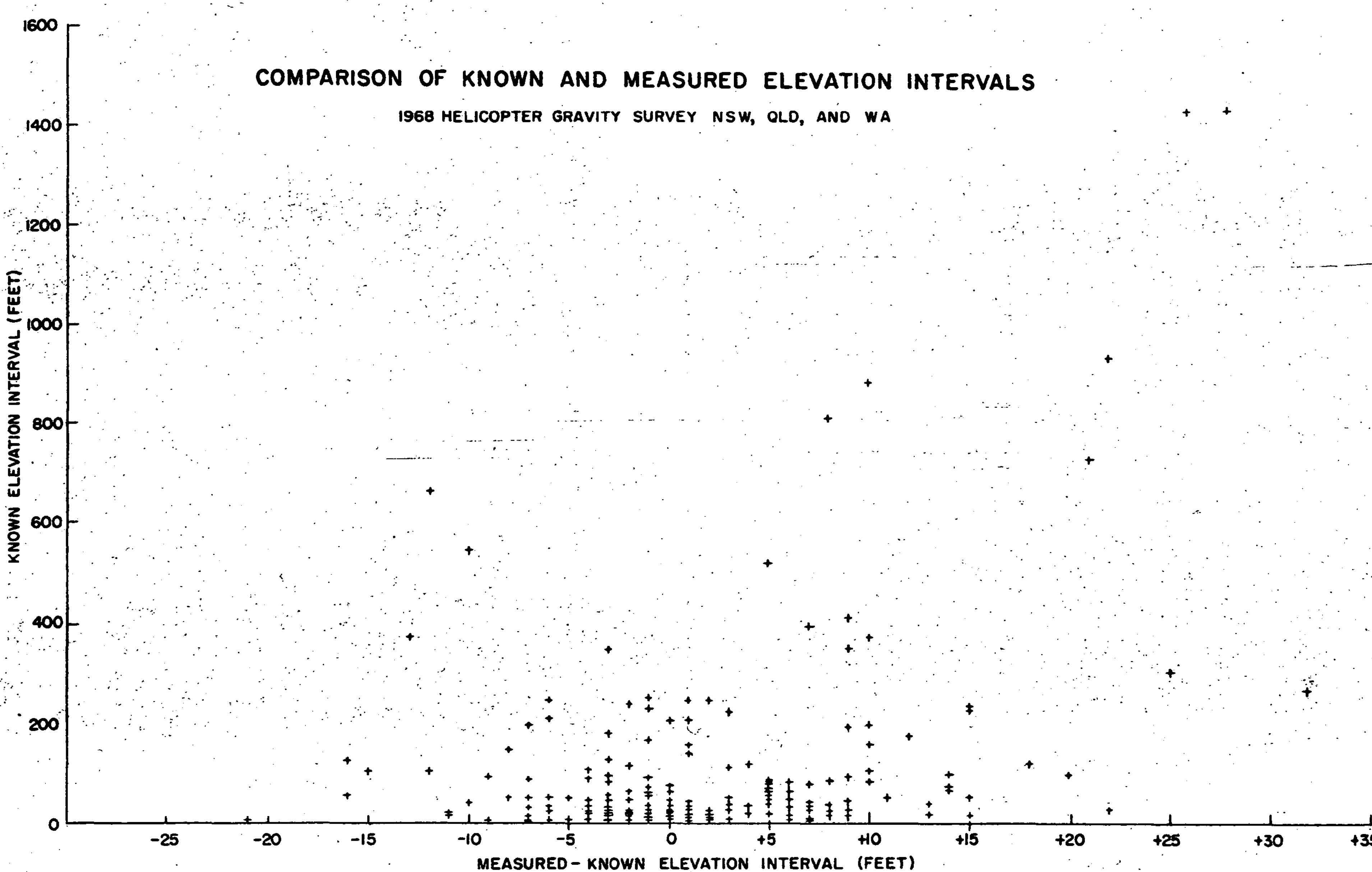


FIGURE 4

G65-243A

To accompany Record No. 1970/89

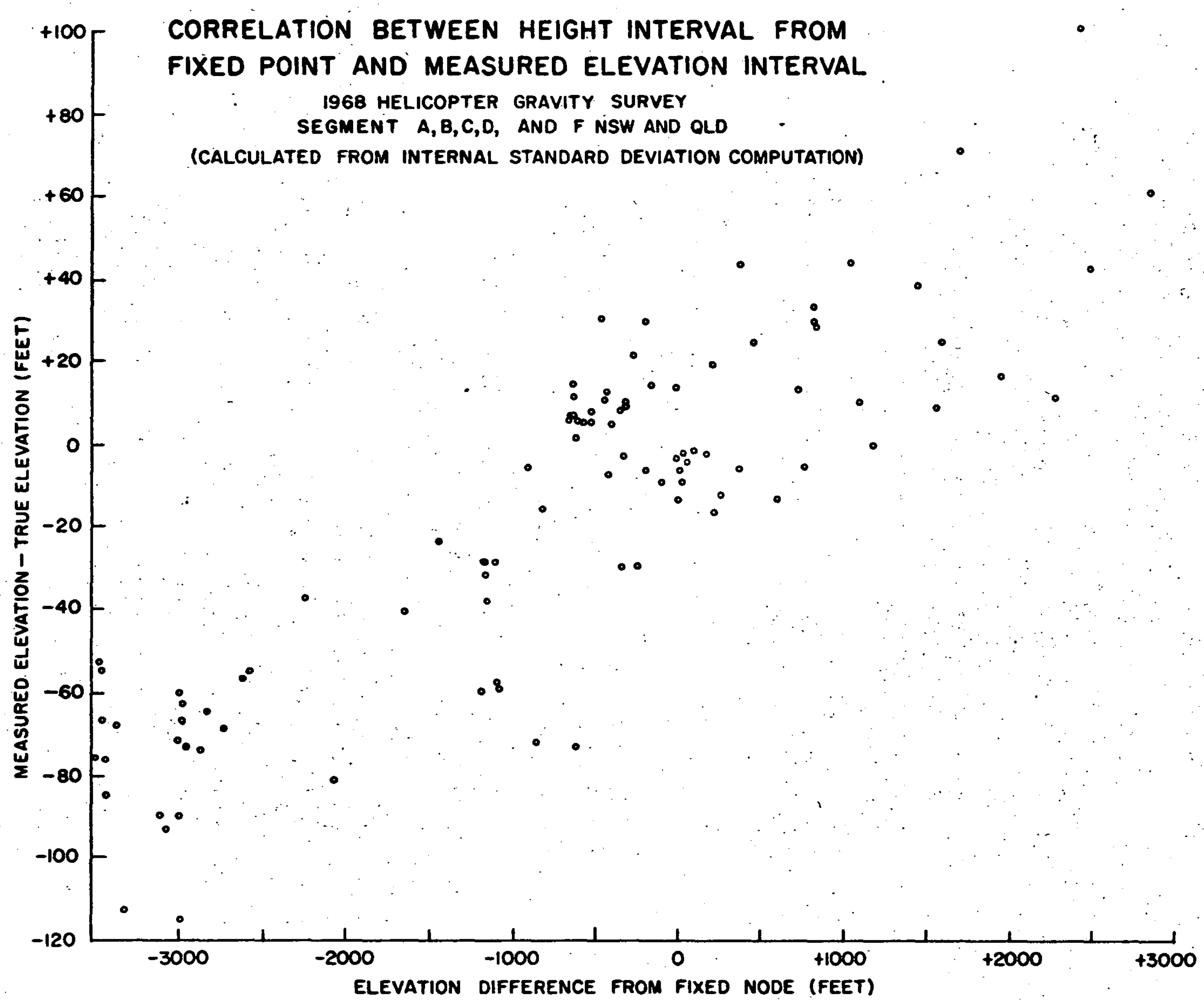
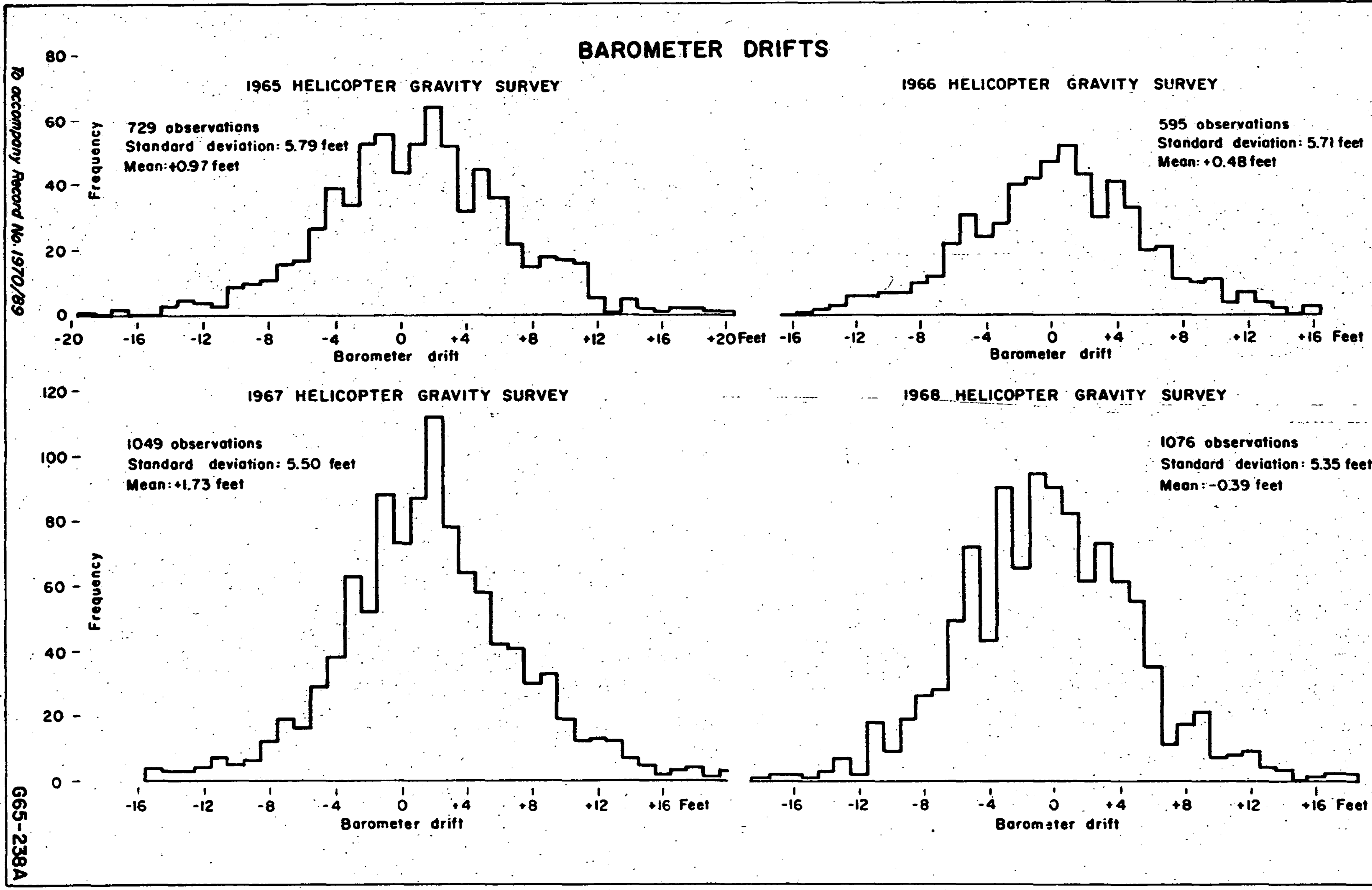


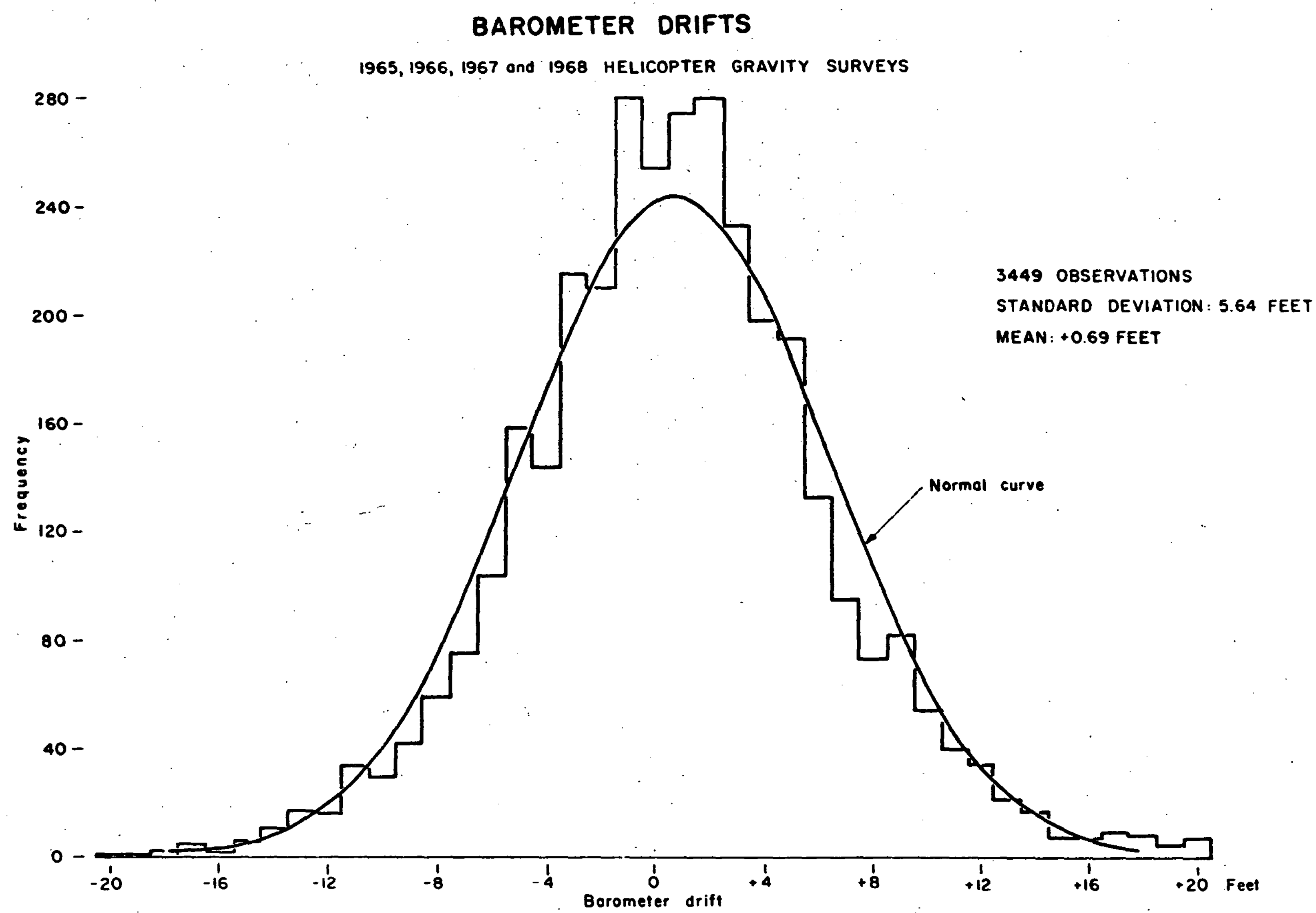
FIGURE 5

G65-244A



BAROMETER DRIFTS
1965 HELICOPTER GRAVITY SURVEY
729 observations
Standard deviation: 5.79 feet
Mean: +0.97 feet
1966 HELICOPTER GRAVITY SURVEY
595 observations
Standard deviation: 5.71 feet
Mean: +0.48 feet
1967 HELICOPTER GRAVITY SURVEY
1049 observations
Standard deviation: 5.50 feet
Mean: +1.73 feet
1968 HELICOPTER GRAVITY SURVEY
1076 observations
Standard deviation: 5.35 feet
Mean: -0.39 feet
Frequency
Barometer drift
Feet
To accompany Record No. 1970/89
G65-238A

FIGURE 6



To accompany Record No. 1970/89

G65-239A

FIGURE 7

To accompany Record No. 1970/89

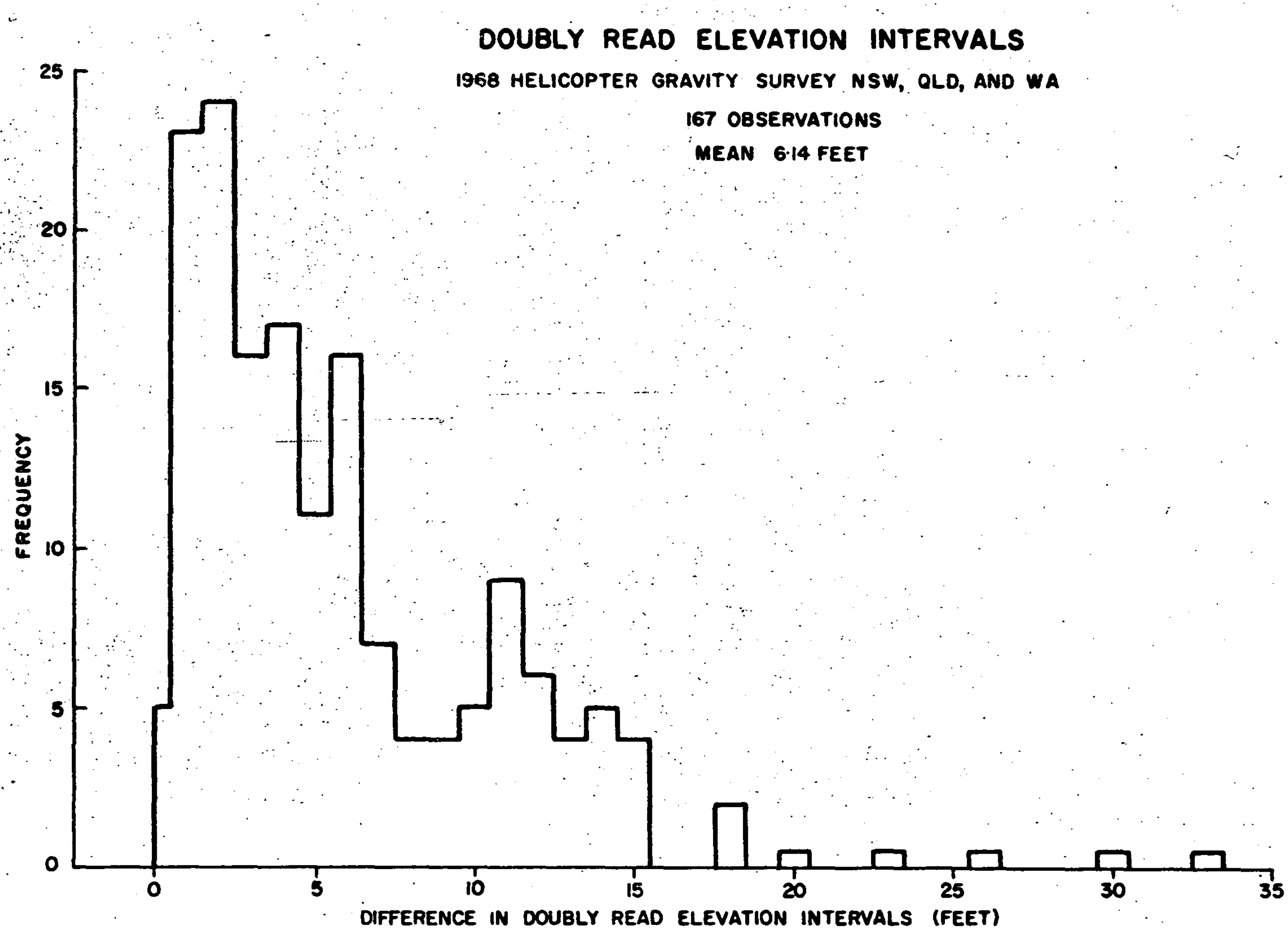


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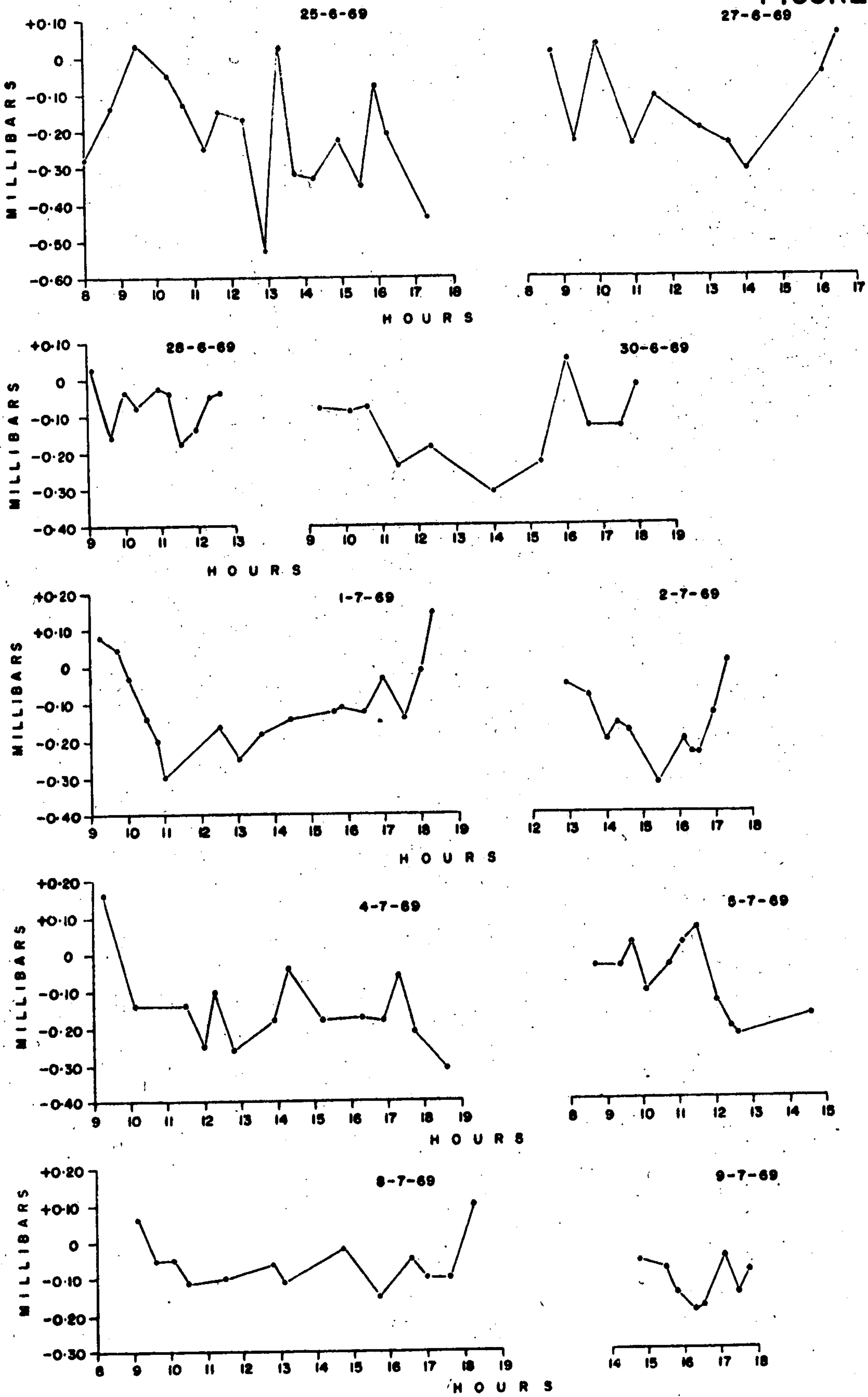
FIGURE 8

FIGURE 9



BAROMETER DIFFERENCES
GOSSES BLUFF, NT 1969
BAROMETERS 751 AND 1173

To accompany Record No. 1970/89

F 53/B2-50A