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by

J. A. Major

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CONTENTS

TABLES

SUMMARY

Two La Cour magnetographs and a Benioff vertical seismograph were in operation at Macquarie Island during 1967. A Willmore vertical seismometer was used to test several sites near the vault with the object of finding a better site, but without success. The Benioff seismometer was returned to Australia in December 1967.

A new La Cour pendulum clock was received in December 1966 and the original was returned to Australia in March 1967.

The scientific results are not included in this report but will be published separately.

1. INTRODUCTION

The Bureau of Mineral Resources (BMR) seismological observatory at Macquarie Island has been in operation since 1950 and the magnetic observatory since 1951 (Oldham, 1953).

Muir (1968) has described the 1966 operations. The author was in charge of the observatory from 10 December 1966 until 22 December 1967. He was succeeded by J. Connelly.

The instruments operating in 1967 were normal-run and rapid-run La Cour magnetographs, and short-period vertical Benioff and Willmore seismometers coupled to a BMR recorder.

Descriptions of the observatory and routines have been given in earlier reports (e.g. van Erkelens, 1961; Hollingsworth, 1960; Turpie, 1959). The work was part of the Australian National Antarctic Research Expedition program, for which the Antarctic Division, Department of Supply provided logistic support.

2. MAGNETIC OBSERVATORY

There were two magnetographs in operation during 1967, a normal-run magnetograph of 15 mm/hour chart speed and a rapid-run magnetograph of 180 mm/hour chart speed. Standard La Cour variometers were used and relevant data are given in Table 1.

In November 1967 sun sights were taken to determine the azimuth of Anchor Rock from the east pier of the absolute house. The method is described in Appendix 1. There is about 4 minutes uncertainty in the results, owing mainly to uncertainty in the latitude and longitude of the station. The sights gave the azimuth of Anchor Rock as lying between 353° 38.2' and 353° 42.7'.

Normal-run magnetograph

On 28 March the clockwork drive for the normal-run recorder was replaced by a BMR synchronous motor operated from the mains. This change produced an increase in chart speed from 14 mm/hour to the standard 15 mm/hour. The rotation of the drum was not uniform, and small breaks occurred in the record. This was cured by attaching counterweights to balance the drum, and also by stretching an elastic band across the drum axle to provide a frictional load for the motor.

On 8 July the normal-run Z Helmholtz coil was found to be open-circuited owing to corrosion. Both the normal-run H and Z coils were removed and re-wound. During these operations the AVO multimeter was placed between the H and D variometers, and its presence produced irreversible changes in the two baseline values. This could have been due to the magnet and attached mirror turning relative to the suspension fibre under the action of a large impulsive field. The H and D variometers were adjusted and orientation tests were performed on 17 July.

Record loss amounted to 3½ days.

Rapid-run magnetograph

The rapid-run magnetograph was not completely satisfactory at any time. The two main defects were:

1. All the long mirrors of the multiple lamp system were in poor condition and required replacing.

2. The time marks did not fall centrally on the variometer trace but were displaced to one side.

The H and Z variometers suffered noticeably from this second defect.

To centre the time marks on the trace, the time mark mirrors at the H and Z variometers were moved from a position beside the variometer lenses to a position vertically below them. The horizontal displacement improved the centring of the time marks, but the vertical displacement increased the parallax. Parallax corrections before and after these adjustments of 5 July were:

Component	Before	After
Z	-14 sec	+ 36 sec
H	zero	+ 24 sec
D	+ 3 sec	+ 2 sec

The sign of the correction is such that

True time of event = time of event scaled from record + parallax correction.

Many of the traces were badly faded, or absent altogether, owing to poor silvering of the multiple lamp long mirrors. Only two spare mirrors were available; these were both narrower than the originals and one was 30 percent shorter. As a temporary measure these were taped over the original H and D mirrors, and replacements and spares were ordered.

Eleven days' record was lost by: forgetting to set lens carriage release mechanism; faults in this mechanism; exposure of record to light; fading of traces; and failure of time marks when the clock stopped.

Control observations

Baseline value determinations. Absolute instruments used throughout 1967 were: BMZ64, BMZ236 (from 22 March), QHM178, QHM179, Askania declinometer 640505 (circle 640620). The BMZ236 was transferred from Wilkes, following the closure of that observatory as a back-up to BMZ64.

Determinations were made twice weekly with all instruments except BMZ236 which was used weekly. In this way it was compared with BMZ64.

Several minor difficulties encountered with the magnetometers are listed below:

(a) the QHM thermometers were difficult to read.

(b) During summer, direct sunlight on the east pier in the afternoon made the QHM temperatures uncertain.

(c) The vernier adjustment on the turn magnet of BMZ64 slipped occasionally; this was dismantled and cleaned, the friction drive surfaces were lightly scored, and the mechanism was re-assembled. It has since been satisfactory.

(d) The prism in BMZ64 telescope came unstuck from its mounting while being cleaned. It was glued in place and in the process lost its silvering; however, it continued to function by total reflection.

Analysis of the Z baseline values revealed that thermometers N.106 and N.107 used with BMZ64 gave different results. Values obtained when N.107 was used were consistently lower (numerically) than when N.106 was used. This suggested that, with the thermometer corrections given, N.107 was reading a higher temperature than N.106.

Thermometer No. 106 had been used (except on 29 March) whenever BMZ64 was compared with Z calculated with BMZ236 throughout the year. BMZ236 was compared with Z calculated from proton precession magnetometer (PPM) readings in December 1967. Thus the preliminary correction of -10 gammas derived for BMZ64 applies only to BMZ64 using thermometer N.106 and not to BMZ64 using thermometer N.107. Results obtained when thermometer N.107 was used were ignored when adopting the Z baseline values.

Comparisons. In December 1967 the magnetometers were intercompared with Toolangi standard instruments as follows:

	Declination	Horizontal Intensity	Vertical Intensity
Observatory	Ask. 505	QHM178	BMZ236
Standard	Ask. 812	QHM177, HTM154	PPM (Elsec)

In accordance with a new policy, QHM177 remained at the station as it is one of the station's set of three and there are sufficient standardizing instruments without using Observatory instruments.

Scale-value determinations. Scale-value currents were measured with meter VML.21164, which was compared with newly developed magnetograph calibrator BMR type MCO-1 during the 1967 changeover. Table 2 gives the meter corrections.

Scale values were calculated using the uncorrected meter readings to yield the 'mean measured scale value' (Table 3). This was adjusted for the meter correction to give the 'mean corrected scale value'. The 'adopted scale value' and the current read from the meter are also given.

The adopted scale values were obtained by rounding the second decimal place to the nearest 0.05. This was done to maintain continuity with the previous year and also because there was doubt in the second decimal place, as the standard deviations of the mean corrected scale value show.

Orientation tests

After disturbances to the normal-run H and D variometers due to the proximity of the AVO multimeter on 8, 9, and 10 July, tests on these variometers were carried out on 17 July.

On 19 October the H variometer magnet was disturbed during adjustments to the baseline mirror. No further orientation tests were performed because the new ex-orientation angle could be calculated. The results are given in Table 1.

The moments of four magnets were determined by deflecting the declinometer magnet suspended in the Earth's (known) horizontal field. The method is described in Appendix 1. The results of these determinations are given in Table 7. It was intended to use these magnets to do orientation tests on the Z variometers, but no orientation tests were performed on either the normal-run Z or any of the rapid-run variometers.

Time control

The pendulum clock received in December 1966 stopped several times during February 1967. The case was checked to ensure it was vertical, and the mechanism was inspected and lubricated with watch-oil, to no avail. Finally on 2 March extra drive weights were added and the clock has operated satisfactorily since then. There was no problem keeping the correction within 30 seconds, but the rate was rather erratic, particularly when high winds vibrated the building.

3. SEISMIC OBSERVATORY

Seismograph

This consisted of a 1-second Benioff vertical seismometer, a 0.2-second galvanometer, and a BMR recorder which ran at 30 mm/minute. The seismometer and galvanometer were connected through a modified Geotechnical control box. The details of the seismograph are given by Sutton (1969).

In March 1967 a portable Willmore seismometer with a free period of 0.8 to 0.9 sec, a Leeds & Northrup filter galvanometer, a second Benioff 0.2-second galvanometer, a modified Geotechnical control box, and 300 yards of shielded cable were received. This was to enable simultaneous recording using the Benioff seismometer in the vault and the portable Willmore seismometer at various sites within about 300 yards of the vault, with the object of determining whether a less noisy site exists near the vault.

Unfortunately the second galvanometer was unserviceable so the sites had to be compared by recording alternately on the Benioff (vault) and Willmore (site) seismometers. Three sites were tested, two on Wireless Hill and one in the gully between Wireless Hill and Camp Hill. None was better than the vault.

Complete details of the instrument connexions, site locations, and record analyses have been left at the Island.

Seismograph tests

Tests were carried out on the seismograph to determine the free period of the seismometer, the damping ratio and magnification of the system, and the damping ratio of the galvanometer.

Table 4 shows the system magnification and damping ratio for the 1967 tests and also includes values obtained in 1965 and 1966. The mean of the 1967 results was divided by the mean of the 1965 and 1966 magnifications.

i.e. the ratio $$\frac{M_2}{M_1} = \frac{\text{mean magnification at 1 Hz from 1967 tests}}{\text{mean magnification at 1 Hz from 1965 and 1966}}$$

tests was calculated. It was found to be 1.33. The change in magnification was due to the increase in recording distance between the galvanometer and BMR recorder. The recording distance was increased on 16 April so that a second Benioff galvanometer and light source could be included on the pier for use with the Willmore seismometer.

On 15 October the free period of the seismometer was adjusted to 1.00 sec; prior to this the period had been 1.07 sec. Table 5 gives the seismometer free period.

On 24 September the galvanometer damping ratio was 22 with the galvanometer damping and seismometer damping controls both set to 7 (i.e. Gd = Sd = 7).

The system magnification at 1 Hz, as determined by weight lift tests, is given by

Magnification = 800X1/Wt

where X1 = initial trace deflection in mm

Wt = weight used, in grams

The system damping ratio (d) is the ratio of successive peak amplitudes in a freely decaying oscillation, i.e. d = X1/X2 = X2/X3 = ...

Chronometers

Chronometer 18789 was brought to the observatory in December 1966, chronometer 19090 was returned to Australia, and 18385 remained at the station.

When the author took over the observatory, chronometer 18385 was in use, and on 16 December 1966, 18789 was started and held as a spare.

Table 6 summarizes the chronometers in use and the duration of the time-marks.

Two modifications were made to chronometer 18385. Firstly on 11 January the second hand was rotated relative to the contact cam so that the contacts closed from 00 sec to 04 sec, whereas previously they had closed from 56 sec to 00 sec. This was to standardize all time-marks within BMR as decided by Canberra Headquarters. Secondly on 15 August the hour contact was shorted out so that 18385 supplied 60 minute-marks per hour and not 59 as previously.

On 30 October and 4 November adjustments were made to the rate of chronometer 18789.

Control circuitry

On 29 December 1966 a lamp current stabilizing device was added to the seismograph control panel as suggested by Sutton (1965). This was intended to maintain a constant current to the recorder lamp as the accumulator voltage dropped when the power failed. The stabilizer had little effect when the supply voltage fell below 6.4 volts. Normally, with the battery charger on, there was 6.7 volts at the control panel. The device was disconnected later in the year by removing one wire; however, the parts were left mounted behind the panel. Slight modifications, by someone more conversant with electronics than the author, may produce a useful device.

The constant-frequency power supply running the recorder motor operated well, and only occasional minor adjustments to the output frequency were needed to keep the time marks aligned. Toward the end of 1967 the voltage of the emergency dry cells under load and no-load was measured and found to be satisfactory.

Earthquakes recorded

A total of 189 earthquakes was recorded. Of these, 84 were reported to ISC, including eleven T phases.

Record loss

Record loss amounted to 11 days including the 1, 2, and 3 December, when the Benioff seismometer was being clamped and packed for return. The other loss was due to various causes including exposure of record to light, lamp failure, installation of experimental equipment, and poor connexions between the seismometer and galvanometer.

4. MAINTENANCE AND IMPROVEMENTS

The seismic vault and office exteriors were painted and a coating of bituminous roofing compound was applied to the junction between the office and vault, the office roof, and the joints in the concrete roof of the vault.

The storeroom roof leaked intermittently throughout the year and in December this was repaired by lifting the flashing between the corrugated iron roof and the vault, packing sponge rubber soaked in bituminous roofing compound beneath the flashing, and re-nailing the latter in place.

The interiors of these buildings were not painted, as a new geophysics office was to be erected during the December 1967 changeover.

The darkroom water supply header tank had to be cleaned twice during the year. During 'freeze-ups', water was carried from the laundry to wash the records. Early in the year the outlet connexion from the sink rusted through and the carpenter replaced it.

Both the absolute and variometer huts were sheeted with corrugated plastic. This work was done mainly by the carpenter, electrician, and diesel mechanic. The author re-puttied the windows of the absolute house and painted the exposed woodwork of the absolute and variometer huts. The western skylight of the absolute hut was cracked and leaking slightly. The crack was covered with Araldite and a coating of roofing compound applied along the edge of the glass.

A battery box was constructed to house two 6-volt batteries in series and an AWA 12-volt to 250-volt inverter to supply the magnetograph motors in the event of a power failure. A 12-volt battery charger was also constructed. It was found that the synchronous motors would not start on the output from the inverter. This defect was remedied by placing a 1.5-microfarad capacitor in parallel with the motors.

In October elephant seals knocked over the BMZ shelter and proton magnetometer piers and pushed the two battery boxes out of plumb. One afternoon was spent repairing the damage.

5. OTHER DUTIES

For 12 days the author was cook, and during this period the records were merely changed and developed; no absolutes or scaling were done. In addition two weeks was spent as 'donga-slushy'. This involved cleaning the bathroom, washroom, and lavatories and sweeping the corridor of the sleeping quarters (dongas). The time required was about one hour per day. The increase in kitchen duties over previous years was caused by the withdrawal of the cook.

The author assisted other members of the party to install a tide gauge and was responsible for the daily record changes. Details of the installation, results of tests performed, and the records have been sent to the Horace Lamb Centre for Oceanographical Research, Flinders University of South Australia, which is conducting the study.

The author was also responsible for the daily record changes of a 3-component induction magnetometer installed by the Geophysical Institute, University of Alaska. The maintenance of the equipment, compiling of reports, and forwarding of the records were the responsibility of the electronics engineer.

On 26 May the author became responsible for the reading of a sunshine recorder installed by John Jenkins from the Botany Department of the University of Melbourne.

The changing of the induction magnetometer records and tide gauge record and reading the sunshine recorder added about 20 minutes to the morning routine record changes.

New huts and equipment were plotted on the camp plan using a theodolite and staff. Survey work was also required during the installation of the tide gauge.

6. ACKNOWLEDGEMENTS

The author is grateful for the co-operation of all members of the 1967 party, and for particular assistance from Messrs R. Schmidt and R. Gully who changed records during his absences, and to Messrs M. Chapman, R. Shennan, and J. Ackerly, to whom credit for the plastic sheeting of the magnetic huts is mainly due.

7. REFERENCES

GREGSON, P.J., 1965 - Macquarie Island geophysical observatory work, 1963. Bur. Min. Resour. Aust. Rec. 1965/23 (unpubl.).

HOLLINGSWORTH, R.J.S., 1960 - Macquarie Island geophysical observatory work, 1959. Ibid. 1960/121 (unpubl.).

MUIR, E.J., 1968 - Macquarie Island Geophysical Observatory, Annual Report 1966. Ibid. 1953/30 (unpubl.).

OLDHAM, W.H., 1953 - Report on work at Macquarie Island, 1951-52. Ibid. 1953/30 (unpubl.).

SUTTON, R.G., 1969 - Macquarie Island Geophysical Observatory, annual report 1965. Ibid. 1969/84 (unpubl.).

TURPIE, A., 1959 - Macquarie Island geophysical observatory work, 1958. Ibid. 1959/123 (unpubl.).

VAN ERKELENS, C.H., 1961 - Macquarie Island geophysical observatory work, 1960. Ibid. 1961/26 (unpubl.).

TABLE 1

MAGNETOGRAPH DATA

Variometer		Orientation References	Month	Magnet N Pole	Change for trace movement up
Normal-run	D	26°46.9'	July	N 0.1°E	Increase easterly
	H	13081 gammas	July	E 0.1°S	Increase
		13069 gammas	Oct	E 0.0°	
	Z	No test		N	Increase numerically
Rapid-run	D	No test		N	Increase easterly
	H	No test		W	Decrease
	Z	No test		S	Decrease numerically

TABLE 2

CORRECTIONS TO SCALE VALUE METER VML 21164

Calibrator Setting mA	FSD Current mA	Meter Reading mA	Correction	
			mA	%
10	50	10.0(0)	0.00	0.00
15	50	14.9(5)	+0.05	0.33
20	50	19.8(9)	+0.11	0.55
25	50	24.8(9)	+0.11	0.44
25	100	24.8(8)	+0.12	0.48
55	100	54.8(9)	+0.11	0.20
60	100	59.8(2)	+0.18	0.30
65	100	64.8(0)	+0.30	0.46
70	100	69.8(9)	+0.11	0.16

TABLE 3

VARIOMETER SCALE VALUES

Variometer		Meter reading mA	Mean measured scale value	Mean corrected scale value	Adopted scale value	Standard Deviation
Normal run	D	25	2.33	2.34	2.35	-
	H	60	24.63	24.67	24.65	0.06
	Z	60	20.67	20.74	20.75	0.05
Rapid Run	D	15	1.01	1.01	1.01	0.01
	H	15	5.38	5.40	5.40	0.07
	Z	15	6.18	6.20	6.20	0.08

H and Z scale values in gammas/mm; D scale value in minutes/mm

TABLE 4

SEISMOGRAPH CONSTANTS

Att	Magnification at 1 Hz:M = 800 X1/Wt						System Damping Ratio = X1/X2			
	1965/66	1967					1967			
	Mean 1	11/05	24/09	18/10	Mean 2	M2/M1	11/05	24/09	18/10	Mean
16				21200	21200					
18	12800			17120	17120	1.34				
20	10472	14400		13560	13980	1.33	11.2		9.4	10.3
22	7915	10640		10200	10420	1.32	12.2		7.5	9.8
24	6345	9160	8320	8304	8595	1.32		12.4	11.1	11.8
26	5060	6880	6584	6496	6653	1.31	17.2	13.5	10.0	13.6
28	4007	5440	5168	5128	5245	1.31	16.2	11.8	10.7	12.9
30	3200	4496	4200	4176	4291	1.34	18.7	13.1	12.2	14.7
32	2530	3552	3356	3352	3420	1.35	17.7	15.6	11.5	14.9
34	1950	2720	2584	2560	2612	1.34	21.2	14.7	13.3	16.3
36		2168	2084	2060	2104		16.9	13.4	10.9	13.7
38		1672	1620	1616	1636		19.0	14.7	11.9	15.2
40		1276	1240	1212	1243		17.7	15.5	13.2	15.5
42		1048	1008	1000	1019		22.8	14.8	14.7	17.4

TABLE 5

SEISMOMETER FREE PERIOD

DATE	11/05	31/08	23/09	15/10	18/10
PERIOD (sec)	1.09	1.07	1.06	1.00	1.00

TABLE 6

CHRONOMETERS USED FOR TIME MARKS ON SEISMOGRAMS 1967

Date From	Date To	Chronometer Number	Time mark format on seismograms	
01/01	11/01	18385	Minute marks:	4 second contacts from 56 sec to 00 sec
			Hour marks :	sixtieth minute mark missing
11/01	14/04	18789	Minute marks:	5 second contacts from 00 S to 05 sec
			Hour marks :	no means of distinguishing hours
14/04	30/10	18385	Minute marks:	4 second contacts from 00 sec to 04 sec
			Hour marks :	sixtieth minute mark missing *
30/10		18789	Minute marks:	5 second contacts from 00 sec to 05 sec
			Hour marks :	no means of distinguishing the hours

* Note on 15/08/67 the hour contact of 18385 was shorted out, hence from 15/08/67 to 30/10/67 there is no means of distinguishing the hours.

TABLE 7

MOMENTS OF MAGNETS TO BE USED FOR Z VARIOMETER ORIENTATION

Magnet	Moment C.G.S.
Normal run Z magnet	7959 ± 50
BMZ Magnet (236/1)	354 ± 10
BMZ Magnet (236/2)	701 ± 10
BMZ Magnet (236/3)	887 ± 10

APPENDIX 1

SUN SIGHTS FOR THE DETERMINATION OF AZIMUTH OF ANCHOR ROCK

In November and December 1967 sun sights were taken to determine the azimuth of Anchor Rock from the east pier of the absolute house.

As sun sights could not be taken from within the hut an external station, marked by a 4" x 4" wooden peg, was used. Also, because anchor Rock was not visible through the theodolite mounted on the east pier, the Askania circle was used to measure the angle between Anchor Rock and North Mark, the latter being visible through the theodolite on east pier.

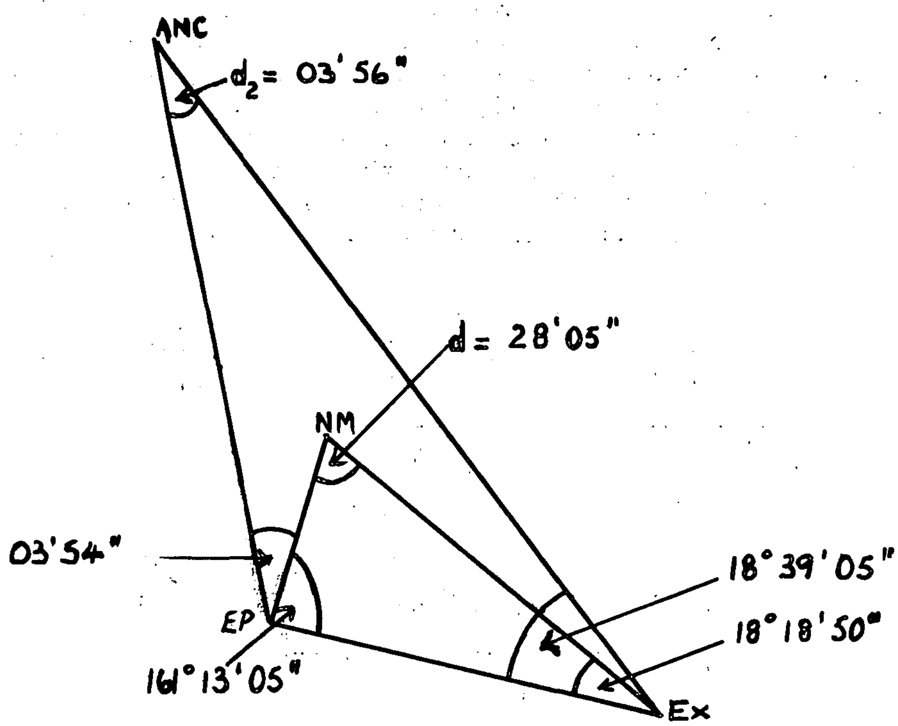
The diagram below shows the angles measured.

EP - east pier

Ex - 4" x 4" wooden peg outside the door of absolute hut and visible from EP

NM - North Mark, visible from EP and Ex through the theodolite

ANC - Anchor Rock, visible from EP through the declinometer telescope and from Ex through the theodolite



d_1 and d_2 are the corrections to the azimuths observed on Ex to give the required azimuths from EP.

Latitude and longitude

Observations of the elevations of the sun (8 sets) and moon (1 set) were made with the theodolite set up over station Ex. From each set, position lines were determined and plotted at a scale of 2" = 1 nautical mile. They converged around latitude 54° 31.6' S, longitude 158° 55.4' E (Position 2). This differs from the co-ordinates derived from the station plan (Position 1) and those scaled from a map of the island, as shown in the following table.

	Station plan 1963 (Position 1)	Observations 1967 (Position 2)	Island map
Latitude S	54° 30.0'	54° 31.6'	54° 29.2'
Longitude E	158° 57.0'	158° 55.4'	158° 57.8'

Azimuth

Two sun observations were made on 9 December 67 to determine the azimuth of Anchor Rock from station Ex; these were corrected by the angle d_2 (above) to give the azimuth for Pier E. Values were computed using both sets of co-ordinates (Positions 1 and 2), and are shown on the summary below. The value determined by Lyons, National Mapping surveyor, in 1958 is included; this value has been used in all declination determinations. It may be significant that the azimuth derived assuming Position 2 is in slightly better agreement with Lyons' value than the value derived using the accepted station co-ordinates.

Set No.	Azimuth Position 1	Azimuth Position 2	Azimuth by Nat. Map., 1958
1	353° 38.2'	353° 41.8'	
2	38.6'	42.0'	
Mean	353° 38.4'	353° 41.9'	353° 40.4'

Errors and consistency

From the formula for the solution of the spherical triangle, and the parameters involved in the two azimuth observations, the error formulas were:

$da_1 = 0.846\ dl - 1.431\ dh$ Set 1

$da_2 = 0.921\ dl - 1.248\ dh$ Set 2

where

da = increment in azimuth

dl = increment in latitude = +1.6'

dh = increment in hour angle = -1.6'

Hence

$da_1 = +3.65'$

$da_2 = +3.47'$

The observed differences (Position 2 - Position 1) were +3.6' (Set 1) and +3.4' (Set 2), which agree very well with the computed values.

APPENDIX 2

DETERMINATION OF MOMENTS OF Z VARIOMETER ORIENTATION MAGNETS

To perform orientation tests on the Z variometers it is necessary to know the moments of the deflector magnets.

For the normal-run Z variometer a magnet with moment about 7550 c.g.s. was to be used in an 'end-on' configuration, and for the rapid-run Z variometer it was intended to use a BMZ auxiliary magnet, mounted in a copper V-block 'end-on' to the variometer magnet. The first magnet is designated 'Normal run orientation (NR/O)'.

In September an adjustable bench was erected in the absolute house. The bench was in the magnetic prime vertical through the declinometer and at the same level as the declinometer. A thread, stretched from the declinometer to a pre-calibrated azimuth scale at the opposite end of the bench (about 2 metres away) defined the magnetic prime vertical. The deflector magnets could then be placed in Gauss's first position relative to the suspended magnet of the declinometer.

Three quantities had to be measured to find the moment of the deflector magnet:

(i) The distance of the deflector magnet from the declinometer magnet. (found from a scale drawn on the bench).

(ii) The deflection produced (measured on the Askania circle).

(iii) The value of H at the time of the experiment (scaled from the magnetogram).

The moments of magnets NR/O, BMZ 236/1, BMZ 236/2, BMZ 236/3, were measured at distances ranging from 50 cm to 200 cm from the declinometer.

<u>The following symbols were used</u>

l - The pole length of the deflector magnet, i.e. the distance from the centre of the magnet to the pole.

L - The physical length of the magnet.

p - The pole strength of the magnet.

M - The moment of the magnet (= 2lp).

r - The distance from the centre of the magnet to the point on the axis where f is measured .

f - The magnetic field strength at a point on the deflector magnet axis, due to the deflector magnet, and acting parallel to the axis. During the measurements f is horizontal and perpendicular to H.

H - The horizontal intensity of the Earth's magnetic field

Ø - The deflection angle of the declinometer magnet

e_1 - Error in M due to uncertainty in measuring Ø

e_2 - " " M " " " " " r

e_3 - " " M " " " " " H

The calculation was based on the following formulae

The field f on the axis of a bar magnet

$$f = 2rlp\,(r^2 - l^2)^{-2} = 2Mr^{-3}\,(1 - l^2/r^2)^{-2} \qquad (1)$$

The deflection of the declinometer magnet is Ø where

$$f = H \tan \text{Ø} \qquad (2)$$

Eliminating f between (1) and (2)

$$M = r^3 H \tan \text{Ø}\,(1 - 2l^2/r^2 + l^4/r^4)/2 \qquad (3)$$

The pole length of a bar magnet is approximately

$$l = 0.4\,L \text{ (McComb, 1952, page 4)} \qquad (4)$$

For the normal-run orientation magnet

L = 20.3 cm

therefore l = 8.1 cm

The minimum distance used for deflections was r = 100 cm;

hence $(l/r)^4 = 4.3 \times 10^{-5}$ which is negligible.

For the BMZ auxiliary magnet

L = 5 cm

l = 2 cm

The minimum distance used for deflections was r = 50 cm; hence, $(l/r)^4 = 2.6 \times 10^{-6}$ which is negligible.

Therefore, ignoring the fourth-order term in (3) we arrive at the formula from which M was calculated.

$$M = r^3 H \tan \text{Ø}\,(1 - 2l^2/r^2)/2 \qquad (5)$$

The table below gives the values of the moments of the magnets and the errors in the determination arising from uncertainties in Ø, r, and H. Note that e_1 and e_2 are functions of r, and the maximum and minimum for each value has been tabulated.

The errors quoted for the moments are the maximum possible errors estimated from an average of several determinations at various distances. These appear realistic in view of e_1, e_2, and e_3.

<u>An estimate of the accuracy with which the moment of the normal-run Z deflector magnet must be known is derived below</u>

From Sutton's report (1965)

$M = 7550$ c.g.s.

$r = 117.1$ cm distance from centre of magnet to centre of variometer

$l = 0.4\ L = 8.1$ cm

Using these data and equation (1) the field at the Z variometer magnet would be

$f = 947$ gammas

The formula used for calculating the exorientation angle was

$$\tan Ex = Su/f \qquad (6)$$

where S is the Z scale value (gammas/millimetre)

u is the deflection of the ordinate on the magnetogram (millimetres)

f is the field due to the orientation magnet (gammas)

Ex is the exorientation angle (radians)

From (6), when Ex is small and expressed in minutes,

$$\tan Ex = Ex \tan 1'$$

and

$$dEx/df = -Ex/f$$

i.e.

$$df = -f dEx/Ex$$

Assuming $Ex = 1^\circ = 60'$

$f = 947$

$df = (\frac{-947}{60})\ dEx$ df in gammas

dEx in minutes

If dEx = 1 minute, which is far more precise than the alignment of the deflector magnet, then df = 16 gammas

Thus an error of 16 gammas in f gives rise to an error of 1 minute in Ex.

Muir 1966, gives a value of $Ex = 0.1^\circ$, in which case df could be 160 gammas before a 1 minute error was introduced into Ex.

To find the allowable error in M so that the field is known to within 16 gammas

$$f = 2M/r^3$$

$$dM = r^3 df/2$$

For $df = 16$ gammas

$$dM = 130 \text{ c.g.s.}$$

Therefore an error of 130 c.g.s. would have to be made in the determination of M before a 1 minute error would result in Ex. Hence the error of ± 50 c.g.s. in M will give negligible error in the exorientation angle provided Ex is small (say less than 10°).

Magnet	Moment (c.g.s.)	e_1		e_2		e_3
		* r = 200	r = 100	r = 100	r = 200	
NR/0	7595 ± 50	± 30	± 4	± 45	± 23	± 6
		r = 150	r = 50	r = 50	r = 150	
BMZ 236/1	354 ± 10	± 13	± 0.5	± 4	± 1.3	± 0.3
		r = 130	r = 50	r = 50	r = 130	
BMZ 236/2	701 ± 10	± 8	± 0.8	± 8	± 3	± 0.5
		r = 120	r = 60	r = 60	r = 120	
BMZ 236/3	887 ± 10	± 7	± 0.9	± 9	± 5	± 0.7

* distances at which e_1 and e_2 were evaluated