COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES,

GEOLOGY AND GEOPHYSICS

RECORDS 1957, No. 79

MAGNETIC WORK AT MAWSON, ANTARCTICA, 1955-1956

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ABSTRACT

This record describes the establishment and operation of the Magnetic Observatory at Mawson, Antarctica, during 1955 and early 1956.

As soon as the huts were erected, absolute magnetic values were read at intervals averaging about eight days. Setting up and initial adjusting of the recording magnetic variometers was completed in July 1955, and from then on, a continuous magnetic record was maintained from which preliminary K-scalings were made and transmitted to Melbourne. Preliminary baseline values were determined for the variometers but lack of time prevented the scaling of hourly magnetic values. These are being scaled and determined in Melbourne, and will be presented in a separate report.

1. INTRODUCTION.

In the summer of 1953-54, the Australian National Antarctic Research Expedition (A.N.A.R.E.) established a base which they named "Mawson", on the coast of the Antarctic Continent in Macrobertson Land at latitude 67°36' S., longitude 62°54' E. (Plate 1). A party of nine men was left there to complete the erection of buildings and spend a year at the base doing meteorological and exploration work. The following year, the writer was the geophysicist in a party of fifteen men sent to relieve the first party and carry out a more extensive scientific programme.

It had originally been planned to establish both magnetic and seismic observatories at Mawson, and for this purpose a set of La Cour pattern magnetic recording and semi-absolute instruments and a Leet-Blumberg three-component seismograph had been ordered. Lack of funds and shipping space made it necessary to modify the plan, however, and it was decided to postpone the establishment of the seismic observatory until the following summer. The further decision to abandon the base at Heard Island made the magnetic observatory buildings and equipment there available for transport to Mawson, thus saving the expense of new buildings and some magnetic equipment.

On the first voyage to Mawson, J.A. Brooks, a geophysicist of the Bureau of Mineral Resources, joined the ship at Heard Island and made absolute magnetic measurements at Magnetic Island (68°32.9' S., 77°55.8' E.) in the Vestfold Hills area of the Antarctic coastline, and at Mawson. He left at Mawson a Watts vertical magnetic balance with which Mr. Robert Dovers, during the following year, made measurements over a proposed magnetic observatory site. The results of this survey, transmitted by radio to Melbourne, indicated that there were no large magnetic anomalies in the area surveyed.

2. THE VOYAGE TO MAWSON.

The M.V. "Kista Dan" left Melbourne on 7th January, 1955 and reached Heard Island early on 23rd January. K.B. Lodwick, the Bureau geophysicist at Heard Island during the previous twelve months, had already packed the magnetic equipment and dismantled the huts ready for transport to Mawson.

The weather was rough during loading operations at Heard Island and three panels of the Absolute Magnetic Hut fell from a sling to the bottom of the hold and suffered minor damage. Several cases of geophysical equipment fell from a net into the sea; some were retrieved immediately and the rest floated ashore, where they were collected the following day. All the cases which were known to have fallen overboard were taken ashore and their contents cleaned and dried; one or two escaped notice however, and it was found later that their contents were damaged by corrosion. Fortunately, no magnetic instruments fell overboard. As several of the earthenware pipes brought from Melbourne for use as magnetic piers at Mawson were broken, the writer and K.B.Lodwick salvaged some of the pipes from the Heard Island observatory site at West Bay.

Throughout the stay at Heard Island gravity readings were made periodically in the concrete-floored gravity hut, using Worden gravity meter No. 169 which had been brought from Melbourne to repeat earlier readings and establish a gravity value at Mawson. The ship left Heard Island late on 25th January, with

K.B. Lodwick aboard to assist in geophysical and general work during the voyage.

Pack-ice presented little trouble and the ship reached the Vestfold Hills and anchored near Magnetic Island on 30th January. The writer and K.B. Lodwick and their instruments were taken ashore in the ship's boat, and easily located J.A. Brooks' magnetic station. It was then about 3.00 p.m. and a series of sun observations was made for longitude and azimuth determinations. Some initial readings were made with B.M.Z. and Q.H.M. magnetometers to determine whether they would be satisfactory at this latitude. The party returned to the ship at 10.30 p.m., after a calm sunny afternoon during which little discomfort was felt while using instruments in the open air. Early next morning, the party returned to the island and completed gravity and magnetic readings and sun observations. The day was cooler and somewhat overcast but it was still just possible to work without using a tent. The mid-day sun observation for latitude was difficult because the single dark slide provided with the theodolite was too dark for seeing through the cloud and the observation had to be made without it.

The ship left Magnetic Island on 1st February and sailed eastward to a point a few miles off the coast of the Larssman Hills, where it had been planned to send a party ashore to take magnetic and gravity readings. The writer and several others set off in a weasel across the ice separating the ship from the shore, but after travelling about two miles it was seen that there was a belt of open water between the ice and the coast, so the project was abandoned. An earlier attempt to read the gravity meter on the sea-ice showed that the apparently firm ice was moving too much to allow the instrument to be levelled. After minor difficulties with pack-ice, the ship reached Mawson harbour on 9th February.

3. DESCRIPTION OF MAWSON BASE.

The scientific station is pleasantly situated on the shore of a sheltered harbour (Plate 1), in a small rocky area almost free of ice and snow. Experience so far shows that for about nine months of the year the sea is frozen as far as the eye can see, to a maximum thickness of about five feet, but during the rest of the year the ice breaks out and drifts northward, leaving the harbour and adjacent coastline free of ice. The last stages of this break-out are delayed by several small islands, which shelter the coast from wind and swell.

Behind the rocky camp area the ice plateau begins, rising rapidly to a height of 250 feet above sea level within the first quarter mile, and then rising less sharply to a height of 1,250 feet at six miles and 6,000 feet at 160 miles inland. On either side of the rocky area the plateau terminates in ice cliffs from 10 to 100 feet high which form the coastline.

The rocky area and the adjacent rocky islands are all of a fairly uniform coarse-grained felspar porphyry, brown in colour and in many places swept clean by the wind. In parts they are strewn with huge boulders both of local rock and a variety of igneous erratics deposited by an earlier, more active, glaciation. In hollows and in the shelter of boulders there is some accumulation of sand and gravel which allows the growth of primitive mosses. These and the coloured lichens which grow on rock surfaces constitute the only vegetation. There are no animals or birds in the Mawson area during winter, but during the warmer months seals come ashore and penguins and other birds frequent the mainland and nearby islands.

The climate is rigorous, and during the period described in this record the air temperatures ranged from minus 22.2°F. to plus 45.3°F., the mean annual temperature being 12.8°F. The annual mean wind was 23 m.p.h. with a maximum gust of 110 m.p.h. Snow fell on many days and there was almost continuous blizzard (i.e. thick falling or drifting snow with high wind) on 30 days. As Mawson is just inside the Antarctic Circle, there are several days in mid-winter when the sun does not rise.

4. THE GENERAL BUILDING PROGRAMME.

The two magnetic huts and eight other buildings required by the enlarged staff and programme for the second year were erected before the ship's departure from Mawson. Both the outgoing party and the personnel who were to remain on the "Kista Dan" helped in this work, K.B. Lodwick in particular deserving mention for his tireless and cheerful efforts. With the departure of the ship on 1st March, the new party settled down to finish tying down the huts, erect electric power lines and install electrical fittings, shelves, furniture and equipment in the huts. Five more buildings were erected during the year.

The building programme was organized by the officer-in-charge, J. Bechervaise, as a joint effort in which everyone took part, and the different projects were assigned priorities according to their urgency and the approach of winter. Every period of reasonable weather was used to complete outside work which would be impossible later.

5. THE MAGNETIC OBSERVATORY BUILDINGS.

The writer considered the magnetic observatory site chosen by P.G. Law and J.A. Brooks to be too far from the main camp area, particularly the site for the Variometer Hut which would have to be visited every day whatever the weather conditions. Finally, after discussions with P.G. Law, it was decided to erect the Absolute Magnetic Hut on the site originally chosen, and to erect the Variometer Hut nearer the main camp on a flat site which it was hoped would be free of snow drifts in winter. A few readings on this site with the Watts vertical balance revealed no large magnetic disturbance.

The two magnetic huts have been described by Ingall (1953). It is a general practice at Mawson to secure huts against the wind by means of steel guy ropes, tightened by turnbuckles and extending from roof corners to heavy ring bolts cemented with molten sulphur into holes bored in the solid rock.

As all this equipment is strongly magnetic, a different procedure had to be adopted for the magnetic huts. The hut bearers project outwards for a foot or more from the walls, and alongside each end bearer a hole was drilled in the rock. Pieces of ¾" non-magnetic brass rod were cut to length and threaded at each end. Their lower ends were cemented into the holes with sulphur, while the upper ends projected through holes in lengths of 4" x 2" timber laid across the bearers. Nuts on the upper ends thus held the bearers firmly down to the rock and wedges driven between the brass rods and the bearers prevented the latter from sliding in the direction of the prevailing wind. The walls are fixed to the bearers with non-magnetic screws, bolts and brackets. Loops of copper cable were tied from the roof edges to the bearers, and as a further precaution against overturning, a single inclined strut or prop was fitted from the roof edging to the ground on the down-wind side. Boulders were stacked on the bearers of the Absolute Hut on its windward side.

(a) The Absolute Hut.

The Absolute Hut was slightly damaged during loading operations at Heard Island. Several broken windows had to be replaced, a new door catch was fitted and other minor repairs were effected. Apart from the panels being waterlogged, the hut was in sound condition and dried out rapidly in the dry Mawson climate. Reassembly resulted in some gaps between panels, and these were sealed with sponge rubber and "Proofkote", a black bituminous sealing compound. Throughout the year, as the hut dried out and settled into place, the joints opened slightly, allowing drift snow to enter, and periodic sealing with "Proofkote" was necessary. The interior of the hut was given several coats of white paint.

A 12 in. square Oregon instrument pier (Plate 2), was erected in the Absolute Hut. The base of the pier was first drilled to fit a brass locating bolt cemented in a hole drilled in the rock below the floor. Into the sides around its base several 4-inch copper spikes were driven, leaving an inch or more projecting. Four more brass bolts were set into the rock around the pier and a concrete slab was poured around the base of the pier and the bolts and spikes. A deep, wide slot was sawn in the top of the pier to accommodate the B.M.Z. turn-magnet, and a fibre plate with three brass footplates was screwed to the top. During the year, the dry atmosphere caused serious splitting of the pier but this was arrested by soaking about a pint of linseed oil into the timber.

The instrument pier is below a skylight, but as there is no natural lighting in winter, an electric lamp was mounted on a ceiling bracket directly above the pier. The Q.H.M. magnetometer requires light from vertically above the eyepiece and it had previously been found that a single open bulb is inadequate for the purpose. In this instance, therefore, an "oyster bowl" lamp fitting was used; having a diameter of about a foot, it provided excellent lighting at any angular setting of the Q.H.M., and with a 100-watt bulb gave good general lighting in the hut. An electric radiator was made from sheet aluminium and brass using a 1,000-watt rod element. This, and all other equipment used in the hut, was tested and found to be effectively non-magnetic; the radiator gave some measure of comfort during absolute observations in winter.

The electric power line to the hut is a plastic and rubber-sheathed copper cable tied at intervals to a tightly stretched, steel cable elevated on 2-inch galvanized iron pipes set in holes drilled in the rock. The poles are normally six to seven feet high and are spaced at about 50-foot intervals. From the meteorological hut, the line goes to the Variometer Hut and on to the Absolute Hut. In the vicinity of the magnetic huts, however, the supporting wire is of heavy, stranded copper cable, and the two poles nearest the Absolute Hut are of 2-inch copper tubing.

At times during the year it seemed that the snowdrift piling up along the slope to windward of the hut might reach and even engulf the hut, but the turbulence of the wind striking the building produced a scouring effect which stopped the drift just short of the wall.

(b) <u>The Variometer Hut</u>.

The Variometer Hut was erected with its long axis in a north-south (magnetic) direction. It was in good condition and, once assembled, needed only an occasional application of "Proofkote" to small cracks which developed at the joints. A new door catch was fitted and one end of the clock-room bench was sawn off to allow the pendulum clock to be hung at a convenient height on the wall.

Two large slate slabs for the recorder and variometers respectively were each supported on two columns (Plates 2 & 3). Each column consists of two earthenware pipes, the lower resting on its flange on the rock and the upper one resting on the lower, flange uppermost. For each column, two hooked and threaded ¾-inch brass rods were cemented with sulphur into holes drilled in the rock. Their hooked upper ends projected about a foot into the lower end of the column. The lower part of the column was filled with concrete made from "Ciment Fondu" high alumina cement, which can be used at much lower temperatures than Portland Cement. Nevertheless, this particular batch of concrete froze without setting. The floor panels were immediately removed, the space round the bearers bagged off to keep out the wind, and several kerosene heaters trained on the columns until the concrete set. After the floor panels were replaced the upper pipes were put in place and cemented to the lower ones by pouring about a foot of concrete into them. Because of the uneven rock surface beneath the hut, the four columns were not of uniform height. Circular metal forms were made and clamped to the flanges, and, when filled with concrete, provided a suitably horizontal base for the slabs which were rested in place and cemented to the columns with plaster of paris.

Among the equipment transferred from Heard Island were four photographic safelight housings, but all were made of steel. Two new housings had to be made of sheet brass to fit the red glass screens provided. One was mounted over the clock-room bench and the other over the recorder slab, where it gave light for recorder changing or, with its glass removed, for instrument adjustments.

The site of the Variometer Hut proved to be free from snow drifts. A little snow occasionally accumulated on the lee side near the door, but was never more than a slight inconvenience.

The hut temperature rose rapidly on calm sunny days. In an attempt to stabilise the temperature, a coat of aluminium paint was applied, but this brought little improvement.

About 50 feet from the Variometer Hut, a box was erected on a stand and attached to one of the power-line poles for support. In this box were housed a 6-volt accumulator, a trickle charger and a rheostat for controlling the rate of charge. This equipment supplies the current for the variometer lamp and scale-value circuits.

A blizzard line of light rope, rigged between the power-line poles, proved useful for hauling oneself along and avoiding being blown over in high winds or losing ones way in blizzards or winter darkness. Without it, the journey to the huts would be almost impossible in very bad weather.

6. ABSOLUTE MAGNETIC INSTRUMENTS.

Absolute observations began on 4th May, 1955, as soon as the Absolute Hut was ready for use. Thereafter, absolute observations were made at intervals averaging about 8 days.

The instruments were of the semi-absolute type and comprised a set of three Quartz Horizontal Magnetometers (Q.H.M.), Nos. 300, 301, and 302, for measuring the horizontal component and direction of the earth's field, and a universal B.M.Z. (Balance Magnetique Zero), No. 115, for measuring the vertical component of the earth's field. These instruments are fully described by La Cour (1936 and 1942). The instruments were received from the makers just before the writer's departure for Mawson, leaving no time to compare them with instruments at Toolangi Observatory, as had been intended. At the end of the writer's period of duty at Mawson they were compared with Q.H.M. No. 174 and B.M.Z. No. 121 by P.M. McGregor, resident geophysicist at Mawson during 1956. B.M.Z. No. 115 was brought back to Melbourne by the writer.

(a) The Quartz Horizontal Magnetometers.

Q.H.M. No. 302 was used exclusively until late in September when time was found to intercompare the three Q.H.M. It was then discovered that No. 302 is optically very inferior to the other two; this can only arise from lack of flatness of its glass windows, which results in a poorly-defined view through the telescope, and causes multiple images. It is satisfactory for H-observations, but cannot be accurately sighted on the azimuth mark for D-observations. This effect was responsible for some of the scatter in earlier baseline determinations for the variometers. When the limitations of Q.H.M. No. 302 were realised, its use was discontinued except for a later H-intercomparison with Nos. 300 and 301.

These Q.H.M. have apparently been designed for use in areas of slightly lower vertical magnetic intensity than Mawson. In the zero-torsion position, the telescope must be tilted to about one degree above the horizontal before the reflected image occupies the centre of the field of view. This is of no consequence when making H-measurements, but causes difficulties with D-measurements for the following reasons. Unless the azimuth mark and the reflected image are both viewed at the same height on the cross-hair, a systematic error is introduced if the cross-hair is not exactly vertical. The cross-hair was adjusted visually to parallelism with a plumb-bob string at the opposite side of the hut, but the scale value of the Q.H.M. is so great that the verticality of its cross-hair cannot be fully relied upon. It is not considered advisable to alter the inclination of the telescope during a D-measurement because there is no means of checking the horizontality of the telescope tilting axis. It is therefore desirable to find an azimuth reference mark which can be seen from the Absolute pier and which lies at an angle of about one degree above the horizontal from the pier. As a further refinement, if the mark is slightly south of either east or west (magnetic) there is no need to clamp the Q.H.M. magnet during a D-measurement. A suitable mark was eventually found to meet the first requirement but it was unfortunately impossible to satisfy the second.

(b) The Magnetometric Zero Balance.

When delivery was taken of B.M.Z. No. 115 in Melbourne, it was found that the outer glass of one of its thermometers was cracked. At the Defence Research Laboratory, Melbourne, additional glass protective tubes were cemented on to the three thermometers and the hole in the outer magnet cover was enlarged to accommodate their increased diameter.

When the B.M.Z. was unpacked at Mawson it was noticed that the mercury column in two of the thermometers was broken, leaving a globule adhering to the top of the upper bulb. One was easily shaken free, but with thermometer No. 407 a very prolonged and vigorous thumping was required to shake the globule down to the main column. This experience points to the advisability of transporting thermometers in an upright position.

The B.M.Z. functioned satisfactorily throughout the year, with the exception of the slow-motion knob on the turn magnet which used to work loose in cold weather. It was locked in place with a small copper key fitting between grooves cut into the knob and shaft.

7. THE MAGNETIC VARIOMETERS.

Details of the La Cour magnetic variometers and 15 millimetres-per-hour recorder are given in reports by La Cour (1930), La Cour and Laursen (1930) and Laursen (1943). This particular set of instruments had been dismantled and carefully packed by K.B. Lodwick. They showed signs of corrosion, as might be expected after several years at Heard Island, but were complete and undamaged except that the small removable glass window at the back of the D-variometer was broken; it was replaced with a window made from perspex sheeting. Both the D-baseline and H-baseline mirrors had lost some of their silvering.

(a) The H-variometer.

The bimetallic compensator strip was assembled so as to give an effective length of 5.2 millimetres, which was the last figure given in the Heard Island Observatory log. After several months of recording there was found to be no obvious correlation of H-baseline values with temperature. The magnet was hung with its north pole pointing east; in this direction the trace shows H increasing positively upwards on the magnetogram. In retrospect, it appears that it would have been preferable to have the north pole pointing westwards to make all three components increase in magnitude downwards on the magnetogram. In the case of the Z-variometer the sense depends on whether the north pole of its balancing magnet is pointed north or south. This had not been decided when the H-variometer was being set up.

(i) Optical adjustments.

The H-variometer was moved once or twice to adjust for focus at the recorder drum and for approximately equal spacing of reserve traces. Tests showed that the moving trace, baseline and temperature traces do not focus simultaneously in one position of the variometer. It must be assumed, therefore, that at least one of the mirrors is not plane, because the difference between the respective optimum settings was too great to be explained by the slight difference in the lengths of their optical paths. The writer's experience suggests that there is room for general improvement in the optical performance of these La Cour instruments.

The two prisms were adjusted to make them parallel to each other both vertically and horizontally, as accurately as could be achieved by visual inspection.

Intensity of the temperature trace was reduced by resting a very narrow strip of paper on the back edge of the lower prism and pushing it across to mask off the desired amount of the reflecting strip on the upper prism. A glance through the lens shows clearly how much of this strip has been marked.

The baseline trace was much too wide and intense. Early attempts to rectify the fault by tilting the mirror so that only a portion of the light passed through the cylindrical recorder lens were successful in reducing the intensity but left the trace broad and indistinct. The following method proved satisfactory. A small strip of shim brass (Plate 5) was bent into a square hook at one end so that it could be hung over the mounting for the baseline mirror and mask the whole mirror. A T-shaped cut in the strip allowed the middle of it to be folded outwards like two shutters, revealing a small portion of the mirror. A few adjustments of the shutters gave a trace much improved in sharpness and intensity.

(ii) Orientation adjustments.

The following method was used to position the swinging magnet accurately at right angles to the earth's field :-

A one-inch hole was drilled in the south wall of the hut about 18 inches above the variometer slab (Plate 4). Above the hole, inside the hut, a short length of ¼-inch brass rod (Plate 4), was fixed horizontally to the wall on two metal brackets. A brass collar, fitted with a locking screw and with a V-shaped groove turned in its outer surface, was drilled to slide neatly on the brass rod. A plumb-bob was hung with its cord resting in the groove of this collar. A second plumb-bob was hung on a similar sliding support on the opposite side of the room. Outside the hut a survey marker was placed a few feet from the wall and directly south (magnetic) from the hole in the wall (Plate 4). The magnetic meridian determined at the Absolute Hut was carried over to this survey marker by a short survey traverse (Plate 7). The theodolite, set up on the survey marker, was adjusted to point north (magnetic), i.e. through the hole in the wall. A piece of white paper on the far inner wall, lit by a lamp, enabled the cords of the two plumb-bobs in the hut to be clearly seen and adjusted by means of the sliding supports to coincide with the line of sight of the theodolite. The plumb-bobs were replaced by a loose thread hung between the grooves of the sliding collars. With two weights hung at appropriate points, the thread represents a magnetic meridional line, horizontal and at the height of the variometers. A Helmholtz-Gaugain coil can be aligned to magnetic north-south or east-west by measuring offset distances from the thread to each side of the coil. As a permanent fixture the sliding brass fittings will considerably simplify routine orientation checks on the variometers.

With a Helmholtz-Gaugain coil mounted around the variometer and aligned with its axis north-south (magnetic), the micrometer head of the variometer was adjusted to a position where a current of about 200 mA passing through the coil produced no deflection of the magnet. The direction of the main H-trace then indicated which way the suspended mirror had to be twisted with relation to the magnet in order to bring the trace back on to the recorder. After two or three attempts the trace was brought approximately to the centre of its portion of the recorder drum. The final adjustment was, of course, made after the D and Z magnets were in place. The coil was then aligned with its axis east-west for scale value determinations. The scale value was about 9.5 gammas per millimetre.

(b) <u>The D-variometer</u>

In anticipation of large fluctuations in the magnetic field at Mawson, an auxiliary lens of 100 cm. focal length was provided to enable the D-variometer to be mounted much closer than normal to the recorder and thus reduce its sensitivity. When the matter was examined, however, it was realized that this modification would involve two difficulties. Firstly, the variometer slab was not large enough; an extension would be required, perhaps resting on both the recorder slab and variometer slab which are of unequal heights. This extension would considerably restrict standing room for making adjustments to the variometers. Secondly, the geometry of the reserve trace system would be upset; new holes would have to be drilled in the prism rack to change the positions of the D-prisms. The D-variometer was therefore set up normally in the hope that it might operate satisfactorily without the auxiliary lens. During seven months of continuous recording it was found that, although the sensitivity is greater than one would wish (it is about 4.6 gammas per millimetre for transverse field, i.e. approximately twice the effective sensitivity of the H and Z-variometers), it was possible to read the trace correctly except for two or three sharp peaks during severe magnetic disturbances.

This D-variometer has a lens of longer focal length than is normal. This fact had been mentioned in the Heard Island Observatory log, and was allowed for when setting up the slabs. Even so, the instrument had to be mounted at the back of the slab for optimum focus at the recorder.

Alignment of the D-variometer in the magnetic field was carried out in the same way as described for the H-variometer. When finally adjusted, with the H and Z-magnets in place, a current of 200 mA passed through a Helmholtz-Gaugain coil carefully aligned in the magnetic meridian produced a barely perceptible deflection of the D-trace. At the same time, the trace was approximately in the centre of its section of the recorder drum.

A spurious trace was noticed on the record. It has twice the sensitivity of the main trace and must be due to some of the light from the suspended mirror being reflected externally from the plane inner surface of the variometer lens-prism and back to the suspended mirror. No method of eliminating this trace could be devised, but, being very faint, it caused no inconvenience in reading the record.

Another spurious trace appeared when the second D-reserve prism on the side nearer the Z-variometer was brought into use. This is due to an internal reflection from the plane surface of the lens-prism. As it could not be removed without completely re-adjusting the variometer, the second reserve prism was taken out of service. As it happened, the second reserve trace on this side was never required during the ensuing seven months of recording.

Several scale-value determinations with the Helmholtz-Gaugain coil gave a scale value accepted as 0.853 minutes of arc per millimetre. The writer neglected to confirm this figure with a torsion test, but it is considered that the value is sufficiently reliable.

(c) <u>The Z-variometer</u>.

The Z-variometer was positioned so that :-

(i) The trace was at optimum focus on the drum,

(ii) The axis of rotation of the balancing magnet pointed to the centre of the Z-section of the recorder drum, and

(iii) The spacing between right and left reserve traces was approximately equal.

Grinding the magnet.

A new balancing magnet had been brought from Melbourne to replace the one in use at Heard Island. The new magnet was first tried with its north pole pointing south, and a small amount of metal had to be ground from its north pole end to make it balance horizontally. The scale value measured was about 4 gammas per mm. and the period of oscillation 3.45 seconds, which is much too sensitive for Mawson.

When reversed, so that its north pole pointed north, the scale value changed to about 13 gammas per mm. with a period of oscillation of 1.42 seconds, which was thought to be too insensitive. A few days later, the magnet was moved and some of the bottom ground away to increase the period to 1.79 seconds. In order to ensure the horizontality of balance of a magnet in the north pole northward position, it is sufficient to grind it until it appears to balance horizontally when pointing north pole southward, but when this was tried the magnet was found to be unstable in this latter direction after its last grinding. Its sensitivity was now 8.0 gammas per mm. and after operating it like this for a fortnight it was decided that it was again too sensitive.

Some metal had to be ground away from the top of the magnet; this proved to be considerably harder than grinding at the bottom. Great care must be taken to avoid scratching the mirror and damaging the knife edges. After much persistence, however, the period of oscillation was reduced from 1.79 to 1.65 seconds, giving a sensitivity of about 9.8 gammas per mm., and it remained at this sensitivity, with its north pole pointing north, for the remainder of the year. The final grinding also restored its stability in the north pole pointing south position, which allowed it to be accurately balanced horizontally.

Compensating for temperature.

During the final grinding of the magnet the hut was heated with an electric radiator. This was switched off before recording recommenced, with the result that the record covered a period of considerable temperature change. As it happened, the record was very free of magnetic disturbance and showed plainly that the instrument was overcompensated for temperature. From start to finish of the record, the T-trace ordinate changed by 34 mm. and the Z-trace ordinate by 18 mm. in the same direction. The bimetallic strip, which had been arbitrarily set at 15 mm., had therefore to be shortened to a length of :-

$$\frac{15 \times (34 - 18)}{34} \text{ mm., i.e. } 7.1 \text{ mm. effective length.}$$

At this setting, no obvious correlation of baseline value with temperature could be found during the following seven months of continuous recording.

Miscellaneous notes.

Baseline determinations showed a rapid rise of 40 gammas in Z-baseline value during the first few weeks. This was very probably a settling-down effect after the grinding of the magnet. Thereafter, Z-baseline values maintained a very satisfactory degree of stability.

The magnetic chamber was kept dry by means of a crucible filled with phosphorus pentoxide. A small jar of coloured silica gel was placed alongside it to act as an indicator of dryness. The upper chamber was kept dry with a glass jar of silica gel, the latter being changed as soon as it turned pink.

The baseline trace was reduced in width and intensity by means of a brass mask (Plate 5) in the same manner as that described for the H-baseline. The temperature trace can very easily be adjusted to the correct intensity by slackening the four screws and sliding the whole prism mounting backward or forward to vary the effective area of the T-mirror. A glance through the lens shows how much of the T-mirror is effective.

(d) The Magnetic Recorder.

A small spring was fitted to one of the drive ratchets to replace one which was missing. The slit in front of the drum was found to be bent and had to be straightened and adjusted to parallelism. At the same time, small brass lugs were soldered to the two separating strips of the slit. These lugs are used to support the ends of screens of sheet brass fitted between the cylindrical lenses. The function of the screens is to confine the trace of each component to its own section of the drum and thus prevent any overlapping. Their presence makes it impossible to set up the double-mirror viewing device, but previous experience had indicated that this device is useless, while the screens simplify the interpretation of disturbed magnetograms.

The cylindrical lenses were adjusted so that :-

(i) The horizontal axis of each is in the same plane as the slit; this is achieved by illuminating the strip from inside the drum-housing, viewing the strip through the lens and adjusting the lens mount until the slit is parallel to the edges of the lens.

(ii) The vertical plane of each lens is parallel to the drum; this is achieved by measuring the distance from the ground glass to the top of the lens (provided the ground glass is parallel to the drum).

(iii) The light spot is focussed to a point on the drum. It is important to focus the spot on a sheet of paper on the drum and not on the ground glass screen. A magnifying glass is helpful. The D-lens of this particular set is not perfect and will not focus to a sharp spot.

A persistent jump of the drum during recording was eventually traced to a tendency of the driving chain to ride up on the sprocket and then jump one tooth. The fault was eliminated by hanging a small weight on the free end of the chain.

The engaging lever on the escapement fitted too tightly in the teeth of the engaging wheel and eventually stopped the drum. This was rectified by filing out the teeth to allow the lever to fit more loosely.

On two occasions some record was lost when the clockwork mechanism stopped. Both the clockwork mechanisms were cleaned and their escapements dismantled, cleaned and oiled.

(e) The Light Source and Prism Rack.

As the recorder slab was not wide enough to carry the prism rack, a strip of heavy fibre sheeting was clamped to the slab by means of four hooked brass bolts. Two circular brass plates with drilled centre-holes were bolted to the fibre strip to serve as rigid bearing plates for the levelling screws of the prism rack. The single rear levelling screw was rested on a one-inch brass block. The prism bar was then carefully adjusted to horizontal.

The prisms had been removed from their supporting pegs and had to be cemented on with sealing wax. This was done as described by Laursen (1943). Parallelism between prism faces and pegs is important.

One of the lamp sockets had to be replaced and all the straight-filament lamps were mounted centrally in their cups with the aid of the special frame provided. This alignment is very important. To ensure rigidity of the lamps, their cups were filled to the top with paraffin wax.

The straight-filament lamps provided were all of "Luxor" brand and were not very satisfactory as the filament is eccentrically placed in the glass envelope, giving rise to a spurious image reflected from the internal surface of the envelope. There is only one horizontal direction in which this reflection coincides with the filament. At least two of the three magnetic traces, therefore, have "ghost" traces alongside them. The "ghosts" were eventually eliminated by placing just in front of the lamp two blackened vertical wires soldered to brass. These wires are carefully aligned between the spurious image and the appropriate variometer.

Another "ghost" trace is caused by the light of one lamp being reflected externally from the envelope of the other; this was eliminated by erecting between the two lamps a small blackened mask of the same height and width as the lamp envelopes.

(f) The Pendulum Clock.

A new La Cour-pattern pendulum clock was brought from Melbourne because the clock at Heard Island was in need of repair. Previous experience has shown that these clocks are not always satisfactory, and some modifications were made to this one before it was put into service.

On the one-minute contacts, loops of very fine copper wire (Plate 5) were soldered between the solder lugs and the contact leaves to eliminate contact resistance at the pivots.

A small brass nut was soldered to the top of the upper leaf to increase contact pressure. Modified in this way, the one-minute contacts gave no trouble. On several occasions a single five-minute contact became faulty but this was easily remedied by cleaning and polishing.

Several of the screws of the contact mountings had rattled loose and the tapped holes in the fibre plates were found to be stripped. These were tapped and fitted with larger screws.

The door of the clock casing was altered to hinge on the left instead of the right, and the contact terminals were moved to the right.

(g) The Control Panel and Scale-Value Equipment.

The Heard Island control panel was in very poor condition and had to be completely rebuilt. The circuit and layout adopted (Plate 6) proved to be very satisfactory. The panel was mounted above the clock-room bench on hinges at its right hand side and all external connecting wires were brought to this side so that the panel could be swung forward to give easy access to wiring at the back.

The 100-ohm potentiometer in parallel with the clock contacts is adjusted to give as high a steady time-lamp current as possible without allowing the lamp to glow brightly enough to show on the record. The function of the potentiometer is to limit to a minimum the current required to pass through the clock contacts and at the same time to prolong the life of the time-lamp.

The scale-value circuit.

Rotary potentiometers were used in the scale-value circuit and gave no trouble provided they were rotated 20 to 30 times each way, with the 5-position switch in the "off" position, before a scale-value test was begun.

The 150-ohm resistor is a safeguard against serious overloading of the scale-value milliameter. The scale-value milliameter, a VML sub-standard instrument, gave no trouble, although the precaution was taken of drying it out thoroughly in an airtight tin containing silica gel before taking it to the Variometer Hut, where any moisture would have condensed and frozen.

The Helmholtz-Gaugain Coils.

One of the two coils had been fitted at Heard Island with extra spacers to increase the distance between the two loops. No reason could be advanced to justify this change, which would alter the coil-constant and lessen the uniformity of the field, so it was returned to its original condition.

A broken wire on a loop of one of the coils was replaced with cotton-covered wire of slightly larger diameter; it is not expected that the coil-constant will have been appreciably altered by this change.

8. AZIMUTH MARKS AND SURVEYING.

(a) Azimuth Marks.

The first mark chosen for an azimuth reference point was a rock face on the right hand side of an island about one mile north of the Absolute Hut. The cliff there overhangs slightly, and the extreme right hand side of the overhang was used; this is clearly visible through the door of the Absolute Hut. It was named Azimuth Mark "A" (Plate 7). To assist in determinations of the true bearing of this point from the Absolute Pier, a brass rod was cemented into a hole drilled in the rock about 30 yards from the pier, exactly on the line between the pier and Azimuth Mark "A". The brass rod was named the "Auxiliary Absolute Station".

Azimuth Mark "B", a length of 2-inch diameter "Duralumin" tubing, was cemented into a hole drilled in the top of a large boulder about 55 yards from the hut. The top of the tube was painted white and a fine longitudinal slit cut in it. The slit is lit by a 4.5 volt torch bulb inside the tube; to provide power for this lamp a 2-conductor cable was laid on the ground back to the Absolute Hut where it connects to the 230-volt power supply.

A 60-watt lamp is included in the circuit to provide the correct current for the torch bulb. An illuminated mark is necessary in winter and also makes possible the reading of absolute observations at night, if necessary. In order to make Mark "B" visible from the Absolute Pier, a hole was drilled in the wall of the hut and fitted with a short length of copper tubing and a cork to keep out snow. A second hole, slightly higher, was drilled to enable sights to be taken on the mark with a theodolite, which is higher than the Q.H.M.

Azimuth Mark "C", a short length of $1\frac{3}{8}$-inch "Duralumin" tubing, was cemented into the solid rock about 100 yards from the Absolute Hut. This mark was carefully located so that it lies about 1° above the horizontal from the Absolute Pier. The advantages of such a mark have been described in Section 6(a). The tube was painted black and the rock behind it white, to provide maximum contrast. The tube is of such a diameter that when sighted through the Q.H.M. telescope it appears to be the same width as the cross-hair and so enables very accurate sights to be taken. Two more holes were bored in the wall for viewing this mark.

(b) Surveying.

To determine the true bearing of Mark "A", sun observations for azimuth were made. It was not possible to begin these until April and the results of the series of observations then made showed a very large scatter. Investigation of the problem indicated that this is to be expected, for the following reasons.

The formula used for calculating azimuths from solar observations is :-

$$\tan^2 \tfrac{1}{2}A = \frac{\sin(s - \phi)\,\sin(s - h)}{\cos s.\ \cos(s-p)}$$

where A = the azimuth angle

ϕ = latitude of the place

h = observed altitude of the sun, corrected for refraction and parallax

p = the sun's co-declination

and $2s = \phi + h + p$

It is desirable to observe the sun at an altitude greater than about 15° above the horizontal; this is especially so in a cold atmosphere in which, as the observed altitude decreases, the refraction correction and presumably the possible errors increase sharply. The April observations had to be made with the sun only about 10°above the horizon.

It will be seen that, if s approaches 90°, the term cos s approaches zero and a small change in s will produce a large change in A. As s is derived from the sum of Ø, h and p, a small error in any of these produces a large error in A. At Mawson, where the latitude is 67°36', if s is to be appreciably less than 90°, the sun's co-declination (p) must be appreciably less than 90°; this is so only in the summer months.

Sun observations were therefore postponed until later in the year. Further observations were made in October, December and February. In all, 22 azimuth values were calculated, from which it was possible to adopt a value of 178°34.2', with an estimated possible error of ± 0.2', for the true bearing (from south) of Mark "A" from the Absolute Pier.

Another error in sun observations was caused by horizontal refraction; this probably arose from a continuous down-flow of cold air from the ice plateau across the line of sight to the mark. It was noticed on many occasions that repeated readings of horizontal angle on a fixed mark showed a much greater scatter than had been expected.

During the winter, an attempt was made to do a star observation for azimuth. The Watts theodolite proved to be very unsatisfactory for this purpose, as it has no provision for illuminating the scales and cross-hair. For this reason, and because of the discomfort resulting from extreme cold, the attempt was abandoned.

9. TIME SIGNALS.

The "Eddystone 680 X" radio receiver was housed in the Meteorological Hut and an aerial erected which gave excellent reception of time signals from station WWVH. On only three or four days of the year was it impossible to receive a time signal.

As a result of the reliability of time signal reception, the observatory routine was simplified. The pendulum clock was set to run a few seconds per day fast, and each day before the record was changed a wrist watch was checked against WWVH. Before putting on the new record the pendulum was stopped and started again at the correct time indicated by the wrist watch, while a note was made of the number of seconds it had been fast. Hence almost every record starts with zero time error and finishes with a maximum error too small to warrant application of a correction.

10. DARKROOM AND PROCESSING OF RECORDS.

Photographic processing presents special problems in cold regions where all water must be obtained from snow, where bottles of solutions must at all times be prevented from freezing, and where provision must be made to have solutions at approximately the right temperature during the actual processing. Drain pipes are useless because they become blocked with ice.

During the first year of occupation at Mawson a darkroom had been constructed in one corner of the Radio Hut. This was assumed to be adequate, and no provision had been made for erecting a special darkroom for processing the magnetic records.

The darkroom was only about 4 feet by 5 feet in area and had been fitted with a bench and shelves, a film-drying rack and an enlarger. The door opened inward. The room had some advantages, however, its smallness, the excellence of its insulation and the fact that it received some warmth from the main radio room meant that only a small amount of heating was required. This was achieved by mounting a 200-watt electric heater under the bench, in series with a "Sunvic TS3" thermostat on the wall which maintained the temperature in the upper part of the room at about 65°F. on all except the coldest days. A high shelf was fitted for storing the solutions, and racks were made for stowing the large dishes required for developing the magnetic records.

Washing water was obtained from any one of several huts where it was customary for snow to be melted; this water had to be carried and kept in buckets. Magnetograms were given a rough rinse and four separate washes of at least 15 minutes; as water was always in short supply, a saving was made by doing the rinse and first two washes with water kept from the final two washes of the previous day's record. Finally, the magnetogram was soaked for 10 minutes in a 12½ percent solution of glycerine in water.

As the darkroom had also to serve for all amateur photography, a special washing dish was made, fitted with a cover to prevent accidental contamination of the wash water.

For a few weeks in summer the snow melted and formed pools on the hillside and the opportunity was taken to arrange siphons and drums so that the magnetograms could be washed with running water near the pools. This saved much carrying-in of fresh water and carrying-out of dirty water.

11. THE GEOPHYSICAL OFFICE.

Office space was generously provided by N.R. Parsons in the Physics Hut, which was built primarily to house the cosmic ray equipment. With the exception of a chair, no office furniture was available for the geophysicist, and a shortage of timber precluded the building of permanent shelves and a desk. It was clear, however, that the writer would have to spend most of his time assembling and adjusting the magnetic equipment rather than in routine office work. A makeshift table was therefore constructed from packing cases, and the wall lined with cases which served as bookshelves and storage for geophysical equipment.

12. EXPEDITION DUTIES.

The fourteen members of the party took it in turns to assist the cook by serving meals, washing dishes and cooking on Sundays. Snow had to be brought in for melting, drums of waste water rolled away and the messing quarters kept clean. The period of duty was one week, during which there was no time to do anything but the essential routine work on any other job. Each man in turn took the night-watch duty which involved staying up to do the weather observation at 02.00 and 05.00 hours, to stoke all the heaters in the camp and to be on hand in case of fire. Every few weeks bags of coke and briquettes had to be moved from the fuel stack to the various huts. Drums of diesel fuel had to be rolled to the engine room.

In the absence of a professional biologist, the writer was appointed biologist to the expedition. In this capacity he made two trips to the Emperor Penguin Rookery at Bretangen, 60 miles from Mawson, spending in all 15 days away from Camp. In addition, some time at camp was devoted to studying the birds and putting identification rings on them, and to catching fish and other marine creatures.

The writer became efficient in the working of the "Warsop" rock drill and use of explosives and spent much of his spare time boring and blasting rocks to clear a good walking track to the Magnetic Huts, to clear a "weasel" track to the dog-lines and to level the sites chosen for the Seismic Hut and Aircraft Hangar. In the same way, several large boulders just offshore were demolished to make it easier for the army DUKWs to come ashore at the main camp and the hangar site.

13. THE RETURN VOYAGE TO MELBOURNE.

The magnetic observatory was officially handed over to P.M. McGregor, geophysicist for the following year, on 1st March, 1956. The "Kista Dan" departed from Mawson on 3rd March and reached the abandoned station at Heard Island on 9th March. It was then decided that there would possibly be time to do an absolute magnetic observation, so the writer went ashore in the ship's boat to the old observatory site at West Bay.

The Absolute Piers were still intact, although the building had been removed. Without the floor, however, they were much too high and it was necessary to build a crude platform from loose pieces of timber. A full set of H,D and Z absolute observations was done with Askania magnetometer No. 508813 and B.M.Z. No. 115. The pier could not be used for the B.M.Z. so the instrument was stood on its tripod a few inches from the pier. The chronometer (Falconer 4916) was regrettably started only shortly before leaving the ship and its rate during the day differed appreciably from that on the following day, thus giving rise to some doubt as to the accuracy of the H measurement.

Late in the day, Mr. P.G. Law decided that there would be time for a gravity measurement and he took the gravity meter (Worden No. 169) ashore. The writer took a few readings with it in the concrete-floored gravity hut in the main camp area. The party then returned to the ship which sailed for Kerguelen Island that night.

The ship reached Kerguelen on March 14th. The writer took a few gravity readings in the Ionospheric Hut and then returned to the ship for the night, leaving the gravity meter ashore in charge of Mr. Law, who with some other members of the party, had been invited to spend the night ashore.

For several days the weather was so rough that it was impossible to bring the boat alongside the "Kista Dan". There was no opportunity for those on board to return to the shore, and the writer advised Mr. Law by radio how to take a reading with the gravity meter. The weather finally moderated somewhat and those ashore were able to return to the ship, bringing the gravity meter with them. The ship then sailed for Melbourne, arriving on the morning of 26th March.

14. ACKNOWLEDGEMENTS.

During the writer's two short periods of absence from camp the magnetic records were changed by R. McNair and N.R. Parsons.

All members of the party are thanked for their co-operation, which enabled magnetic recording to commence much earlier than had been expected. Special recognition is given to the officer-in-charge, John Bechervaise, for his continued interest in the project.

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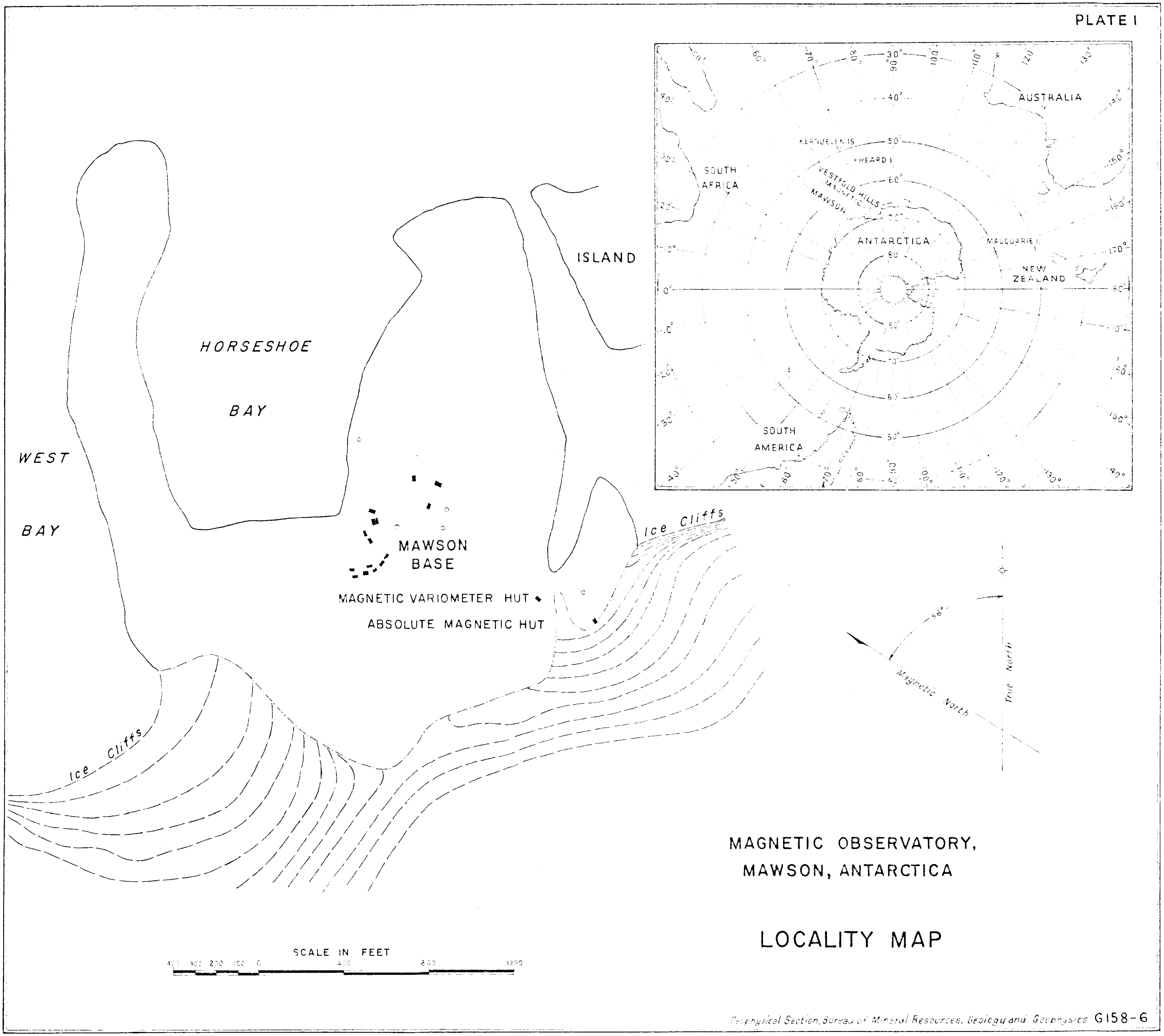
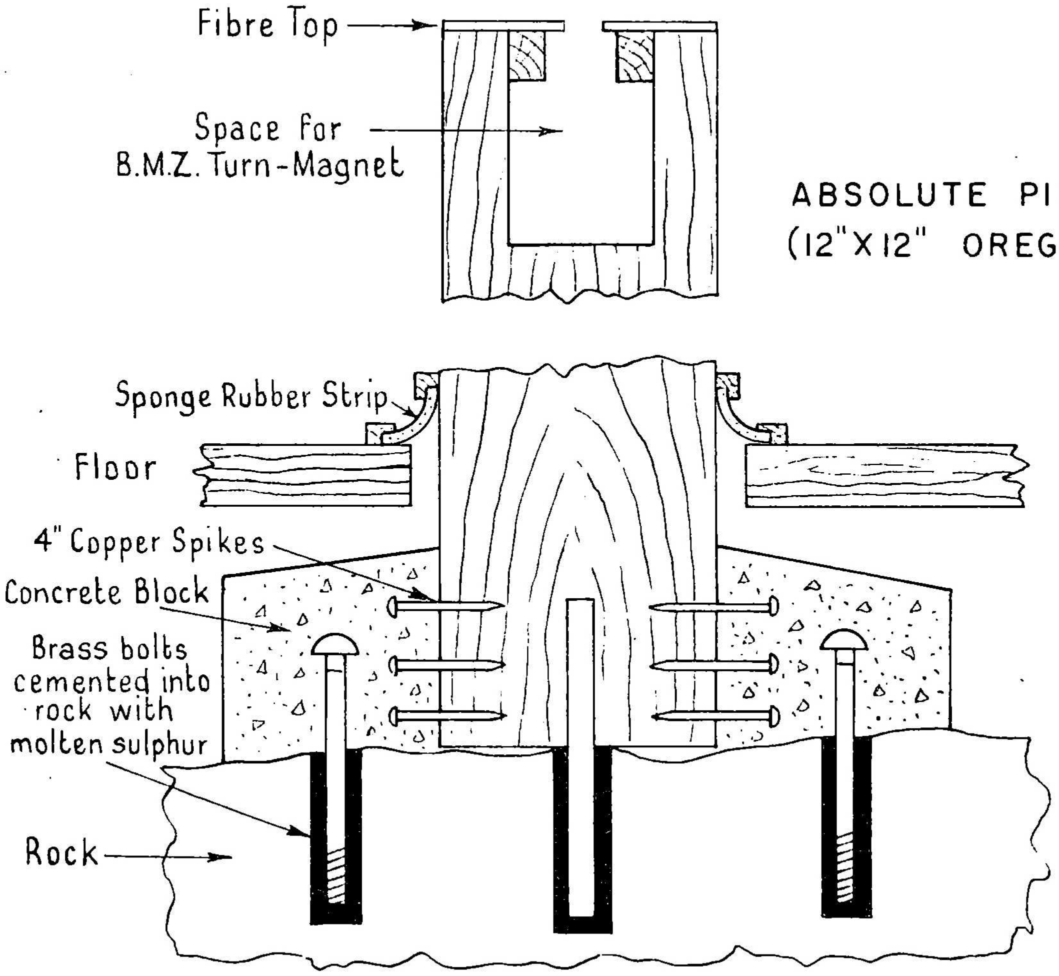


PLATE I
AUSTRALIA
KERGUELEN IS.
HEARD I.
SOUTH AFRICA
VESTFOLD HILLS
MAWSON
ANTARCTICA
MACQUARIE I.
NEW ZEALAND
SOUTH AMERICA
HORSESHOE
BAY
ISLAND
WEST
BAY
MAWSON
BASE
MAGNETIC VARIOMETER HUT
ABSOLUTE MAGNETIC HUT
Ice Cliffs
Ice Cliffs
Magnetic North
True North
MAGNETIC OBSERVATORY,
MAWSON, ANTARCTICA
LOCALITY MAP
SCALE IN FEET
400 300 200 100 0 400 800 1200
Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics G158-6

ABSOLUTE PIER
(12"X12" OREGON)



MAGNETIC OBSERVATORY, MAWSON, ANTARCTICA

DETAILS OF ABSOLUTE AND VARIOMETER PIERS

COLUMNS FOR VARIOMETER PIERS

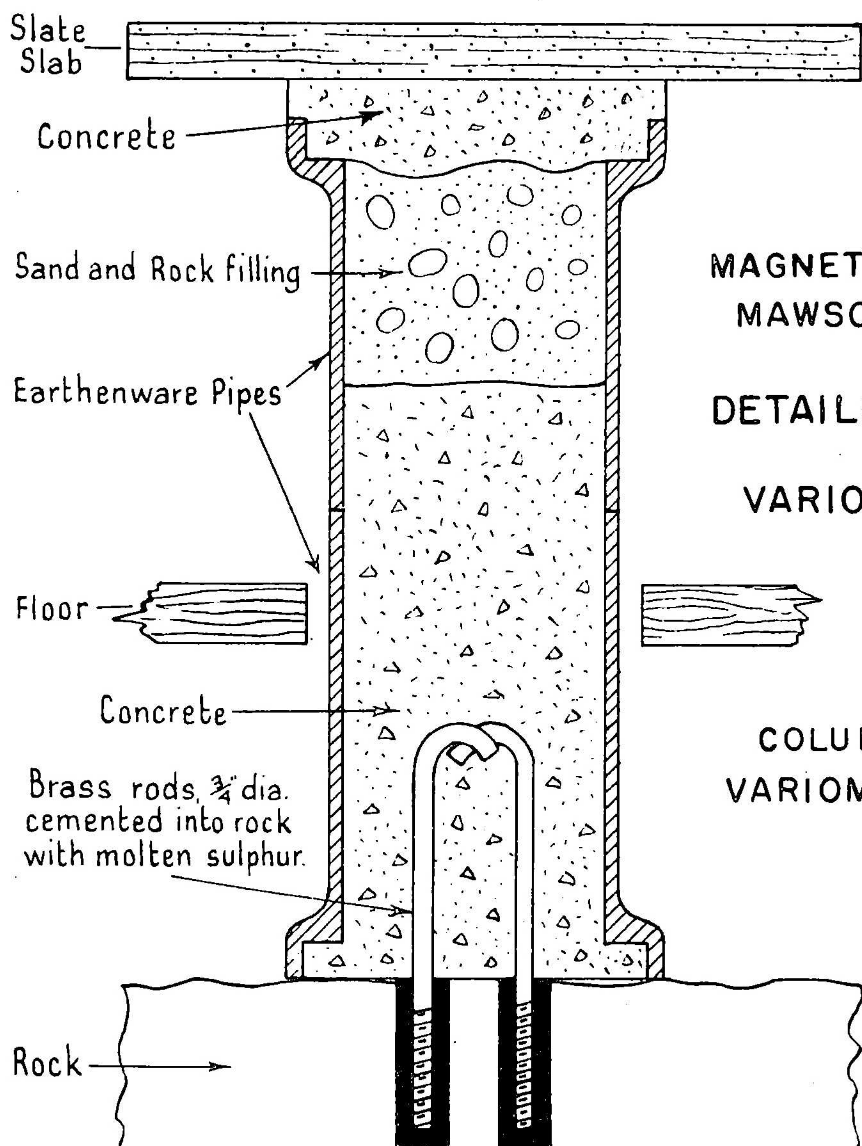
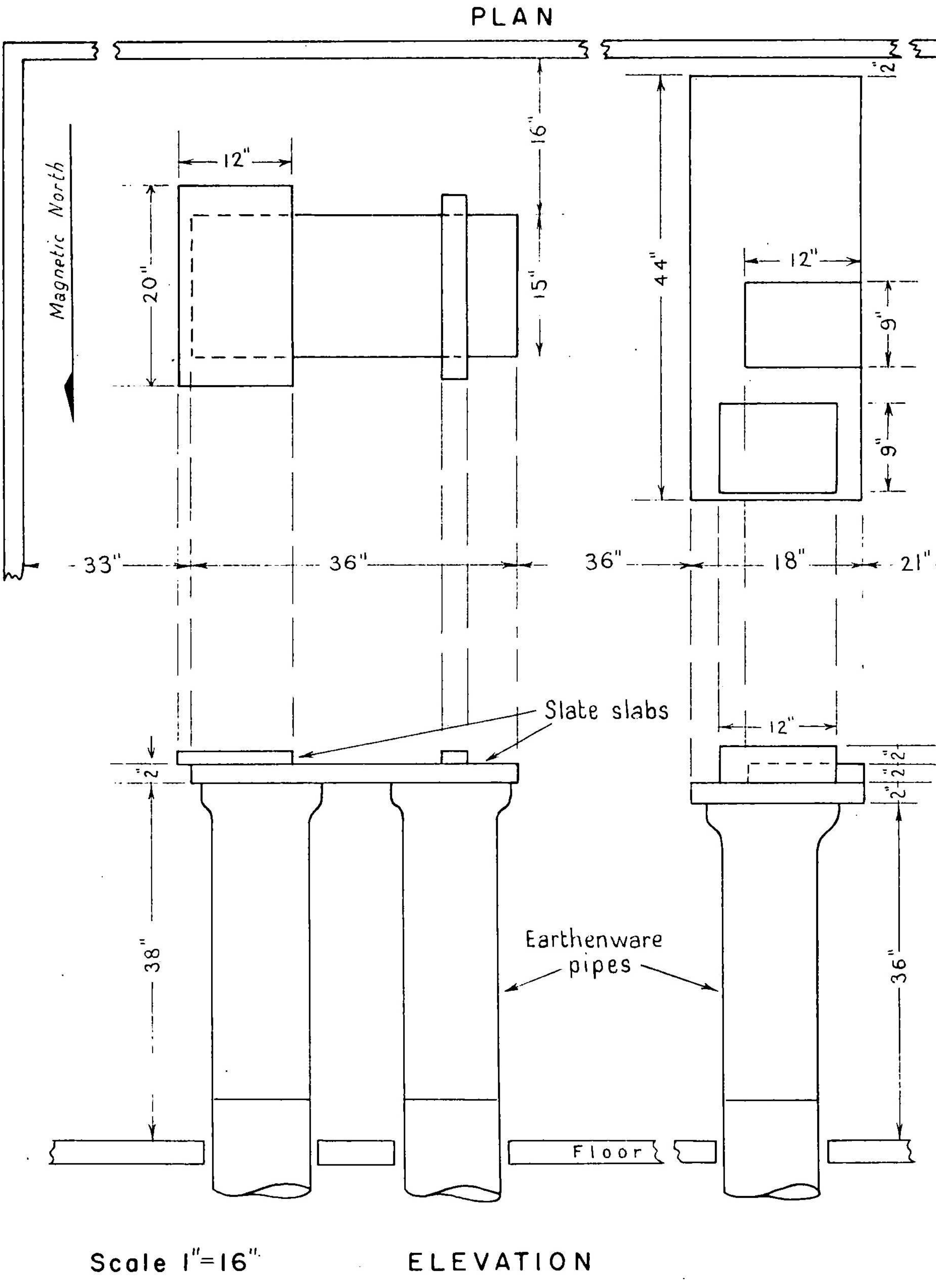


PLATE 3



MAGNETIC OBSERVATORY,
MAWSON, ANTARCTICA

LAYOUT OF PIERS FOR
MAGNETIC VARIOMETERS
AND RECORDER

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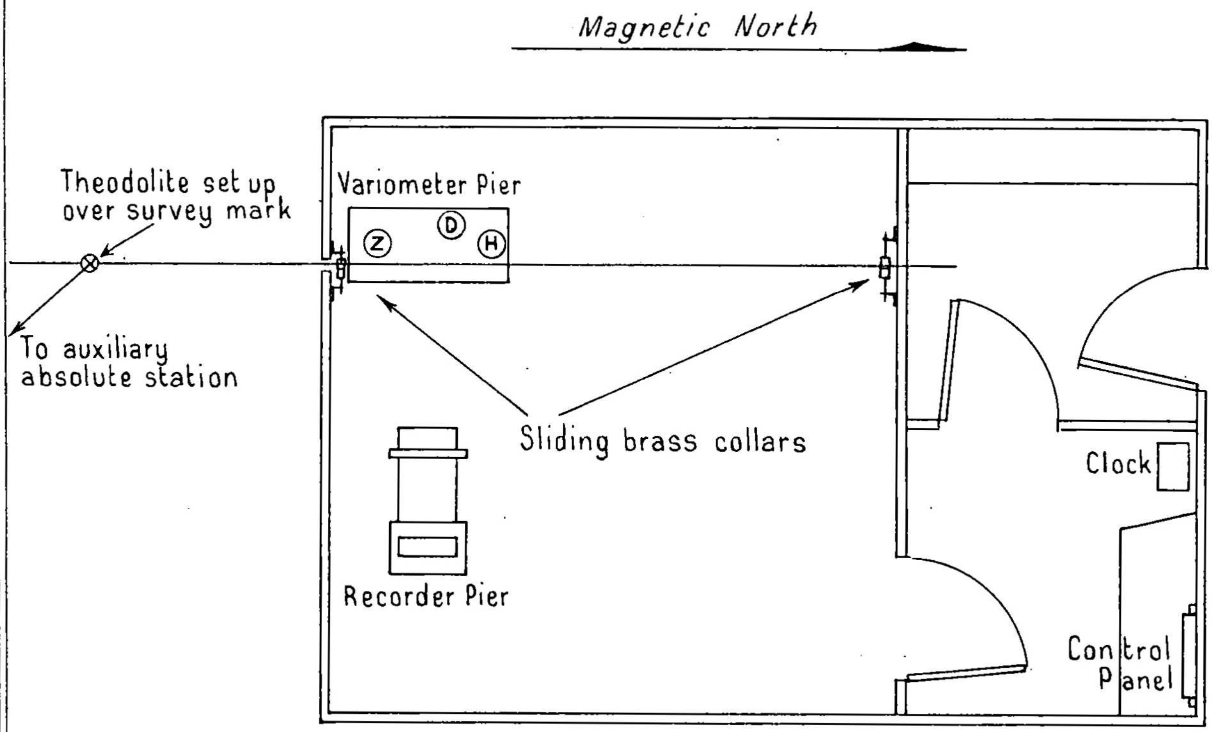
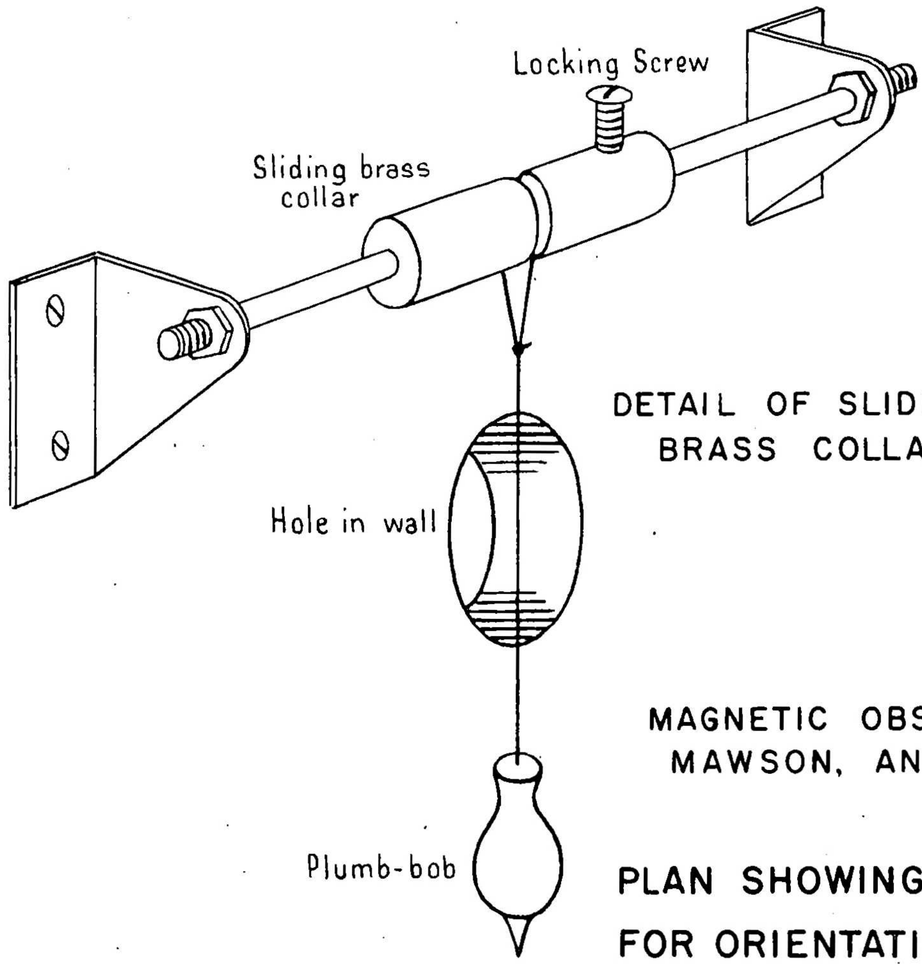
PLATE 4



ARRANGEMENT FOR ORIENTATION TESTS ON VARIOMETERS



DETAIL OF SLIDING BRASS COLLARS

MAGNETIC OBSERVATORY, MAWSON, ANTARCTICA

PLAN SHOWING EQUIPMENT FOR ORIENTATION TESTS ON MAGNETIC VARIOMETERS

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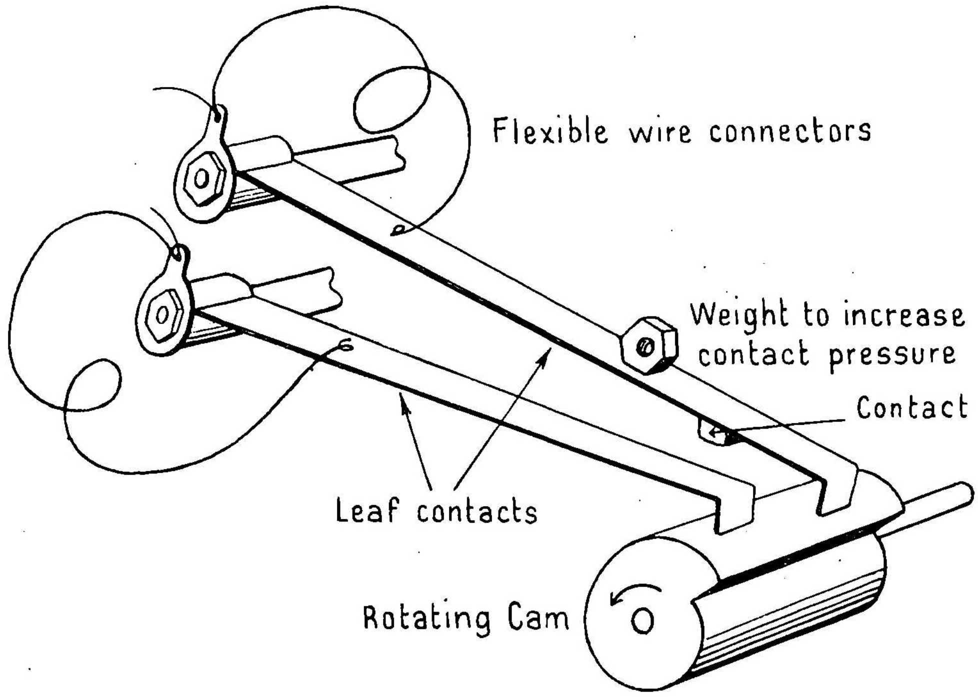
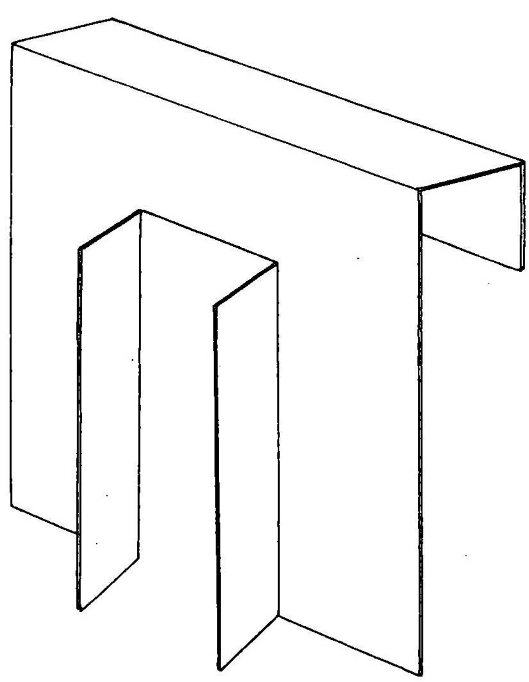


PENDULUM CLOCK CONTACTS

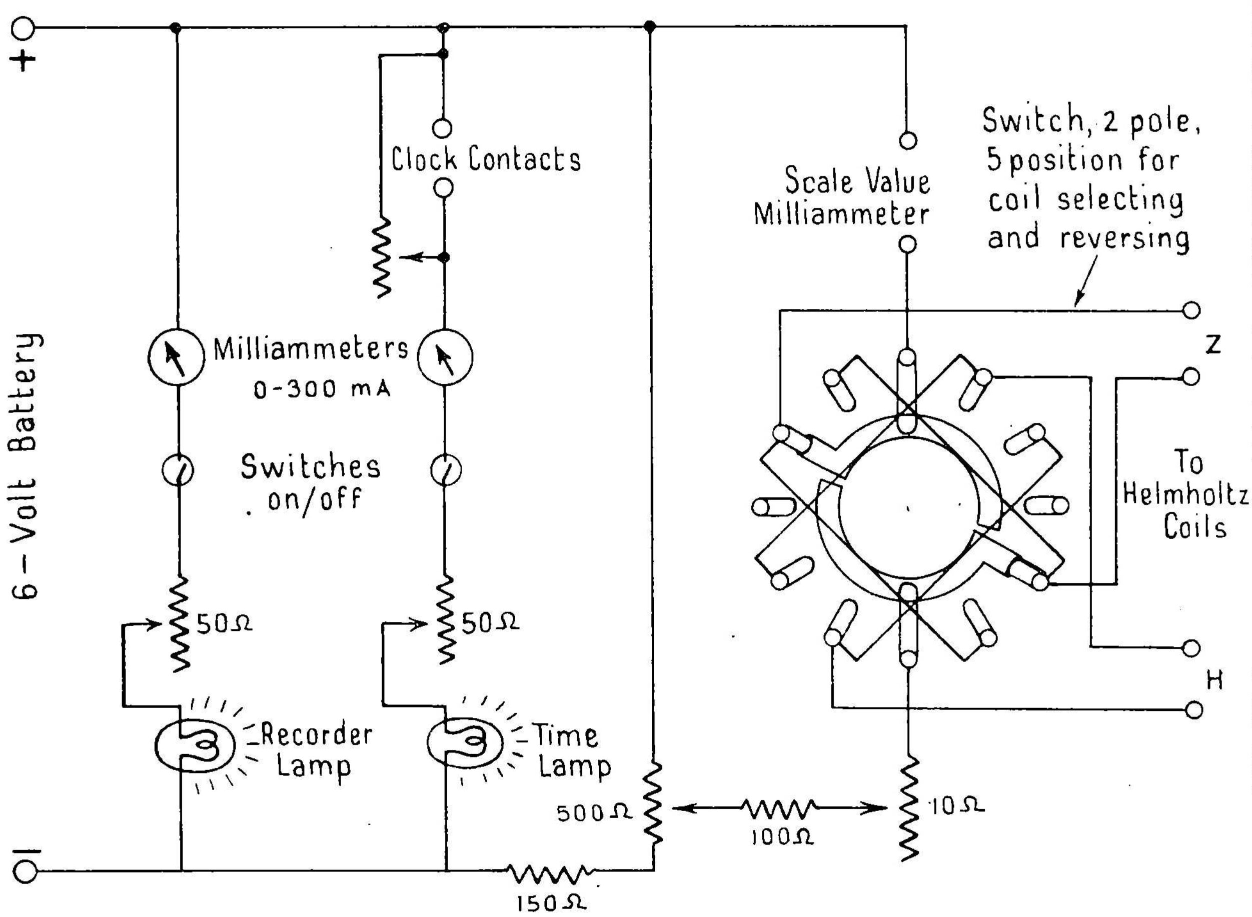


MASK FOR VARIOMETER BASELINE MIRRORS

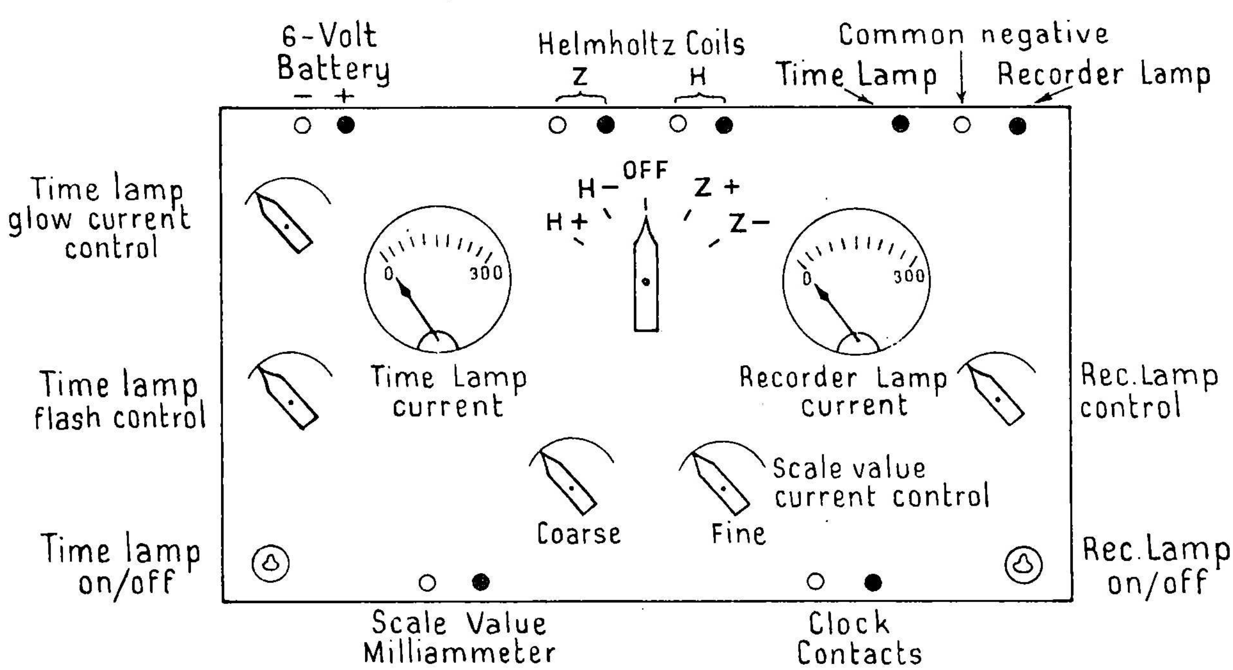
(Made of shim brass)

MAGNETIC OBSERVATORY,
MAWSON, ANTARCTICA

PLATE 6



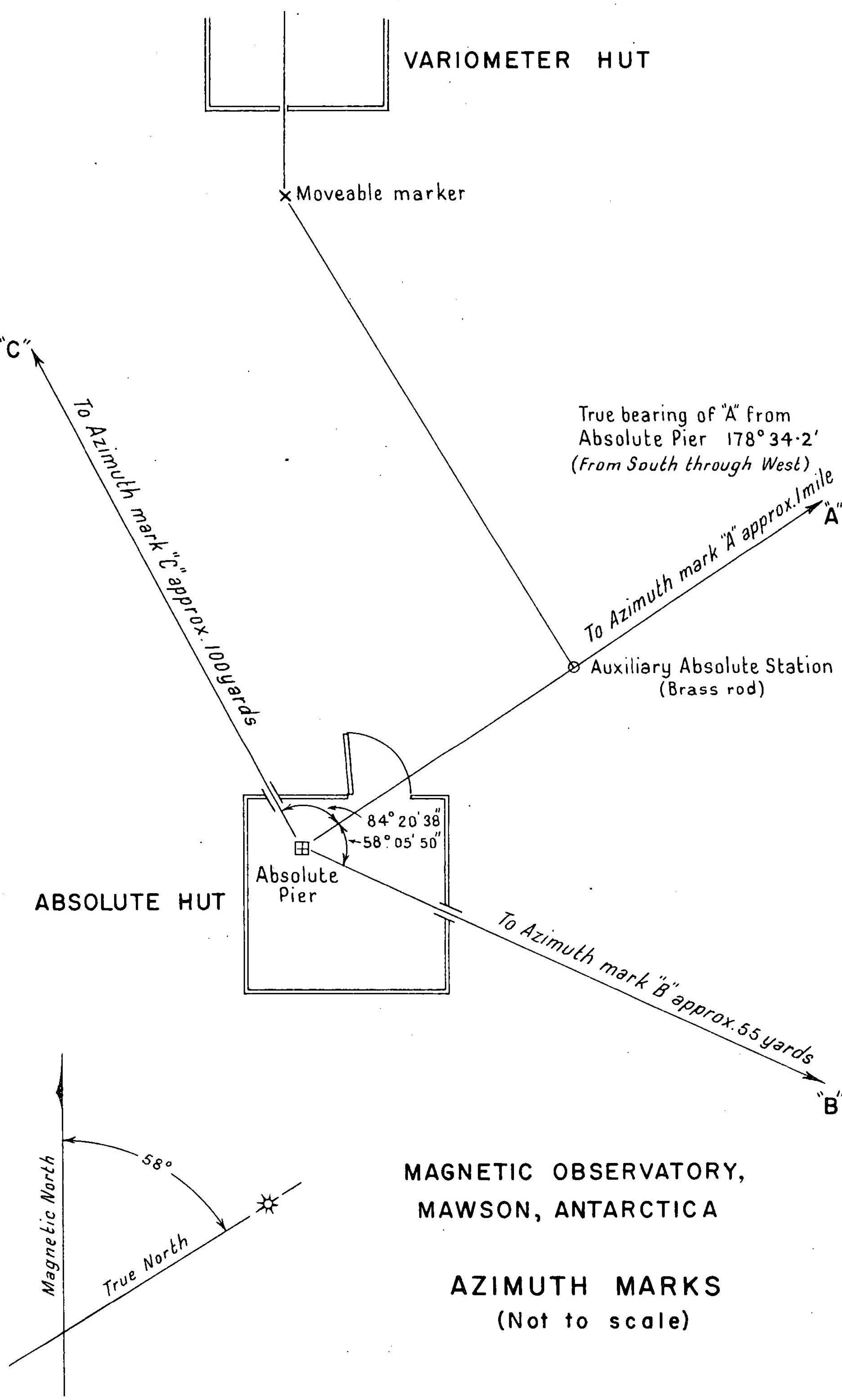
CIRCUIT DIAGRAM OF VARIOMETER LAMP CONTROL AND SCALE VALUE EQUIPMENT



LAYOUT OF VARIOMETER CONTROL PANEL

MAGNETIC OBSERVATORY,
MAWSON, ANTARCTICA

PLATE 7



MAGNETIC OBSERVATORY,
MAWSON, ANTARCTICA

AZIMUTH MARKS
(Not to scale)

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