NATIONAL ANTARCTIC EXPEDITION

1901-1904

[Publications]

PHYSICAL OBSERVATIONS

WITH

DISCUSSIONS BY VARIOUS AUTHORS

PREPARED UNDER THE SUPERINTENDENCE OF THE ROYAL SOCIETY

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1908

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PLATES.

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PREFACE.

THE present volume contains a series of Reports on various portions of the Physical observations made during the voyage of the "Discovery" in the National Antarctic Expedition, together with other observations taken in different regions of the world in further illustration of the subjects under discussion. The Royal Society, having undertaken the supervision and publication of the Physical work of the Expedition, placed the preparation of these Reports in the most competent hands available.

The Tidal work of the "Discovery," which was in charge of Lieutenant M. BARNE, R.N., has been here discussed by Sir GEORGE DARWIN, to whom we are also indebted for the discussion of the Tidal observations of the "Scotia," which were entrusted to the Royal Society by Dr. W. S. BRUCE, the leader of the Scottish Antarctic Expedition. The analysis of the "Scotia" observations has been furnished by Mr. SELBY and Mr. HUNTER, Tidal Assistants at the National Physical Laboratory.

The other Physical work of the "Discovery" which is included in the present volume, consisting of Pendulum observations, Earthquake registers, Auroral journal and Magnetic observations, was in charge of Mr. L. C. BERNACCHI during the Expedition, except the Magnetic work at sea, which was undertaken by Lieutenant ARMITAGE. Engineer Commander R. W. SKELTON, besides his valuable contributions to the Photographic work, rendered much assistance in the Pendulum observations. All the officers of the ship, both scientific and naval, lent their help in the recording of Auroral phenomena. The results of these various lines of physical research are presented in the following pages.

The account of the Pendulum observations has been prepared by Mr. BERNACCHI. The discussion of these results has been supplied by Dr. CHREE, F.R.S., of the National Physical Laboratory, whose valuable assistance has been placed at the service of the Royal Society by the Director, Dr. GLAZEBROOK, F.R.S.

To Dr. JOHN MILNE, F.R.S., we are indebted for the interesting discussion of the results of the Seismological observations and the comparison of these observations with others made contemporaneously in different parts of the world.

Mr. BERNACCHI has re-written and arranged the Auroral journal, to which Dr. E. A. WILSON has contributed a series of striking drawings.

The Report on the Magnetic observations has been supplied by several contributors. Mr. BERNACCHI, who spent some months in the reduction of the Differential Magnetic work, has written the introductory statement as to the conditions in which the observations were taken. Commander CHETWYND, R.N., of the Hydrographic Department of the Admiralty, has been so good as to supply the section on the reduction of the Absolute and Relative Magnetic observations.

As planned by the Royal Society, simultaneous Magnetic observations were taken on pre-arranged term-days at certain observatories, as well as at the Winter Quarters of the "Discovery." The results as measured from the magnetograms have been given in Tables of Hourly Values compiled by Commander CHETWYND and by Dr. CHREE.

The rest of the Magnetic work of the "Discovery" is now in course of being worked out at the National Physical Laboratory and will form the subject of a separate volume.

The Magnetic work of the "Scotia," which was entrusted to the Royal Society by Dr. BRUCE, was placed in the hands of Dr. CHREE, who has discussed it in the present volume, while Mr. MOSSMAN, who took the original observations, has furnished the account of the conditions in which they were taken.

ARCH. GEIKIE,
Sec. R. S.

Royal Society, Burlington House,
2nd July, 1908.

I. TIDAL OBSERVATIONS

IN THE

ANTARCTIC REGIONS, 1902-1903.

ANTARCTIC TIDAL OBSERVATIONS.

I. TIDAL OBSERVATIONS OF THE "DISCOVERY."

BY

SIR GEORGE DARWIN, K.C.B., F.R.S.

THE "Discovery" wintered in 1902 and in 1903 at the south-eastern extremity of Ross Island, on which Mount Erebus is situated, in south latitude 78° 49′ and east longitude 166° 20′.

The station is near the west coast of a great bay in the Antarctic Continent, and the westerly coast line runs northward from the station for about 9° of latitude. To the eastward of the bay, however, the coast only attains a latitude of about 75° and follows approximately a small circle of latitude. Since the tide-wave comes from the east and travels to the west the station is not sheltered by the coast to the westward, and the continent to the eastward can do but little to impede the full sweep of the tide-wave in the Antarctic Ocean. It is true that Ross Island itself is partially to the east of the anchorage, but it is so small that its influence cannot be important. Of course the westward coast line must exercise an influence on the state of tidal oscillation, for regarding the tide-wave as a free wave coming in from the east, it is clear that it will run up to the end of the bay and then wheel round northward along the westerly coast. It would seem, then, that the situation is on the whole a good one for such observations. Of course their value would have been much increased if it had been possible to obtain other observations elsewhere.

The following account by Lieutenant MICHAEL BARNE, R.N., explains the manner in which the tidal observations were made:—

"On our arrival in the vicinity of our Winter Quarters on February 8, 1902, a good deal of the previous year's ice remained attached to the land. As there was no foreshore, and pieces of this ice were constantly moving out, it was impossible to erect a tide-pole. With the final departure of the old ice, the temperature fell, and young ice formed continually, only to be quickly broken up by the almost incessant easterly winds.

"As this state of affairs promised to last for a considerable time, an effort was made to obtain records of the tides. A stout graduated pole was erected alongside the ice foot in about 10 feet of water, the lower end being heavily weighted and the upper end securely guyed. Some intermittent observations were secured in this manner, but they are probably of little value, as the ice was continually forming round the pole, which was only with difficulty freed from it. Besides this, communication with the shore, and consequently approach to the tide-pole, was constantly interrupted.

"On the ship being finally frozen in, a tide gauge of the following nature was erected (fig. 1).

"A single length of pianoforte wire (sounding wire) was led through a block, secured to the head of a tripod. One end of this length was attached to eight 25-lb. sinkers, which were lowered to the bottom. Four 25-lb. sinkers were secured to the other end in such a manner as to allow of their free movement, between the ice and the block, as the ice, with the tripod, rose and fell with the tide. An indicator was clamped to the wire, and a suitable scale secured to the tripod.

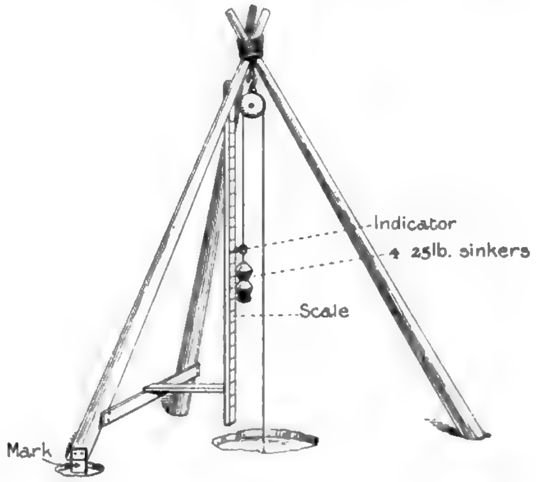

Fig. 1.

"It was thought that the motive force supplied by the weight of four sinkers would be sufficient to draw the smooth surface of the wire through the ice as the water rose and fell, whilst, in case it should fail to do so, the weight of eight sinkers would not be sufficient to break the wire.

"As it was considered possible that the ice, owing to the proximity of the land, might not maintain a uniform position relative to the surface of the water, a small hole was occasionally opened close to one of the tripod legs, to which was attached a mark, indicating the height to which the water should rise. A few observations showed that no error from this cause was to be apprehended.

"This gauge was placed about 200 yards from the ship, and two-hourly readings with but slight interruption were continued from April 12 to April 28.

"Some sluggishness in its movement, which was eventually noticed, and its final breakdown, was possibly partly due to the thickening of the ice, but principally, I think, to the fact that too small a block was employed at the tripod head. The scale was, by accident, secured so that the readings increased upwards, consequently they have to be inverted.*

"It was originally intended to place a tide gauge in the ship, owing to the far greater convenience of position, but it was thought that the position of the ship relatively to the water surface might alter and this might lead to errors. It was hoped that by placing one on the ice as well as one in the ship, check observations might be obtained to determine if this source of error existed. This was eventually accomplished on April 25, but by the time the ship gauge was erected the outside gauge had ceased to be entirely satisfactory, for the reasons given. The observations, however, show a close approximation of movement.

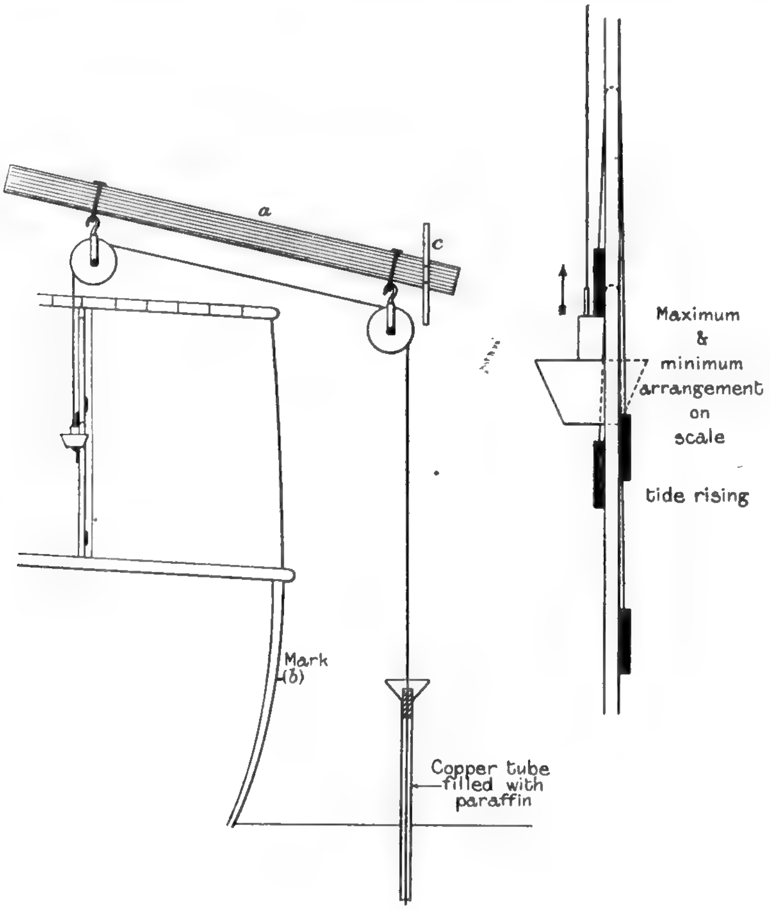

Fig. 2.

"The ship gauge was arranged as shown in fig. 2. The supporting blocks were secured rigidly, and, until May 10, the wire was led directly through the ice. As the friction was gradually increasing, a suggestion made by Dr. WILSON was adopted on that date, and the wire was taken through a tube, filled with paraffin oil and closed at the top and bottom with a hard wooden plug through which the wire passed. A maximum and minimum arrangement, with balanced weights, was added, as shown in the

* This oversight was rectified before May 12.—G. H. D.

sketch.* Unfortunately, both on May 10 and May 12, in refitting the gauge, the indicator had to be fixed afresh and therefore the observations cannot be referred to a common zero.

"A mark was placed on the ship's side to ascertain any vertical movement of the ship relatively to the water surface, and a long plummet was secured in the engine room, to show any alteration in her inclination to the vertical.

"On April 6, 1903, the tide gauge was re-erected and observations continued, but, owing to the large number of observers employed, the maximum and minimum arrangement was not fitted.

"The height of the mark (*b*) on the ship's side above the water was ascertained about once a month in the same manner as during the winter of 1902, *i.e.*, by digging a hole through the ice below the mark and measuring its height. On these occasions the difference between the heights of the leading blocks was measured in the following manner. A wooden scale (*c*) marked in half inches was secured to the beam (*a*) in a vertical position, close to the outer block, with its zero mark on a level with the top of the sheave. A wooden instrument, shaped like the letter T, and having a lead weight attached to its lower end and a hole, *A* (see fig. 3) in the centre of its upper end, was hung freely on a nail in such a manner that its upper side was horizontal and on a level with the top of the sheave of the inner block. By bringing the eye on a level with the upper side of this T-piece, and noting the position on the scale at which the upper side, if produced, would cut it, the reading of the scale was obtained which gave the difference in height of the blocks.

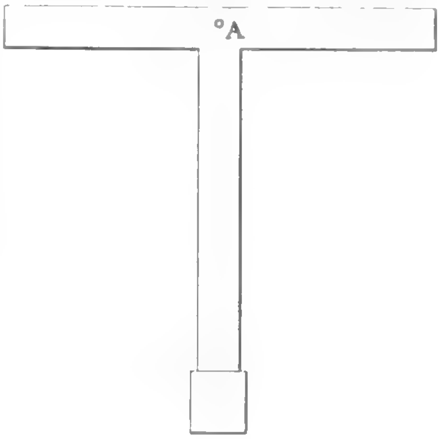

Fig. 3.

"By taking periodical measurements of the height of the mark, and the difference between the heights of the blocks, data were obtained by which readings could be corrected for alteration of the trim and the list of the ship respectively and reduced to a common zero, namely that on April 6, when the tide gauge was erected for the winter of 1903.

"On September 21, 1903, the wire carried away close to the place where it was secured to the weight resting on the bottom. On examination the wire was found to be greatly eaten away, from the point of attachment to a height of several feet, presumably on account of an action between the cast-iron sinkers and the steel pianoforte wire."

The series of hourly observations was occasionally interrupted by accidents, and the trim and list of the ship changed a little from time to time. Accordingly it is not possible to treat the observations as a continuous whole. The series was therefore broken into a succession of months, so chosen as to avoid periods of manifest irregularity or of accidental interruption, and each month was treated independently.

The choice of the method of harmonic analysis to be employed seemed to lie between that explained in the "Admiralty Scientific Manual" and that devised for the use of the tidal Abacus.† The method of the

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I take this opportunity of correcting a mistake in the Manual article, discovered by Mr. SELBY when reducing the "Scotia" tidal observations. At p. 63—

For the tide K_2. In the formula for tan ψ, in the denominator, for 3·67 p, read 3·71 p, for a fortnight's observation, and 3·84 p, for a month's observation. In the formula for H_s wherever 3·67 occurs read 3·71 for a fortnight, and 3·84 for a month's observation. The formula $H'' = \frac{1}{3\cdot67} H_s$ remains correct.

For the tides K_1 *and* P. In the formula for H′ the 3 in the numerator (but not that in the denominator) should be replaced by 3·007 for a fortnight's observation, or by 3·027 for a month's observation. The formula $H_p = \frac{1}{3} H'$ remains correct.

For $\kappa' = \kappa_p = \zeta' + V' + \phi$ read $\kappa' = \kappa_p - \zeta' + V' + \phi + 6^\circ\cdot88$ for a fortnight, and $\kappa' - \kappa_p + \zeta' + V' + \phi + 13^\circ\cdot29$ for a month.

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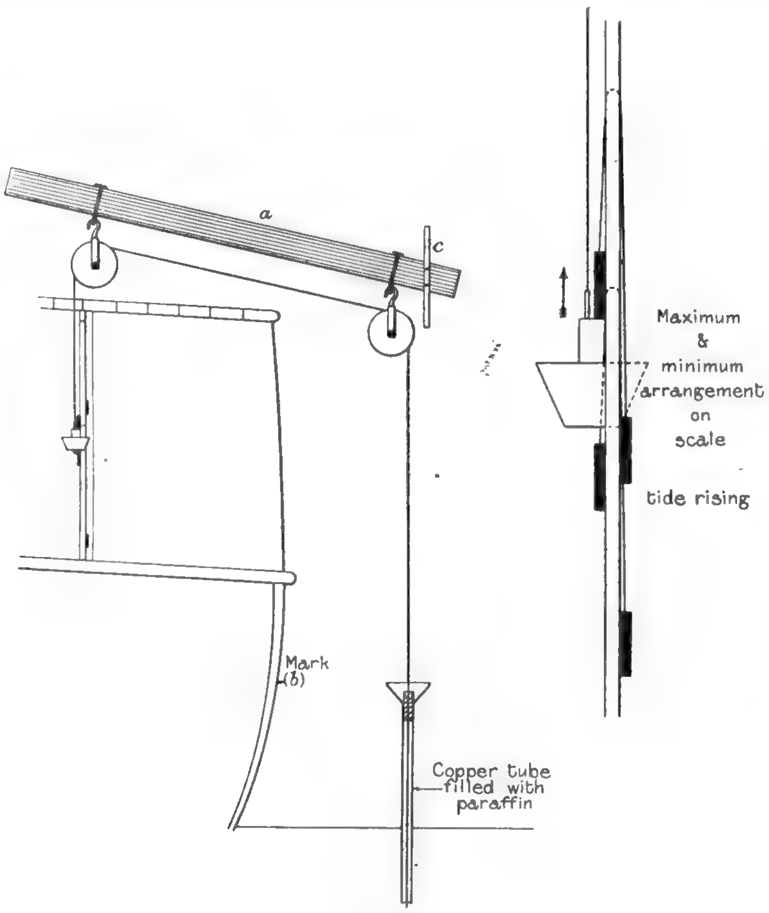

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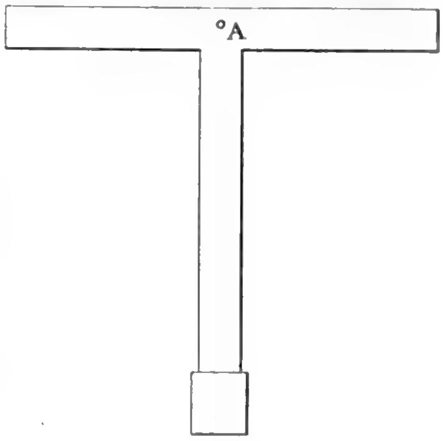

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Manual is considerably more laborious than the other, and it was highly desirable that the Abacus should be used if it could be trusted for a short series of observations. I therefore asked Mr. WRIGHT, who carried out the reductions and was familiar with the use of the Abacus, to reduce the first month in duplicate by the two methods. Curves were drawn through ordinates representing the mean height of water at the 24 hours of mean lunar time, as derived in the two ways. Although the whole range of height in the 24 mean lunar hours was only about six inches, the two curves showed a substantial agreement. The same process was then applied with O-time, when the range was found to be about 15 inches, and the agreement of the two curves was very close. The method of the Manual showed several sharp peaks or irregularities in the curves which were nearly smoothed out by the use of the Abacus. Such peaks would not affect the values of semi-diurnal or of diurnal components to a sensible amount, and as they are clearly accidental I concluded that the use of the Abacus was quite satisfactory, and accordingly that method was adopted throughout.

In the use of harmonic analysis it is necessary that the month under discussion should differ a little in length according to the tide which is being evaluated. For finding the M_2-tide months of 30 days or of 29 days would be almost equally advantageous, but as 30 days gives us one more day of observation that period was adopted. Similarly 30 days is appropriate for the S_2-tide. For a short period of observation it is necessary to regard this tide as compounded of the S_2 and K_2-tides, and we must also suppose its range to vary with the sun's parallax. The separation of these two tides from one another depends on theoretical considerations, which appear to be well founded.

Similarly, in a short series of observations the K_1 and P-tides must be treated as fused together in a single tide, and they are separable by theoretical considerations only. For these two tides a month of 27 days is appropriate. Lastly the analysis for the O-tide demands the use of a month of 28 days.*

I determined, then, to separate the months in such a way that the shortest months (27 days) should follow one another as closely as possible, while the longer months should overlap slightly. Whenever any event occurred whereby it seemed likely that the observations might be vitiated, the months were chosen so as to omit the time of possible or actual abnormality.

It was clearly desirable that the largest possible number of independent or nearly independent months should be discussed. This consideration led in one case to an overlap of as much as six days; thus the fifth month of 27 days ended on October 19, while the sixth month began on October 13.

In the few cases where hourly observations were missing, the defects were made good by interpolation. Although the observations began in April, 1902, the first satisfactory continuous period began on May 12. It will be well to state the epochs for the succession of twelve months which it was possible to obtain, and to add a few comments on the observations.

First month. This begins with 0^h May 12, 1902. The observations really begin at 2^h, but extrapolated values were used for 0^h and 1^h.

Second month. This begins with 0^h June 5, 1902.

On the afternoon of July 5 the wire attached to the sinker parted and the observations ceased. The apparatus was only reinstalled at 5 p.m. on July 23.

Third month. This begins with 0^h July 24, 1902.

Fourth month. This begins with 0^h August 23, 1902.

Fifth month. This begins with 0^h September 23, 1902. The height for 6^h on October 20 was interpolated.

On October 1 it was found that the ship had shifted so as to affect the readings by one inch. The date at which the shift had occurred was unknown, and, moreover, so small a change could not affect the results sensibly.

Sixth month. This begins with 0^h October 13, 1902. On November 9, the four hourly values, 1^h to 4^h inclusive, were missing and were supplied by interpolation.

As already remarked, this month considerably overlaps the one before it. This was necessary if a

* This use of months of various lengths necessitates some small arithmetical changes in the method as explained in the paper on the Apparatus referred to above.

seventh month was to be secured before the observations ceased for the season, but the choice of the stage at which the overlapping should be made to occur was more or less arbitrary.

Seventh month. This begins with 0^h November 13, 1902. The observation for 22^h of December 9 is missing and was supplied by interpolation. On December 13 the wire parted and the series ended for the year.

In the second winter, that of 1903, somewhat greater care seems to have been taken to note the small shifting of the ship.

Eighth month. This begins with 0^h April 6, 1903. Between April 22 and May 3 the ship shifted so as to make the readings too high by 3 inches, compared with the earlier ones. As an arbitrary correction I deducted 1 inch from all heights from 0^h April 24 to 0^h April 27; from 1^h April 27 to 0^h April 30 I deducted 2 inches; and for the rest of the month the full 3 inches. These arbitrary corrections were submitted to independent harmonic analysis, and it appeared that they afforded corrections so minute as to leave the tidal constants virtually unchanged.

Ninth month. This begins with 0^h May 9, 1903. The ship shifted considerably at some time about June 12, and as it is only possible to obtain one month before that date, there is an unutilized gap of a few days between this month and the one before it.

Tenth month. This begins with 0^h June 15, 1903. On July 10 a sensible shift in the trim and height of the ship was discovered. This necessitates the addition of $4\frac{1}{2}$ inches to all heights, $2\frac{1}{2}$ inches being due to angular movement and 2 inches to vertical movement. As an arbitrary correction I added 2 inches to all heights from 0^h July 8 to 0^h July 9; and afterwards I added the full $4\frac{1}{2}$ inches.

Eleventh month. This begins with 0^h July 14, 1903.

Twelfth month. This begins with 0^h August 14, 1903.

After September 8 the observations were only taken every two hours, and for the remainder of the month the values at the odd hours were interpolated.

The observations stop on September 20, but are not used in the reductions after September 13.

No corrections have been applied for changes in the barometric pressure. As the application of such a correction would have been very laborious and, moreover, somewhat speculative, I have relied on the automatic elimination of the inequalities produced by taking mean values.

The following are the results of the twelve harmonic analyses, the heights being stated in inches :—

Month.		1902.							1903.				
		1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.
M_2	H (inches)	2·272	2·286	2·180	1·931	1·735	1·562	1·206	1·908	2·195	2·330	2·406	2·177
	κ	0°·93	2°·48	13°·78	22°·37	26°·04	32°·16	30°·50	347°·57	355°·04	3°·83	8°·65	14°·57
S_2	H	0·906	1·390	1·051	0·928	1·203	1·272	1·196	1·368	1·431	1·009	0·829	1·262
	κ	270°·57	277°·69	276°·62	284°·70	275°·40	274°·10	249°·27	268°·61	267°·83	271°·42	280°·66	273°·55
K_2	H	0·247	0·379	0·287	0·253	0·328	0·847	0·326	0·373	0·390	0·275	0·226	0·344
	κ						Same as for S_2						
K_1	H	9·229	9·583	9·759	11·148	8·913	9·465	9·637	9·974	10·119	11·381	10·142	11·561
	κ	13°·05	15°·81	11°·32	18°·92	18°·61	11°·70	16°·78	7°·84	13°·57	9°·25	10°·41	8°·83
P	H	3·076	3·194	3·253	3·716	2·971	3·155	3·212	3·325	3·373	3·794	3·381	3·854
	κ						Same as for K_1						
O	H	8·562	8·251	9·257	9·879	8·456	9·706	9·075	9·353	10·079	9·717	9·460	9·561
	κ	1°·68	354°·55	4°·85	1°·52	2°·62	1°·86	358°·47	357°·90	354°·07	2°·60	2°·58	356°·78
A_0 inches		25·46	27·19	34 98	28·99	27·26	27·24	22·94	25·79	25·95	22·64	23·57	15·93

N.B.—The values of A_0 represent merely the changes in the position of the ship and have therefore no physical significance; all the heights are stated in inches.

The values of H and κ are somewhat irregular from month to month, and it is therefore not permissible to adopt the mean values of H and κ as representing the mean tide. I have therefore formed H cos κ and

H sin κ for each month and have taken the mean of each as giving the mean values of H cos κ and H sin κ. It is easy to compute from these the proper mean values of H and κ for each tide. The results are given in the following table:—

MEAN Values of Tidal Constants.

Semidiurnal tides.		Diurnal tides.	
M_2	H = 1·966 inches = 0·164 feet κ = 9°·9 = 10°	K_1	H = 9·245 inches = 0·770 feet κ = 14°·05 = 14°
S_2	H = 1·142 inches = 0·095 feet κ = 272°·1 = 272°	P	H = 3·082 inches = 0·257 feet κ = 14°·05 = 14°
K_2	H = 0·311 inches = 0·026 feet κ = 272°·1 = 272°	O	H = 9·264 inches = 0·772 feet κ = 359°·5 = 0°

The sum of the semi-ranges of the three diurnal tides is 21·6 inches and of the three semidiurnal tides is only 3·4 inches. This result corresponds with the fact that little trace of the semidiurnal tide is to be discovered from mere inspection of the tide curve.

When tidal observations have been reduced it is always important to verify that the constants found do really represent the tidal oscillation, for, in computations of such complexity, it is always possible that some gross mistake of principle may have slipped in unnoticed. Such a verification is especially important in a case where the tides are found to be very abnormal, as here, and where the results from month to month are not closely consistent. I accordingly asked Mr. GLAZEBROOK to run off curves for two periods with the Indian tide-predicter at the National Physical Laboratory. The constants used were the means for the tides evaluated. It is probable that a better result might be attained if a number of other tides, with constants assigned by theoretical considerations from analogy with the constants actually evaluated, had also been introduced, but I did not think it was worth while to do so. Evidence will be given hereafter to show that the smaller elliptic diurnal tides must exercise an appreciable influence.

The periods chosen for the comparison were about three weeks, beginning on May 12, 1902, and nearly the same time in November. It does not seem worth while to reproduce the whole of the observed and computed curves for these periods. The observed tide-curve has frequently sharp irregularities, presumably produced by weather or by unperceived shifts of the ship, and the maxima are sometimes sharp peaks instead of flowing curves. However, on the whole, the computed and observed curves follow one another very well, at least throughout all those portions where the diurnal tide is pronounced. Where the diurnal inequality is nearly evanescent, and the semidiurnal tide becomes perceptible, the discordance is sometimes considerable, although, even in these cases, every rise and fall of the water is traceable in the computed curve. Such discordance was inevitable, for at this part of the curve all those tidal oscillations which have any importance have disappeared, and only those tides remain which are very small; moreover, most of these tides are avowedly omitted from the computed curve.

I give two figures. The first shows the two curves where the diurnal tide is large, viz., from 0^h to 24^h November 18; it is a rather favourable example of the general agreement referred to above. The second figure, from 12^h May 29 to 12^h May 30, is selected because it exhibits by far the worst discordance which occurred in the six weeks under comparison.

I conclude that the reductions are quite as good as could be expected from tide-curves which present as much irregularity as these do. It would not be possible to make a very good tide-table from the constants, but no one wants a tide-table for Ross Island. We only need sufficient accuracy to obtain an insight into the nature of the Antarctic tides, and the constants are quite sufficient for that end.

When the mean heights of water at the 24 hours of mean lunar time were plotted in curves for each month, it became obvious that a pure semidiurnal inequality did not represent the facts very closely, and that there remained also a sensible diurnal inequality. Such an inequality is given by the tide M_1, and if we neglect the minute portion of the tide M_1, which depends on the terms in the tide-generating potential, which vary as the fourth power of the moon's parallax, such an inequality is found to depend on the composition of two elliptic tides with speeds $\gamma - \sigma - \varpi$ and $\gamma - \sigma + \varpi$. The genesis of this compounded tide is explained in the Report to the British Association for 1883.

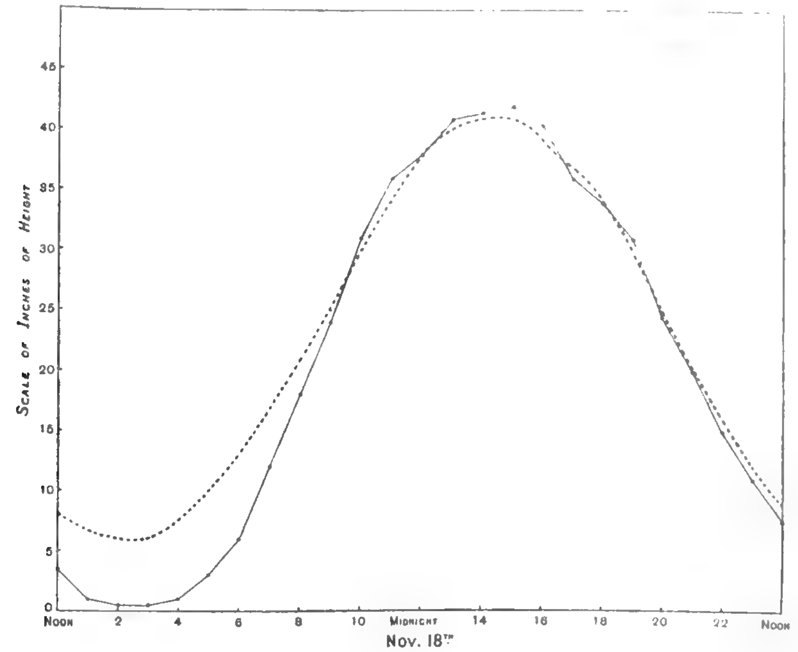


Fig. 4.

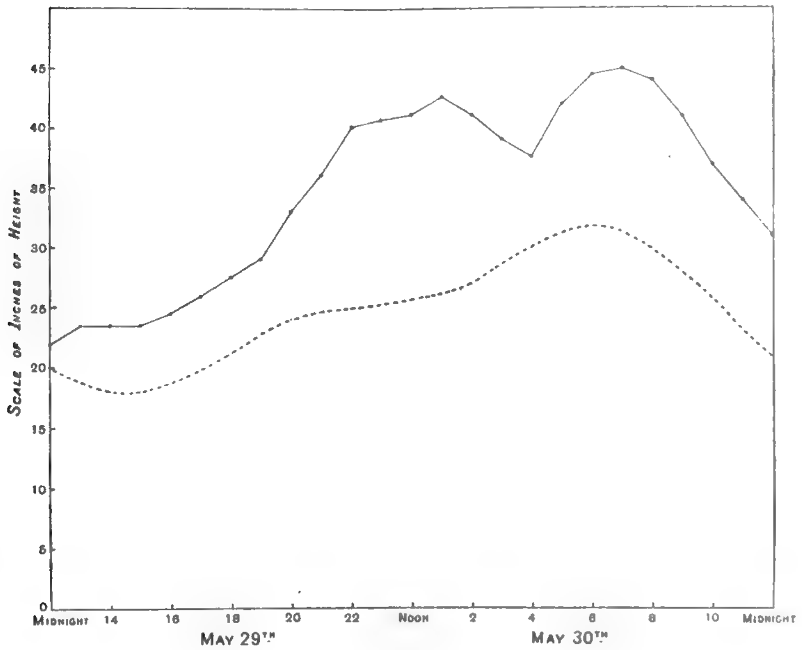


Fig. 5.

I accordingly thought it worth while to evaluate the M_1 tide for each of the twelve months under reduction. The results come out sufficiently discordant to render it impossible to assign any definite value to the tide, yet there appears to be some sort of method in the phases. Thus the phases for the twelve months come out for 1902, 9°, −3°, −45°, 6°, −32°, 70°, 12°, and for 1903, 6°, −159°, −179° −42°, −10°.

Two of the phases, those for the 9th and 10th months, are very discordant, but for these months the amplitude of M_1 is small; it is also very small for the 6th month with phase 70°. The mean of all the other phases is such that κ is pretty small, and this agrees with what is to be expected, because κ for the tide O is small. It thus appears probable that there has been a sensible disturbance from the M_1 tide of the values of the mean heights of water as arranged in mean lunar time. It should be noted that the whole amplitude of oscillation is so small that it is really surprising that this effect should be traceable at all.

There is one feature in the results which is so singular that it is well to refer to it. If we look at the heights and phases of the M_2 it will be observed that there is a progressive change both in amplitude and phase as the season of 1902 advances, and this change is repeated in 1903.

Mere inspection does not convince one of the degree of regularity, and I have, therefore, prepared a figure which exhibits the march of H cos κ and of H sin κ. The values for each month may be taken to appertain to the middle of the month, and the points surrounded by rings in fig. 6 give the values for the season of 1902, while those marked with crosses give the values for 1903. The broken line shows conjectural curves which appear to satisfy the observations. The conjectural curves are such that (in inches)

$$\text{H} \cos \kappa = 1\cdot65 - 0\cdot75 \cos (\eta t + 2°),$$

$$\text{H} \sin \kappa = 0\cdot23 + 0\cdot53 \cos (\eta t + 79°),$$

where η is 360° per annum and t is expressed in months.

There would thus be an annual inequality in H cos κ and H sin κ, and their mean values, viz., 1·65 and 0·23 inches, would show that the mean lunar semidiurnal tide is expressed by H = $1\frac{2}{3}$ inches, κ = 8°.

The mean given previously as derived only from the observations was H = 2 inches, κ = 10°.

It will be noticed that the greatest retardation occurs about midsummer, and at the same season there is a considerable decrease of amplitude. It is almost impossible to believe that the thawing of the sea could decrease the amplitude of the tide, although it might possibly increase it.

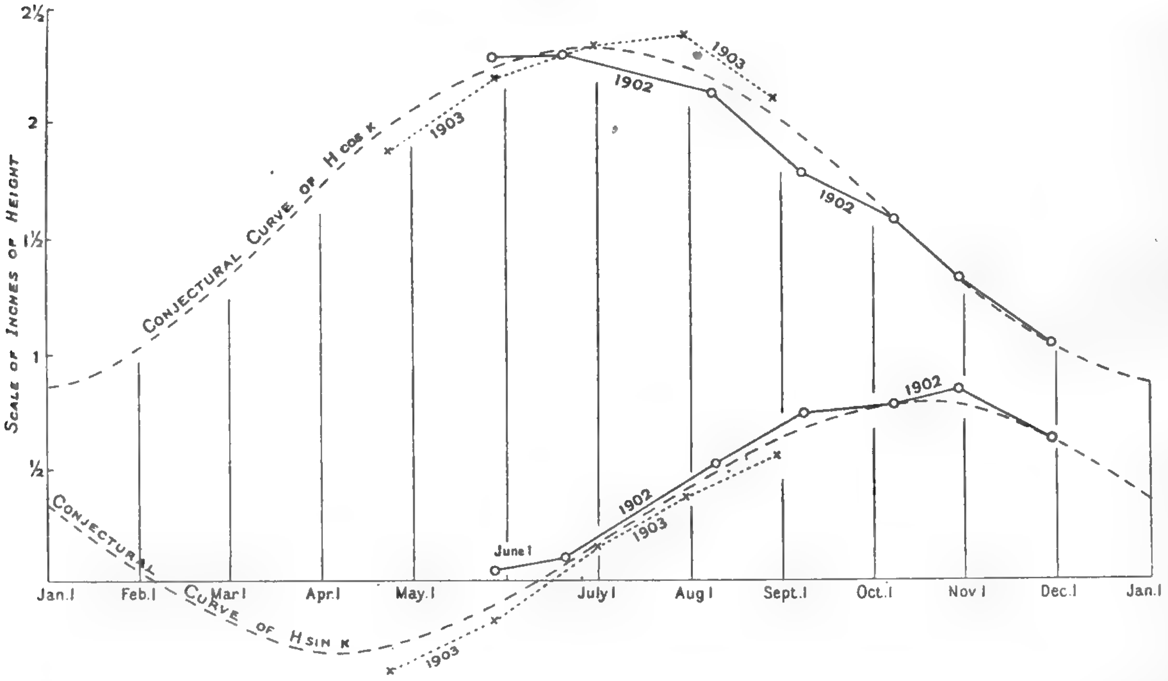


Fig. 6.

It would be strange if this result, depending as it does on 12 independent observations, should arise from mere chance. Yet there is no astronomical tide which can give an annual inequality in the lunar semidiurnal tide. I note that if the observations of 1903 were pushed backward one month the whole of the observations would fall into a more perfect curve. Hence, an inequality of 13 months would satisfy the conditions more perfectly than one of 12 months. There is, theoretically, a minute tidal inequality of long period (LAPLACE'S first species) with a period of 14 months due to the variation of latitude, but it is difficult to see how any perturbation of the lunar semidiurnal tide could be produced in this way.

But if we have found a true physical phenomenon, the same kind of effect ought probably to be produced on all the other tides. Yet when the observations for the other tides are plotted out in the same way, the points appear to be arranged almost chaotically. It is true that some slight tendency may be perceived for an increase of amplitude towards midwinter, but the effect is too uncertain to justify reduction to numbers.

A much longer series of observations would be needed to throw a clear light on the point raised, but the result is so curious that it would not have been right to pass it by in silence.

Tidal observations were made at Ross Island (called Erebus Island on the memorandum) by Dr. WILSON from 2^h January 11, 1904, to 8^h January 13. The place of observation was some 40 or 50 miles to the northward of the winter station. As there seemed some reason to suspect a seasonal variability in the tides, it seemed worth while to compare with actuality a tide-curve computed with the constants derived from the winter observations. A curve was therefore run off at the National Physical Laboratory for a few days beginning with 0^h January 11, 1904. Although the sites of the two sets of observations are not identical, comparison with actuality shows a satisfactory agreement. It is unfortunate that these observations were made just after the time when the diurnal inequality had vanished and was beginning to increase again; for at these times the agreement is liable to be imperfect between computed and observed curves. On these grounds no surprise need be felt on account of the fact that the semidiurnal tide is somewhat more clearly marked in the observed tide-curve than in the computed one, and that the whole range of the diurnal tide on January 11 was 3 inches greater, and on January 12 about 6 inches (out of 28 inches) greater than appears from the computed curve. The computed and observed times of high and low water agree closely with one another. We may, on the whole, accept these summer observations as proving that our tidal constants are substantially correct.

The semidiurnal tides, although small, exhibit clearly another peculiarity; it is that (κ of S_2) − (κ of M_2) exhibits a seasonal change of roughly the same character in both years.

In all cases "the age of the tide" is negative and its mean value is about −4 days; in other words, spring-tide occurs four days *before* or ten days *after* full and change of moon.

If the phases of M_2 and S_2 differed by 180° we should have neaps at full and change, and springs at half moon. This case corresponds to "direct" lunar tide and "inverted" solar tide. In the actual case

$$(\kappa \text{ of } M_2) - (\kappa \text{ of } S_2) = 370^\circ - 272^\circ = 98^\circ;$$

thus the observations show a result a very little nearer to this condition than to the ordinary one where springs coincide with full and change of moon.

The unusual relationship between the M_2 and S_2 tides is such as to make it worth while to examine what would be the condition of affairs in an ocean of uniform depth covering the whole planet. From the few soundings which have been made it would seem that the ocean may be about 600 fathoms in depth, although further north the depth appears to be considerably greater. I have therefore taken the formulæ of Mr. HOUGH ('Phil. Trans.,' A, 191 (1878), pp. 177, 180) and evaluated the lunar and solar semidiurnal tides for an ocean of 7260 ft. in latitudes 60°, 65°, 70°, 75° with the following results:—

LUNAR Semidiurnal Tide.

Latitude	60°.	65°.	70°.	75°.
H of equilibrium tide	6·052 centims.	4·324 centims.	2·832 centims.	1·622 centims.
Factor of augmentation for dynamical tide . .	1·932	1·496	1·098	0·755
H of dynamical tide for ocean of 7260 ft. (direct tide)	11·69 centims. 4½ inches	6·47 centims. 2½ inches	3·11 centims. 1¼ inches	1·22 centims. ½ inch

SOLAR Semidiurnal Tide.

Latitude	60°.	65°.	70°.	75°.
H of equilibrium tide	2·816 centims.	2·012 centims.	1·318 centims.	0·755 centim.
Factor of augmentation for dynamical tide . .	−6·441	−4·390	−2·556	−1·003
H of dynamical tide for ocean of 7260 ft. (inverted tide)	−18·14 centims. −7 inches	−8·83 centims. $-3\frac{1}{4}$ inches	−3·37 centims. $-1\frac{1}{3}$ inches	−0·751 centim. $-\frac{1}{3}$ inch

We thus find that in these high latitudes the solar tide is more magnified than the lunar, and is inverted. Thus in latitude 60° the solar tide is much larger than the lunar and is inverted, whereas in latitude 70° they are nearly of equal magnitude and the inversion of the solar tide still continues.

For an ocean of twice the depth both the tides are direct, and they are not so much magnified.

Although the Antarctic Ocean runs all round the globe it is of course unjustifiable to apply these results directly to the oscillations of the actual ocean, but they serve to show that we have no reason to expect considerable semidiurnal tides so near to the pole, and also that the great discrepancy between the phases of M_2 and S_2 is not so surprising a fact as it might appear at first sight.

It is useless to carry out a similar investigation for the diurnal tides, because the variations in the depth of ocean exercise so large an influence on the result. We know, in fact, that for an ocean of uniform depth the K_1-tide vanishes completely, and the O-tide nearly vanishes.

I find that the equilibrium O-tide is $3\frac{1}{2}$ inches in latitude 60° and falls to 2 inches in latitude 75°. Thus the amplitudes of the diurnal tides observed by the "Discovery" are very much larger than the equilibrium values.

The Scottish Antarctic Expedition passed the winter of 1903 in S. latitude 60° 44′ and W. longitude 44° 39′ at the South Orkney Islands; they were thus nearly opposite to the station of the "Discovery." Their station was well adapted for determining the general character of the tides in the Antarctic Ocean. The reduction of their observations was made by Mr. SELBY at the National Physical Laboratory, and gave the following results:—

	M_2.	S_2.	K_2.	K_1.	P.	O.
H	1·522 ft.	0·912 ft.	0·249 ft.	0·482 ft.	0·161 ft.	0·558 ft.
κ	172°	198°	198°	15°	15°	359°

It will be noticed that these results are quite normal, save that the S_2-tide is rather large compared with M_2, and there is a well-marked diurnal inequality. They acquire a special interest when considered in connection with the "Discovery's" results. We see that the semidiurnal tides are "inverted," but have little or no retardation, whereas the M_2 of the "Discovery" is small, but "direct," also with little retardation. We are thus led to suspect that to the northward of the latitude of the South Orkneys, where the "Scotia" wintered, the semidiurnal tides are inverted with small retardation; that somewhere between the South Orkneys and near to the Antarctic Continent there is a nodal line for the M_2-tide. There must be also a similar node for the S_2-tide, and we may, perhaps, suppose that the node of the S_2-tide is nearer to Ross Island than that of the M_2-tide.

When we turn to the diurnal tides we find an entirely different condition, for at both places the phases are virtually identical, and there seems a *primâ facie* case for maintaining that the phase of the diurnal tide throughout the whole Antarctic Ocean is approximately the same as in the equilibrium theory. I cannot venture to offer any theory in explanation of the greater magnitude of the diurnal tide at Ross Island than at the South Orkneys.

II. TIDAL OBSERVATIONS OF THE "SCOTIA," 1902–1904.

I. Analysis of the Observations.

The anchorage at which the tidal observations here dealt with were taken was at the head of Scotia Bay, Laurie Island, South Orkneys, in latitude 60° 43′ 42″ S., longitude 44° 38′ 33″ W. The bay is about 3 miles deep and faces S.E.; the depth of water at the anchorage was 10 fathoms, increasing to about 100 fathoms at the mouth of the bay. Here the "Scotia" was frozen in from March 25 to November 23, 1903. (See Map at end of volume.)

The apparatus used consisted of a long wire fixed to the sea bottom by means of a heavy weight. The wire was carried over a davit by means of a pulley. At the extremity of the wire was another lighter weight, which rose and fell with the tide along a graduated wooden scale. The floe in which the "Scotia" was frozen moved with the tide, the height of which was thus shown by the position of the movable weight. The observations were made by the leader, officers, and staff of the Expedition under the direction of Captain Thomas Robertson.

The period covered by the observations is from 10.30 a.m., May 26, 1903, to midnight on October 16 of the same year. On September 4 the wire broke and had to be replaced, and at this point there may be a discontinuity of zero. The observations for the last month have accordingly been treated as a distinct series. The observations recorded give the height of the tide at every half-hour from May 26 to September 4, and at every hour from September 5 to October 16. Records of the barometric pressure and of the strength and direction of the wind are also available. On May 26 the height of the tide was noted every 5 minutes from 5.45 a.m. to 9 a.m.

In analysing the observations hourly heights were used, commencing for the first three months from 1 a.m. on May 26, 1903 (13 h. May 25, local mean time). The harmonic components for which an analysis was carried out were M_2, O, N_2, S_2, K_2, K_1, P.

For the first three components named the method of analysis was that used for the Indian Tides, and described in the 'B.A. Report' for 1883. The periods chosen were 86 M days, 89 O days and 78 N days, these periods being selected to minimise the effects of the S_2, K_1, and M_2 components respectively, and to be as large as the first series of observations permitted.

For the components S_2 and K_2 and K_1 and P the process employed was essentially that given by (Sir) G. H. Darwin in the 'R.S. Proceedings,' vol. LII (1893), p. 365, where a method is indicated for dealing with a short series of observations extending over a few months. In analysing for K_1 and P, however, 27 days' observations in each month were employed instead of 30. [See Article by (Sir) G. H. Darwin in Appendix to 'B.A. Report' for 1886.] Each month's observations were separately analysed and the means formed as recommended on p. 367 of the paper referred to above.

The most important feature of the method, in regard to the results of the analysis tabulated below, is that the ratios of the amplitudes of S_2 and K_2, and of K_1 and P respectively are assumed to have their theoretical values, and that the "lags," in the case of each pair of components having nearly equal speeds, are taken to be the same. That in this instance this theoretical assumption is in sufficiently close agreement with the facts may be regarded as established by the results of the analysis.

The values of the tidal constants obtained from the analysis are given in the subjoined table, H denoting the semi-range or amplitude (in feet) and κ the epoch or "lag" of a component:—

	M_2.	O.	S_2.	K_2.	K_1.	P.	N.
1st month H			0·897	0·244	0·446	0·149	
1st month κ			200°·6	200°·6	16°·8	16°·8	
2nd month H	1·518	0·564	0·892	0·243	0·487	0·162	0·298
2nd month κ	172°·3	357°·7	198°·4	198°·4	11°·3	11°·3	153°·5
3rd month H			0·953	0·260	0·473	0·158	
3rd month κ			197°·6	197°·6	13°·8	13°·8	
4th month H	1·537	0·543	0·907	0·247	0·522	0·174	—
4th month κ	172°·1	3°·1	194°·7	194°·7	16°·5	16°·5	—
Mean H	1·522	0·558	0·912	0·249	0·482	0·161	0·298
Values κ	172°·3	359°·0	197°·8	197°·8	14°·6	14°·6	153°·5

The agreement between the values of the constants in successive months is as close as can be expected and may be regarded as quite satisfactory.

The zero readings (mean sea-level) for the successive months were found to be 4·37, 3·61, 3·90, 3·00 feet respectively. In regard to the last value, it should be remembered that this belongs to the period following the breaking of the wire. It would seem certain that there was an irregular change of zero due to shifting of the ship's position in the ice, consumption of coal, &c., and that from these values there is nothing to be inferred.

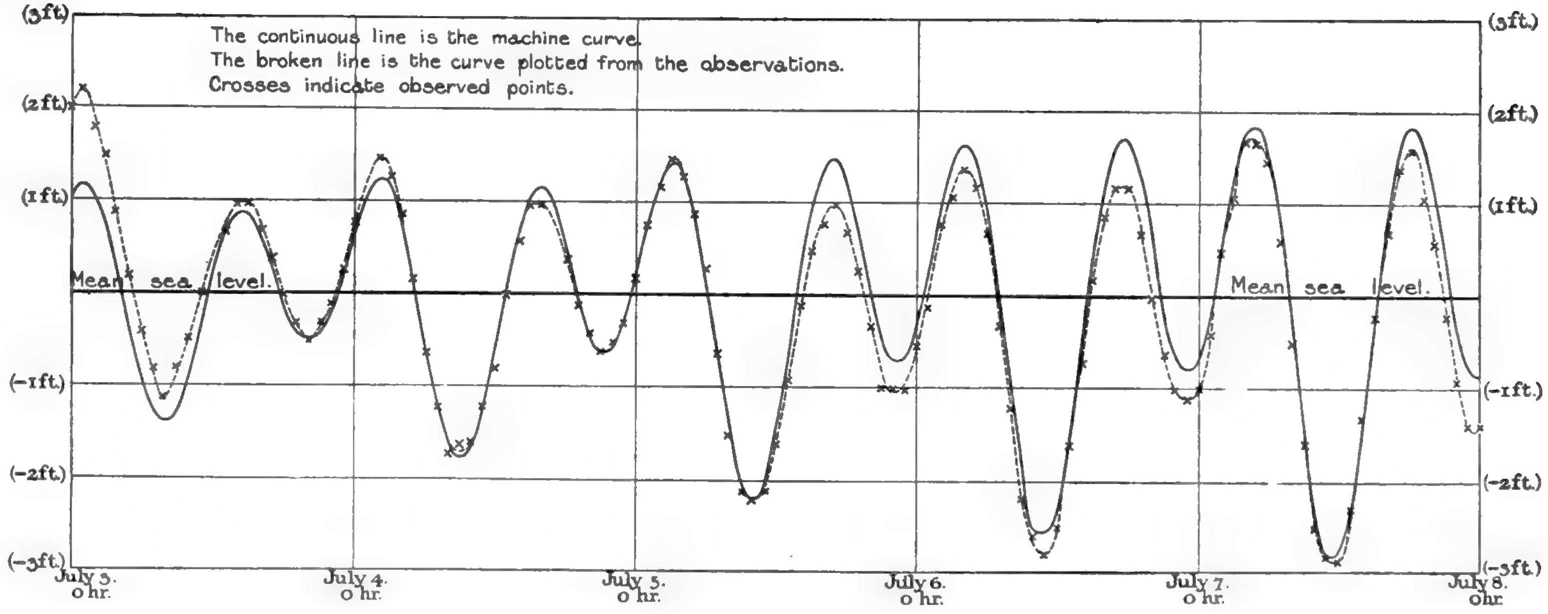
As a check on the analysis the initial values for the various components obtained were calculated for 0 h., June 1, 1903, and, with the aid of the Indian tide-predicting machine in the charge of the National Physical Laboratory, a curve was run off for the two months June and July. The observed heights for the five days beginning 0 h., July 3, 1903 (astronomical time), have been plotted for comparison with the curve given by the machine. The two curves are shown in the diagram on p. 15 opposite. The curve obtained from the observations, where distinguishable from the machine curve, is indicated by a broken line. Crosses mark the observed points. The mean sea-level for the "observation" curve is that given by the mean of the five days' heights. The agreement over these five days is sufficiently close. It may be noted that where the two curves separate they could in each case be brought much nearer to coincidence by a change of zero, as distinct from the addition of another harmonic term, and that such change of zero, as already pointed out, is to be expected.

The differences between the observed heights and the machine heights were also obtained for every hour on the following days: June 4, June 19, July 1, July 11, and July 24. The zero in each case is arbitrary, but if the analysis were accurate and complete the difference should be constant. The actual differences on these five days, however, would appear to indicate a variation having an approximate amplitude of 5 inches, and possibly of approximately diurnal period. This is not apparent in the comparison curves, and further investigation would be necessary before any conclusion could be arrived at in regard to it.

With reference to the wind records, there is nothing calling for any special comment in connection with the tides. It is clear that the winds have not sensibly impaired the value of the observations, which appear to have been taken with great care, and have been found quite satisfactory for purpose of analysis.

F. J. Selby, M.A.,
J. de Graaff Hunter, B.A., } Tidal Assistants at the National Physical Laboratory.

December 20, 1906.



Comparison of the curve given by the tide-predicting machine with the curve plotted from the actual observations for the 5 days from July 3, 0 h., to July 7, 24 h., 1903.

II. Discussion of the Preceding Results.

The tides seem to be normal for a place in the Southern Ocean. The semi-diurnal tides are considerable, but the solar tide is unusually large compared with the lunar tide, the ratio being $\frac{3}{5}$, or 0·6, as compared with 0·465 of the equilibrium theory. The semi-diurnal tides are almost exactly "inverted," so that low water occurs very nearly when the moon is on the meridian.

The "age of the tide," or the mean interval from full and change of moon to springs, is $(197°\cdot8 - 172°\cdot3) \div 1°\cdot016$ hours, or 25 hours. This is a normal result, for the ages at Madras, Bombay, and Karachi are 29 hours, 32 hours, and $27\frac{1}{2}$ hours, respectively.

The diurnal tides are well marked, as might be expected; and it is interesting to note that they are "direct" and almost exactly in the phase indicated by the equilibrium theory. The age of the diurnal inequality may be defined as the mean interval which occurs after the moon has attained her maximum declination before the diurnal tide reaches its maximum. This is given by the excess of κ for K_1 over κ for O, divided by twice the moon's mean motion. Thus, in the present case, the age is $\{14°\cdot6 - (-1°\cdot0)\} \div 1°\cdot098$ hours, or $14\frac{1}{4}$ hours. There does not seem to be any prevalent rule as to this "age" in India, for whereas at Madras the corresponding period is 14 hours, at Bombay and Karachi this retardation is replaced by a small acceleration.

These results are very valuable, as relating to the only ocean uninterrupted by land throughout the whole circumference of the globe, yet in themselves they do not seem to present any features of special interest. But they do acquire much importance when considered in connection with the very abnormal results obtained by the "Discovery," which I hope to discuss in the volumes to be devoted to the scientific work of that expedition.

I wish to use the present opportunity of drawing attention to a mistake which was made in the article on Tides in the 'Admiralty Scientific Manual.' It was discovered by Mr. Selby when he came to apply the methods of that article to these reductions. The mistake occurs in the 'British Association Report' for 1886, referred to above by Mr. Selby, and was carried on into the Manual. The principle of the method was given correctly in my paper in the 'Proceedings of the Royal Society' for 1893, vol. 52, p. 365, but certain small changes are needed for applying the method to the case in point.

I hope to correct the mistake in vol. 1 of my Collected Papers, which are to be published by the Cambridge University Press, but it may suffice here merely to correct the errata in the Manual as follows:—

At p. 63,—*For the tides* K_2 *and* S. In the formula for $\tan \psi$, in the denominator, for $3\cdot67\ p_{\prime}$ read $3\cdot71\ p_{\prime}$ for a fortnight's observation, and $3\cdot84\ p_{\prime}$ for a month's observation. In the formula for H_s, wherever 3·67 occurs, read 3·71 for a fortnight, and 3·84 for a month's observation. The formula $H'' = \frac{1}{3\cdot67} H_s$ remains correct.

For the tides K_1 *and* P. In the formula for H′ the 3 in the numerator (but not that in the denominator) should be replaced by 3·007 for a fortnight's observation, or by 3·027 for a month's observation. The formula $H_p = \frac{1}{3}H'$ remains correct.

For $\kappa' = \kappa_p = \zeta' + V' + \phi$ read

$\kappa' = \kappa_p = \zeta' + V' + \phi + 6°\cdot88$ for a fortnight, and $\kappa' = \kappa_p = \zeta' + V' + \phi + 13°\cdot29$ for a month.

The succeeding numerical example must be corrected accordingly. The only sensible change is that $\kappa' = \kappa_p = 334°$ in place of 327°.

G. H. Darwin.

December, 1906.

II. PENDULUM OBSERVATIONS.

PENDULUM OBSERVATIONS.

I. Results of the Observations, by L. C. Bernacchi, F.R.G.S

II. Discussion of the Results, by C. Chree, Sc.D., LL.D., F.R.S.

I. RESULTS OF THE PENDULUM OBSERVATIONS.

BY

L. C. BERNACCHI, F.R.G.S.

INTRODUCTORY.

AMONG the investigations that the "Discovery" Polar Expedition had placed upon its programme were those for the determination of the force of gravity in a high southern latitude. As there could be no question of anything but relative determinations, it was decided, after consulting Professor VON HELMERT, to apply for the loan of the Stückrath pendulum apparatus of the South Kensington Museum.

INSTRUMENTAL EQUIPMENT.

The apparatus was lent to the Expedition by the authorities of the South Kensington Museum. The complete outfit comprised a set of three quarter-metre invariable pendulums with agate knife-edges, to swing on three separate agate planes, an air-tight case in which they were swung, a dummy or temperature pendulum, flash apparatus, air pump, dry cells, and various accessories.

The stand was a heavy metal one, provided with levelling screws, and arrangements for starting, stopping, raising and lowering the pendulums from the outside. A heavy case fitted over the pendulums and rested on a smooth level rim of brass at the base of the stand, which was fitted with a similar rim so that the rims came in close contact, a thin layer of vaseline being previously spread between them. The knife-edges were made horizontal by means of small pendulums with levelling tubes in their heads. Two windows in the case permit the mirrors at the top of the pendulums and the thermometer being seen. The bulb of this thermometer was inserted in the stem of a dummy pendulum of the same size and metal as the swinging ones and held in the case near them.

The flash apparatus is for the purpose of observing coincidences between a chronometer and the swinging pendulum. An electromagnet in circuit with a break-circuit chronometer moves a shutter at the end of each second, thus throwing a flash of light through a narrow slit. The image of this slit is seen in an observing telescope supplied with a reticle of wires. These are so adjusted that when a pendulum is at rest the image of the slit coincides with one of the wires. When the pendulum is moving, the apparent position of the flash depends on the position of the pendulum when the reflection occurs. The period being slightly greater than half a second, the pendulum falls behind the chronometer at each swing. If s is the number of seconds between two coincidences, or the *coincidence interval*, then the pendulum executes $2s-1$ vibrations in s seconds, hence its period $= \frac{s}{2s-1}$ seconds.

THE REDUCTIONS TO STANDARD CONDITIONS.

The effects of changes of temperature and pressure were investigated at the National Physical Laboratory (Kew Observatory Department), and coefficients were deduced. The following are the corrections employed, applying to all three pendulums the mean results obtained :—

Temperature correction to reduce to 0° C.

$$-0\cdot00000464t,$$

where t is the observed temperature in degrees Centigrade.

Pressure correction $= \dfrac{-10^{-7} \times 0 \cdot 888p}{1 + 0 \cdot 00367t}$, where p is the pressure in millimetres of mercury at 0° C. and t the temperature inside the receiver.

The "pressure correction" really depends on the density, and so on the temperature as well as the pressure of the air in the receiver; that is how $\dfrac{p}{1 + 0 \cdot 00367t}$ is accounted for.

There should be an allowance made for the fact that the pressure p is due in a small degree to aqueous vapour, whose density is only $\frac{3}{5}$ of that of air under the same pressure. But to make this small allowance one requires to know the vapour pressure, and of this we had no note. At low temperatures, however, the vapour present is necessarily very small.

Rate correction $= -0 \cdot 00001157$RP, where R is the rate in seconds per day, P the period of the pendulum in seconds. The rate correction is negative if R is positive or chronometer gaining. Sidereal time was employed throughout.

The correction for finite arc of oscillation is given in various forms. That of the United States Coast and Geodetic Survey is equivalent to

$$\frac{-0 \cdot 01357\,(n+n')\,(n-n')}{\log_{10}(n/n')}\,\mathrm{P},$$

where P is the period of the pendulum.

Also

$$n = \frac{\text{semi-arc in millimetres at start}}{\text{distance between scale and plane on which pendulum swings in millimetres}},$$

$$n' = \frac{\text{semi-arc in millimetres at end}}{\text{distance as above}}.$$

The value of one scale-division on the instrument was 3 millims., the distance between scale and mirrors at Winter Quarters about 2858 millims.

No experiments were made in the Antarctic for flexure coefficient. As it is a function of the pillar, no certain allowance seems feasible. The types of pillar used were, however, sufficiently similar to make it unlikely that the neglect of a flexure correction causes any serious error.

The above formulæ assume 0° C. and 0 millim. as the standard temperature and pressure, as it is easiest to reduce to these even when the mean temperature and pressure of the experiments are widely remote from these values.

The Melbourne Observations (*November* 10, 11, 1901).

The pendulum apparatus was erected in the cellar of the Melbourne Observatory. Swings were taken with two pendulums, Nos. 37 and 39. It was found impossible to stop the leakage of air into the receiver when exhausted, and accordingly the observations were made at atmospheric pressure. The rates of the chronometer 6711 employed in the experiments were determined by direct comparison with the sidereal clock in the transit room of the Observatory. Observations with the two pendulums were also made by Mr. P. Baracchi, Government Astronomer of Victoria.

The Christchurch Observations, New Zealand.

Sets of swings were taken at Christchurch Magnetic Observatory in November, 1901, before the sailing of the "Discovery" for the Antarctic, and again on her return in May, 1904. The Observatory is in latitude 43° 31′ 50″ S., and longitude 172° 38′ 9″ E.; it is situated on a large alluvial plain (Canterbury Plain), and is 25 feet above the level of the sea.

The observations were taken in the Absolute Magnetic House, a small wood building exposed to changes of temperature; therefore the temperature during the experiments had a large range, and changed rapidly. There was no way of obviating this difficulty, no cellar being available.

Observations of November 26 and 27, 1901.

These were taken with all three pendulums, Nos. 37, 38, 39, swung at atmospheric pressure, the pressure being recorded by a mercurial barometer lent by Dr. EVANS of Canterbury College, N.Z., particulars of the errors of the instrument being supplied.

The cistern of the barometer was placed on a level with the pendulums.

A break-circuit sidereal chronometer, No. 6711, by KULLBERG, London, was used throughout, and its rate was determined by telegraphic signals from the Astronomical Observatory at Wellington, N.Z. Eleven signals were sent at intervals of 30 seconds, commencing at 9.30 p.m. on the evenings of November 25, 26, 27. The results are as follows:—

November 26, chronometer lost, in 24 hours, 0·87 second sidereal.
„ 27, „ „ „ 0·66 „ „

The arrangement of observing was as follows:—

Twelve coincidences were observed, six to the right and six to the left, then an interval of fifty coincidences was allowed to pass, and then twelve more coincidences were observed. During this process four readings of pressure, temperature, and arc were obtained. The pendulum was then left swinging for two hours, and then the same observations repeated.

All three pendulums were swung in this manner. On the following day the case was taken off, the pendulums reversed on the agate planes, and the whole process of observing repeated.

The same thermometer, No. 753 (Centigrade), was used throughout the observations in noting the temperature of the pendulums, of which the corrections were determined at the National Physical Laboratory.

Observations of May 30, 1904.

These were conducted in the same house as those of 1901, and the method of observing was the same. The pendulums, however, were not swung at atmospheric pressure, but at a considerably reduced pressure. The manometer employed was an open U-tube kindly lent by Dr. EVANS of Canterbury College.

The barometer used in connection with the manometer was No. C 895, by HICKS, London, whose corrections were known and applied.

The rates of the chronometer, No. 6711, were determined by telegraph signals from Wellington Observatory, and taken as −1·20 seconds daily.

THE ANTARCTIC OBSERVATIONS.

Winter Harbour. Latitude 77° 50′ 50″ S. Longitude 166° 44′ 45′ E.

Observations of July 31 and August 1, 1902.

The pendulum apparatus was set up in a wood hut on shore at Winter Harbour in a small room partitioned off from the rest, where the temperature was kept as uniform as possible by means of lamps.

A brick pillar firmly cemented was sunk below the surface of the frozen earth to a depth of 1 foot, and rose 3 feet above the surface. The section of the pillar was 2 feet by 2 feet.

Upon this the pendulum stand was placed, small holes being drilled into the surface of the bricks to take the legs.

The agate planes were then carefully levelled by means of the two small levelling pendulums, and the pendulums were placed in the supporting V's, No. 39 at the back, No. 37 on the right, and No. 38 on the left, the two latter being at right angles to the first. The light from the mirrors of the two pendulums at the sides is thrown into the observing telescope by means of two prisms placed near the centre.

The flash apparatus was erected on a small box filled with cement, and therefore very heavy, which, in turn, rested upon a larger box on the floor filled with heavy materials. The distance between the scale and the mirrors was 2858 millims.

Pressure.—The pressure was observed by means of a large manometer open to the atmosphere and therefore subject to the variations of atmospheric pressure.

The manometer was tightly secured to a flat board, and a long millimetre scale of wood screwed alongside the tube. It was then placed upright close to the pendulum case, and the level of the mercury in both ends of the tube was read off by means of a T-square four times during each set of fifty coincidences. A mercury station barometer placed close to the manometer was read off simultaneously.

The correction to the mercury barometer, $-0 \cdot 002$ inch throughout, was determined at the National Physical Laboratory.

The small and very delicate manometer supplied with the apparatus, and which was most carefully packed by Messrs. NEGRETTI & ZAMBRA, London, and sent out to New Zealand by mail boat, was found

Interior of Observation Hut, showing—

1. Marine barometer. 2. Observing telescope and flash apparatus.

on opening the case to be broken. The manometer employed was constructed by Engineer Commander R. W. SKELTON, R.N., the chief engineer of the "Discovery."

At Kew Observatory, in 1901, some trouble was experienced with the "air-tight" case. At Melbourne and Christchurch, in the same year, it was found quite impossible to reduce the pressure to anything like 60 millims., so that the pendulums had to be swung under atmospheric pressure. The whole weight of the extremely heavy stand and case is supported by only three comparatively slender screws, and the metal rim above the screws was "pressed up" and the contact between the rims was no longer perfect. Mr. SKELTON, by means of a surfacing plate, actually found this to be the case. He therefore re-surfaced both rims, which process considerably mitigated the evil. Indeed, it appeared at first as if we should be troubled with only a very small leakage, for when the pressure within the case was exhausted in

15 minutes to 50 millims., in the subsequent 25 minutes there was not a leakage of half a millimetre. On returning to the instrument on the following morning (July 30) it was found, however, that the leakage had amounted to 280 millims. in 11 hours 12 minutes.

Rates in the Antarctic.

The sidereal chronometer No. 6711 by Kullberg was employed and connected up with the electro-magnet, the current being supplied by two Obach dry cells.

A portable transit instrument was set up in the Absolute Magnetic House for the purpose of observing stars at the commencement and ending of the observations for determining the rate of the chronometer; but the persistent bad weather made these observations impossible, so that the only rate available for the

Interior of Observation Hut, showing—

1. Open U-tube manometer. 2. T-square for reading-off same.
3. Pendulum apparatus. 4. Brick pier. 5. Exhausting pump.

sets of pendulum observations taken on July 31 and August 1 is that obtained by comparison with the "Discovery's" marine chronometer on board.

The rate of chronometer No. 6711 in England, Australia, and New Zealand was small and uniform, and the comparisons with the "Discovery" chronometers in Winter Harbour during 1902 and 1903 indicate that its rate still remained small and uniform. Soon after the "Discovery" had reached her winter quarters this chronometer was set going in the Physicist's cabin, and compared from time to time with the marine chronometers in charge of the Navigator, Lieut. A. B. Armitage. The average temperature within the cabin was 52° F., seldom varying 5° on each side; although the temperature in the observing hut was much lower, it was kept as uniform as possible, and the temperature of the chronometer frequently noted during the observations.

Observations of February 1 *to* 6, 1903.

Observations were taken under exactly similar conditions to those taken in July and August, 1902. The pressure was about the same and the temperature fairly uniform throughout. The method of noting coincidences and the distance of the flash apparatus from the pendulums were the same as previously. The flash apparatus worked well. When completing the last pendulum swing the vacuum suddenly failed.

On taking the case off, small risings were found in the rims of the base near the supporting screws. The rim had to be re-surfaced, which process delayed the completion of the observations until February 6.

Observations of September 5 *and* 6, 1903.

The pendulum apparatus was set up in a similar manner and in exactly the same spot as in July–August, 1902, and February, 1903. The distance between the pendulums and scale was a little greater than before, viz., 2932 millims. Preparations were made to commence observing on the 4th. Observing was commenced at about 10 a.m., with everything in good adjustment and the temperature of the chamber $+1^\circ$ C., but, unfortunately, soon after starting, the mirrors and prisms under the receiver became "fogged" and covered with moisture, and observing had to be discontinued.

The thorough drying of the pendulum apparatus and readjustments occupied the rest of the day, and observing had to be postponed until the 5th.

An unsuccessful attempt was made during the evening of the 4th to take transit observations of stars for determining the rate of the chronometer. The portable instrument supplied to the Expedition was not of a very satisfactory character, the axis or pivots which rest in the V's being so worn that the telescope would not remain at any required altitude. The low temperature—nearly -40° F.—so contracted the spirit in the striding level that the ends of the bubble could not be seen, and therefore no value for level error could be determined. The cold was also extremely trying to the observer, who was compelled to give up the attempt after about two hours. The subsequent nights were overcast. The rate of the chronometer was therefore determined, as on the previous occasions, by comparison with the "Discovery's" chronometers.

Complete sets of swings were taken on the two following days, September 5 and 6, Engineer Commander Skelton rendering assistance throughout and observing independently.

Local Geology.

The Winter Quarters were situated near the end of a peninsula running out in a south-westerly direction from the base of the island formed by Mounts Erebus and Terror. The peninsula is about ten miles long by a mile broad, and has an average height of 600 to 700 feet. The rocks of which it is composed are of practically three varieties:—

1. A yellow breccia, which occurs in three well-marked heights, the nearest of which is three miles distant from Winter Quarters and 1400 feet high. This rock does not appear to be developed to any great extent, but occurs as a volcanic pipe surrounded by the basalt which forms the major part of the peninsula.

2. The trachyte found on Observation Hill, a hill three-quarters of a mile distant from the ship and 750 feet in height. This hill is conical in shape, the upper half being composed of a trachyte of specific gravity 2·2, and the lower half of a lava containing lapilli of a very varying composition and with a specific gravity of 2·87 in one case, but on the south-east side of it there is a rock of greater specific gravity.

3. A black basalt, which is by far the most important rock both as regards its development and physical properties. It forms the hill called Harbour Height and reaches from Hut Point to the base of Castle Rock, if not beyond it. It forms three-quarters of the rock of the peninsula, and rises to an average height of 700 feet between the two points mentioned above and lies roughly perpendicular to the magnetic meridian. It has a specific gravity of 2·9, and under the microscope shows frequent plates of magnetite. Hut Point is entirely formed of it, and it is on this rock that the pendulum observations were made.

Further afield, Mount Erebus rises as a full-bodied cone with its base 12 miles and its summit 20 miles distant. The rocks found at its base have a specific gravity of approximately 2·9. The mountain lies north by east of Winter Quarters, and is 12,000 feet high.

Mount Terror, lying 40 miles east of the ship, is only 10,000 feet high, and is composed of basic rocks of specific gravity 2·9, with small local intrusions of trachyte of a specific gravity of 2·4. The two are joined by a ridge some 8000 feet high and of similar rock to that which forms the masses of Erebus and Terror.

There is no important land development to the southward, there being only two islands under 3000 feet high and composed chiefly of basalt of specific gravity about 2·9. These are respectively 15 and 20 miles distant from the ship.

Mount Discovery lies south-west from the ship at a distance of 30 miles. It is also conical, with a height of 8000 feet and the diameter of the base some 10 miles. It appears to be chiefly composed of the basic rock so common in this locality.

Turning to the west there is a totally different development. A great mountain chain running nearly due north and south lies at a distance of 40 miles from the ship and rises to heights of 12,000 and 13,000 feet, and is on an average 11,000 feet high. This chain is composed of granites, diabases, and quartzites. The granites form the core of the chain and rise to a height of 4500 feet above sea-level. They vary in composition and have a specific gravity between 2·6 and 2·7.

Above this occurs a diabase up to a height of 8000 feet. This rock lies practically horizontally on the plutonic rocks (though interrupted by faults) and has a specific gravity of roughly 2·8, while above it and also horizontal a sandstone occurs which has a specific gravity not greater than 2·67. This practically completes the series of the Prince Albert Mountains.

Near Hut Point the soundings showed McMurdo Sound to be comparatively shallow. The water quickly deepened from 2 fathoms at Hut Point to 180 fathoms a mile further out in the Sound to the west, while 10 miles away to the west-north-west the sounding was 100 fathoms. The deepest sounding was 400 fathoms at a point 2 miles south-east of Observation Hill, and other soundings showed that the water was much deeper to the south and the south-east than to the north and north-west of Winter Quarters. The Sound therefore may be taken to be 25 miles wide with an average depth of 200 fathoms. The ship anchored in Winter Harbour had 9 to 11 fathoms of water, while on the north side of Hut Point the water quickly deepened to 50 fathoms close in to the land. Hut Point itself is continued half a mile to the south-west below water in a shoal which gives soundings of from 2 to 25 and 40 fathoms.

Most of the above geological information has been kindly supplied by Mr. H. T. FERRAR, Geologist to the Expedition. It may be possible from this geological information to investigate the effect of topographical irregularities and determine a correction for the density of the local rocks.

CONCLUDING REMARKS.

In the following reductions the period has been determined for each separate set of 50 coincidences, and corrected independently for temperature, pressure, &c. In the reduction of the pressure observations the temperature of the mercury in the barometer has been assumed to be the same as that of the mercury in the U-tube, since they were quite close to one another. The difference in the height of the columns was then corrected for temperature.

It must be borne in mind that the observations of July, August, and September were taken in what is practically the middle of the Antarctic winter, or, more correctly, during the coldest months of the year. The February observations are at the end of the comparatively warm summer, when the pack ice has moved far to the north, and after huge masses of ice have been shed from the glaciers and the great ice fields of the Antarctic lands, and in turn drifted away to the north.

My thanks are due to Engineer Commander R. W. SKELTON, R.N., who not only rendered most valuable services in assisting to set up the pendulum apparatus, &c., but soon made himself thoroughly competent in taking observations. Independent sets of swings were taken by him on every occasion at Winter Harbour.

Table I.—Observational Data.

Date and place.	Observer.	Pendulum.	Position.	Coincidence interval in seconds.	Corrected temperature.	Arc in millimetres. Initial.	Arc in millimetres. Final.	Corrected pressure in millimetres.	Period uncorrected in seconds.	Corrections (seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate.	Corrections. Sum of corrections.	Period corrected in seconds.
					° C.										
1902 July 31 and August 1 at Winter Quarters	Bernacchi	37	D	30 ·6010	−2 ·27	31 ·5	29 ·4	56 ·6	·5083052	− 9	+105	− 51	+47	+ 92	·5083144
			,,	·5861	−1 ·71	21 ·6	18 ·0	104 ·8	095	− 4	+ 79	− 94	+47	+ 28	123
			R	·5709	−0 ·64	21 ·0	18 ·4	55 ·3	135	− 4	+ 30	− 49	+47	+ 24	159
			,,	·5495	−1 ·05	13 ·6	11 ·7	105 ·2	195	− 2	+ 49	− 94	+47	0	195
		38	D	30 ·6126	−1 ·41	34 ·8	31 ·8	61 ·2	·5083021	−11	+ 65	− 55	+47	+ 46	·5083067
			,,	·5923	−1 ·32	22 ·5	20 ·7	107 ·7	077	− 4	+ 61	− 96	+47	+ 8	085
			R	·5983	−1 ·15	26 ·4	24 ·0	59 ·2	062	− 6	+ 53	− 53	+47	+ 41	103
			,,	·5835	−0 ·03	18 ·0	15 ·0	104 ·3	102	− 3	+ 1	− 93	+47	− 48	054
		39	D	30 ·5686	−4 ·29	19 ·8	17 ·7	50 ·1	·5083143	− 3	+199	− 45	+47	+198	·5083341
			,,	·5357	−2 ·89	12 ·9	11 ·1	100 ·1	232	− 1	+134	− 90	+47	+ 90	322
			R	·5379	−1 ·99	27 ·0	24 ·3	55 ·4	228	− 6	+ 92	− 50	+47	+ 83	311
			,,	·4981	−1 ·17	18 ·1	15 ·1	103 ·0	338	− 3	+ 54	− 92	+47	+ 6	344
	Skelton	37	D	30 ·5923	−2 ·12	30 ·7	27 ·0	64 ·3	·5083077	− 8	+ 98	− 58	+47	+ 79	·5083156
			,,	·5680	−1 ·66	18 ·9	17 ·7	112 ·6	145	− 3	+ 77	−101	+47	+ 20	165
			R	·5678	−0 ·54	19 ·2	17 ·8	62 ·3	145	− 3	+ 25	− 55	+47	+ 14	159
			,,	·5679	−1 ·14	12 ·7	11 ·8	110 ·3	154	− 1	+ 53	− 98	+47	+ 1	155
		38	D	30 ·6021	−1 ·32	33 ·3	30 ·1	65 ·8	·5083051	−10	+ 61	− 59	+47	+ 39	·5083090
			,,	·5748	−1 ·36	21 ·9	19 ·8	112 ·3	126	− 4	+ 63	−100	+47	+ 6	132
			R	·6004	−1 ·07	26 ·2	23 ·4	64 ·0	055	− 6	+ 50	− 57	+47	+ 34	089
			,,	·5646	+0 ·01	16 ·2	15 ·0	108 ·3	154	− 2	0	− 96	+47	− 51	103
		39	D	30 ·5493	−4 ·10	19 ·2	17 ·4	56 ·0	·5083196	− 3	+190	− 50	+47	+184	·5083380
			,,	·5455	−2 ·76	12 ·0	10 ·9	105 ·2	208	− 1	+128	− 94	+47	+ 80	288
			R	·5243	−1 ·88	26 ·5	22 ·8	60 ·6	265	− 6	+ 87	− 54	+47	+ 74	339
			,,	·5043	−1 ·05	16 ·8	14 ·4	108 ·2	321	− 2	+ 49	− 96	+47	− 2	319

1903 February 1 and 2	Bernacchi	37	D	30·5408	−0·36	33·3	28·2	60·0	·5083219	− 9	+ 17	− 53	+71	+ 26	·5083245
			,,	·5198	+0·32	20·8	17·1	105·1	278	− 3	− 15	− 93	+71	− 40	238
			R	·5259	+0·43	33·4	29·2	67·8	260	− 9	− 20	− 60	+71	− 18	242
			,,	·4684	+1·18	20·8	16·6	172·1	420	− 3	− 55	−153	+71	−140	280
		38	D	30·5579	+0·82	32·1	29·5	49·2	·5083172	− 9	− 38	− 44	+71	− 20	·5083152
			,,	·5173	+1·32	22·5	19·8	91·0	284	− 4	− 61	− 80	+71	− 74	210
			R	·5226	+1·24	29·7	25·9	60·2	270	− 7	− 58	− 53	+71	− 47	223
		39	D	30·5087	−1·35	34·2	30·3	67·3	·5083309	−10	+ 63	− 60	+71	+ 64	·5083373
			,,	·4810	−0·74	19·5	17·7	120·5	385	− 3	+ 34	−107	+71	− 5	380
			R	·4906	−0·52	36·9	31·8	61·0	360	−11	+ 24	− 54	+71	+ 30	390
			,,	·4630	+0·06	22·3	18·9	104·4	436	− 4	− 3	− 93	+71	− 29	407
	Skelton	37	D	30·5436	−0·26	30·9	26·7	65·8	·5083213	− 8	+ 12	− 58	+71	+ 17	·5083230
			,,	·5233	+0·37	19·2	17·4	110·8	269	− 3	− 17	− 98	+71	− 47	222
			R	·5188	+0·45	32·1	27·0	78·1	282	− 8	− 21	− 69	+71	− 27	255
			,,	·4669	+1·20	18·9	15·9	182·8	424	− 3	− 56	−162	+71	−150	274
		38	D	30·5526	+0·85	31·5	29·1	53·8	·5083186	− 9	− 39	− 48	+71	− 25	·5083161
			,,	·5288	+1·31	20·4	17·4	95·1	253	− 2	− 61	− 84	+71	− 76	177
			R	·5278	+1·29	28·2	24·3	71·2	256	− 7	− 60	− 63	+71	− 59	197
		39	D	30·5123	−1·32	33·0	29·5	70·8	·5083300	− 9	+ 61	− 63	+71	+ 60	·5083360
			,,	·4769	−0·70	20·5	18·0	124·1	397	− 4	+ 32	−110	+71	− 11	386
			R	·4904	−0·47	35·1	30·6	66·8	359	−10	+ 22	− 59	+71	+ 24	383
			,,	·4719	+0·10	21·3	18·0	109·3	411	− 4	− 5	− 97	+71	− 35	376
February 6	Bernacchi	37	R	30·5821	−3·68	37·5	33·6	60·9	·5083106	−12	+171	− 55	+71	+175	·5083281
			,,	·5616	−3·39	23·7	20·4	100·9	161	− 5	+157	− 91	+71	+132	293
		38	R	30·6424	−4·56	27·6	24·3	62·0	·5082938	− 6	+212	− 56	+71	+221	·5083159
			,,	·6156	−4·13	17·8	14·4	110·7	·5083013	− 2	+192	−100	+71	+161	174
		39	R	30·5491	−3·19	36·0	32·1	61·8	·5083196	−11	+148	− 55	+71	+153	·5083349
			,,	·5398	−2·87	21·6	18·6	98·0	221	− 4	+133	− 88	+71	+112	333
	Skelton	37	R	30·5914	−3·63	36·3	33·0	64·7	·5083078	−12	+168	− 58	+71	+169	·5083247
			,,	·5763	−3·38	23·4	20·7	104·7	121	− 5	+157	− 94	+71	+129	250

TABLE I.—Observational Data (continued).

Date and place.	Observer.	Pendulum.	Position.	Coincidence interval in seconds.	Corrected temperature.	Arc in millimetres. Initial.	Arc in millimetres. Final.	Corrected pressure in millimetres.	Period uncorrected in seconds.	Corrections (seventh decimal place). Arc.	Corrections. Temperature.	Corrections. Pressure.	Corrections. Rate.	Corrections. Sum of corrections.	Period corrected in seconds.
					° C.										
1903 February 6 (continued) at Winter Quarters	SKELTON	38	R	30 ·6338	−4 ·51	26 ·4	23 ·4	68 ·2	·5082962	− 6	+209	− 62	+ 71	+212	·5083174
			,,	·5156	−4 ·08	15 ·9	14 ·4	115 ·9	·5083040	− 2	+189	−104	+ 71	+154	194
		39	R	30 ·5419	−3 ·15	34 ·2	30 ·9	65 ·0	·5083216	−10	+146	− 58	+ 71	+149	·5083365
			,,	·5417	−2 ·91	21 ·0	18 ·6	101 ·2	218	− 4	+135	− 91	+ 71	+111	329
September 5 and 6	BERNACCHI	37	D	30 ·6130	−1 ·60	33 ·6	31 ·0	46 ·9	·5083020	−10	+ 74	− 42	+ 76	+ 98	·5083118
			,,	·5992	−1 ·70	23 ·1	20 ·5	96 ·5	059	− 5	+ 79	− 86	+ 76	+ 64	123
			R	·5566	+1 ·03	29 ·2	25 ·9	45 ·2	176	− 7	− 48	− 40	+ 76	− 19	157
			,,	·5585	+0 ·55	18 ·3	16 ·6	82 ·1	170	− 3	− 26	− 73	+ 76	− 26	144
		38	D	30 ·6420	−2 ·73	28 ·5	26 ·2	51 ·3	·5082939	− 7	+127	− 46	+ 76	+150	·5083089
			,,	·6281	−1 ·70	18 ·6	16 ·8	102 ·7	976	− 3	+ 79	− 92	+ 76	+ 60	036
			R	·5948	+0 ·91	29 ·7	27 ·4	51 ·2	·5083069	− 8	− 42	− 46	+ 76	− 20	049
			,,	·5461	+1 ·16	20 ·8	18 ·0	89 ·0	205	− 4	− 54	− 79	+ 76	− 61	144
		39	D	30 ·5801	−3 ·59	32 ·7	30 ·4	52 ·4	·5083114	−10	+167	− 47	+ 76	+186	·5083300
			,,	·5276	−2 ·45	21 ·6	19 ·3	105 ·2	256	− 4	+114	− 94	+ 76	+ 92	348
			R	·5175	+1 ·08	27 ·9	24 ·9	48 ·6	284	− 7	− 50	− 43	+ 76	− 24	260
			,,	·4973	+0 ·99	18 ·0	15 ·9	91 ·4	340	− 3	− 46	− 81	+ 76	− 54	286
	SKELTON	37	D	30 ·6056	−1 ·60	33 ·1	30 ·1	52 ·0	·5083041	−10	+ 74	− 46	+ 76	+ 94	·5083135
			,,	·5796	−1 ·73	22 ·0	19 ·9	100 ·7	117	− 4	+ 80	− 90	+ 76	+ 62	179
			R	·5715	+1 ·00	27 ·0	24 ·3	49 ·5	135	− 6	− 46	− 44	+ 76	− 20	115
			,,	·5586	+0 ·50	18 ·0	15 ·9	84 ·7	170	− 3	− 23	− 75	+ 76	− 25	145
		38	D	30 ·6583	−2 ·64	27 ·3	25 ·5	56 ·7	·5082897	− 7	+122	− 51	+ 76	+140	·5083037
			,,	·6141	−1 ·65	18 ·0	16 ·8	106 ·2	·5083017	− 3	+ 77	− 95	+ 76	+ 55	072
			R	·5858	+0 ·88	29 ·1	25 ·5	56 ·5	095	− 7	− 41	− 50	+ 76	− 22	073
			,,	·5727	+1 ·18	19 ·5	17 ·4	93 ·9	131	− 8	− 55	− 84	+ 76	− 66	065
		39	D	30 ·5796	−3 ·25	32 ·1	29 ·1	58 ·4	·5083112	− 9	+151	− 52	+ 76	+166	·5083278
			,,	·5388	−2 ·52	20 ·7	18 ·6	111 ·1	225	− 4	+117	−100	+ 76	+ 89	314
			R	·4936	+1 ·16	26 ·8	23 ·8	54 ·0	352	− 6	− 54	− 48	+ 76	− 32	320
			,,	·4951	+0 ·99	17 ·5	15 ·4	95 ·4	348	− 3	− 46	− 85	+ 76	− 58	290

1901 November 10 and 11 at Melbourne	Bernacchi	37	D	27 ·5963	+17 ·17	23 ·1	18 ·0	762 ·4	·5092264	− 4	−797	−637	+247	−1191	·5091073
			,,	·5937	+17 ·55	10 ·5	7 ·8	763 ·3	290	− 1	−814	−637	+247	−1205	085
		39	D	27 ·5042	+17 ·35	21 ·6	17 ·7	759 ·0	·5092579	− 4	−805	−634	+ 77	−1366	·5091213
			,,	·4997	+17 ·57	9 ·3	7 ·8	758 ·3	593	− 1	−815	−632	+ 77	−1371	222
1901 November 26 and 27 at Christchurch	Bernacchi	37	D	27 ·9690	+17 ·58	32 ·4	25 ·5	762 ·1	·5091012	− 8	−816	−636	+ 51	−1409	·5089603
			,,	·9812	+18 ·44	12 ·0	9 ·6	761 ·2	0972	− 1	−856	−633	+ 51	−1439	533
			R	28 ·0143	+13 ·32	30 ·3	24 ·3	756 ·1	0862	− 7	−618	−640	+ 39	−1226	636
			,,	·0020	+14 ·50	11 ·4	8 ·1	755 ·3	0902	− 1	−673	−637	+ 39	−1272	630
		38	D	28 ·0057	+15 ·30	26 ·1	20 ·1	755 ·1	·5090890	− 5	−710	−636	+ 39	−1312	·5089578
			,,	27 ·9910	+17 ·36	13 ·2	9 ·0	753 ·9	0939	− 1	−806	−629	+ 39	−1397	542
			R	·9960	+18 ·70	26 ·1	20 ·4	753 ·3	0922	− 5	−868	−626	+ 39	−1460	462
			,,	·9365	+20 ·89	9 ·0	6 ·6	751 ·8	1119	− 1	−969	−620	+ 39	−1551	568
		39	D	27 ·9325	+12 ·36	31 ·0	24 ·3	764 ·6	·5091133	− 7	−573	−650	+ 51	−1179	·5089954
			,,	·9480	+13 ·86	10 ·9	8 ·8	763 ·9	1081	− 1	−643	−646	+ 51	−1239	842
			R	·9213	+14 ·79	26 ·4	20 ·4	763 ·4	1170	− 5	−686	−643	+ 51	−1283	887
			,,	·9137	+16 ·92	10 ·2	7 ·2	762 ·5	1195	− 1	−785	−637	+ 51	−1372	823
1904 May 30 at Christchurch	Bernacchi	37	D	28 ·2530	+11 ·22	34 ·5	31 ·5	61 ·0	·5090080	−10	−521	− 52	+71	−512	·5089568
			,,	·1996	+13 ·25	21 ·0	18 ·7	129 ·2	254	− 4	−615	−109	+71	−657	597
		38	D	28 ·2442	+13 ·67	31 ·5	28 ·2	60 ·9	·5090108	− 9	−634	− 51	+71	−623	·5089485
			,,	·2388	+13 ·78	18 ·9	17 ·5	132 ·2	127	− 3	−639	−112	+71	−683	444
		39	D	28 ·2539	+ 8 ·29	32 ·4	30 ·0	61 ·7	·5090077	− 9	−385	− 53	+71	−376	·5089701
			,,	·1956	+10 ·06	20 ·7	17 ·4	126 ·4	267	− 3	−467	−108	+71	−507	760
	Skelton	37	D	28 ·2472	+11 ·45	33 ·0	29 ·7	67 ·5	·5090099	− 9	−531	− 57	+71	−526	·5089573
			,,	·2021	+13 ·32	19 ·5	16 ·8	135 ·3	246	− 3	−618	−114	+71	−664	582
		38	D	28 ·2351	+13 ·72	30 ·0	26 ·1	70 ·0	·5090139	− 8	−637	− 59	+71	−633	·5089506
			,,	·2288	+13 ·75	18 ·6	16 ·8	137 ·7	159	− 3	−638	−116	+71	−686	473
		39	D	28 ·2343	+ 8 ·46	32 ·1	27 ·6	70 ·2	·5090141	− 9	−393	− 60	+71	−391	·5089750
			,,	·1943	+10 ·37	18 ·6	15 ·9	136 ·0	271	− 3	−481	−116	+71	−529	742

II. DISCUSSION OF PENDULUM RESULTS

BY

C. CHREE, Sc.D., LL.D., F.R.S.
(FROM THE NATIONAL PHYSICAL LABORATORY).

§ 1. In drawing conclusions from the pendulum observations made during the British Antarctic Expedition of 1902–1904, due allowance must be made for the conditions under which the work was done. Those responsible for the Expedition found themselves shortly before its departure without a physical observer. At the last moment, Mr. L. C. Bernacchi consented to fill the breach, and in the very short time that remained he did all that was possible to obtain familiarity with the instruments. He had fortunately had a good deal of previous experience in observing times of vibration in connection with magnetic observations, and the observational results obtained by him and Mr. Skelton during the Expedition appear as consistent as could be expected under the conditions of observation. The apparatus had arrived at Kew some time before Mr. Bernacchi joined the Expedition, and the pendulums had been swung by Mr. E. G. Constable, senior assistant in the Observatory Department, in order to obtain their periods. Even then some difficulty was experienced in getting the cylinder containing the pendulums to remain air-tight during the observations, which were taken at a pressure of about 60 millims. of mercury. Greater difficulty was experienced during Mr. Bernacchi's introduction to the instruments, but this was attributed to the fact that meantime the apparatus had been dismounted and had been somewhat hurriedly re-erected. The defect, however, as explained in Mr. Bernacchi's introduction, proved even more troublesome in the Antarctic.

When observing, Mr. Bernacchi's usual practice was to set the pendulum swinging, and then shortly after take two sets of observations of the time answering to 50 coincidences, one set with the pendulum moving in the one direction, the other with it moving in the opposite direction. The pendulum was then left swinging unobserved for about an hour and a half, and thereafter two other similar sets of 50 coincidences were taken. The mean time of the two sets of observations differed by about two hours, and the leakage was such that in this interval the pressure inside the receiver rose on an average from about 60 millims. to 110 millims. The leakage was not conspicuously worse during any one set of experiments than during the others.

During each set of coincidences four readings were taken of the pressure, and the arithmetic mean of these was accepted as the pressure of the observation.

The "pressure correction" is, within the limits of accuracy of its determination, a linear function of the pressure, and the rate of leak would normally be nearly uniform during the time occupied by a set of coincidences. Thus the fact that the cylinder was leaky will presumably have made little if any difference in the accuracy of the mean final values; but it is probably in part accountable for the somewhat large discrepancies occasionally apparent between the results of the different sets of coincidence observations with the same pendulum on the same day.

Difficulty was also experienced in connection with the temperature. At Winter Quarters, whilst the regular diurnal inequality of temperature was small, large sudden changes were not unusual. The room in which the pendulums were swung usually varied very perceptibly in temperature during the observations, and the temperature in different parts of the room (*e.g.*, beside the pendulums and beside the barometer) sometimes differed rather largely. The change of temperature in progress during the observations was sometimes a rise, sometimes a fall. A change of 1° C. in the temperature of the pendulums means an alteration of 46×10^{-7} second in their time of swing. Thus a very little error in the temperature assigned has an appreciable effect on the period. Here, again, there was probably little, if any, effect on the mean final values, but there was unquestionably in the temperature variations an active source of irregularity between the different individual results.

§ 2. Some other sources of uncertainty remain to be mentioned. Under Antarctic conditions, with the instrumental outfit supplied, it did not prove possible to take astronomical observations of sufficient accuracy to determine chronometer rates from day to day, with the high precision desirable for pendulum observations. From time to time, at intervals varying from 8 days to 4 months, stellar and solar observations were taken by Lieutenant ARMITAGE with a theodolite, and from these he deduced the error of the chronometer "A," which served as the standard to which the others were referred. These observations were carefully made, but between the dates of two successive observations the rate of the standard A had to be assumed uniform.

During the pendulum observations, Mr. BERNACCHI compared the chronometer, Kullberg 6711, used in the pendulum observations, with A, through the intermediary of a chronometer watch; this was compared with A in the ship, and with 6711 in the observational hut. The rates accepted for 6711 thus depend on the accuracy of the comparisons with it and with A of the chronometer watch used as intermediary, on the steadiness of A, and ultimately on the accuracy of Lieutenant ARMITAGE'S observations.

To reduce the uncertainties of the comparison with the intermediary watch, Mr. BERNACCHI'S usual practice in the later observations was to compare it with 6711 after an exact 24-hour interval by the watch, taking seven successive readings of the watch at 10-second intervals, and estimating the corresponding times on 6711 to 0·1 second. Different watches were employed during the different sets of observations. That employed in September, 1903, had the steadiest rate, and the uncertainties as to the rate of 6711 were then probably least.

As to the accuracy of Lieutenant ARMITAGE'S observations, one can form an opinion only from the greater or less apparent regularity in the results. For some time after its arrival at Winter Quarters, chronometer A seems to have gained slightly. It then began to lose, and continued to do so during the remainder of the time. The losing rates deduced from Lieutenant ARMITAGE'S observations varied as follows:—

	Rate of A losing.
May 13, 1902, to August 7, 1902	0·60 seconds
August 7 " October 26 "	0·90 "
October 26 " February 4, 1903	0·75 "
February 4, 1903, to February 21 "	1·35 "
February 21 " March 1 "	1·12 "
March 1 " July 6 "	1·17 "
July 6 " October 8 "	1·12 "

The apparent irregularity in the rate about February, 1903, is suggestive of some uncertainty in the observation on February 4. The rates actually assumed as applicable to A during the pendulum observations at Winter Quarters were:—

July to August, 1902	−0·6 seconds
February, 1903	−1·1 "
September "	−1·1 "

These assumed rates are hardly likely to be affected by any large errors. At the same time it is impossible to feel absolutely certain that an error as large as 0·5 second may not have existed, especially in the result assumed for February, 1903.

The rates finally deduced for the pendulum Chronometer 6711 during the observations at Winter Quarters were:—

July to August, 1902	−0·8 seconds
February, 1903	−1·2 "
September "	−1·3 "

Chronometer 6711 when at Kew, both before and after the Expedition, possessed a very steady rate, so that the uniformity in the above results is at least in harmony with its general character.

An error in the rate accepted for 6711 of 1 second per diem means an error of approximately 59×10^{-7} second in the time of swing of the pendulums.

§ 3. A second source of uncertainty, already alluded to by Mr. BERNACCHI, is the absence of observations for determining the so-called "flexure" correction, which arises from the absence of absolute rigidity in the pendulum and its supports. Flexure experiments were made at Kew before the Expedition set sail, and after its return, but the results apply strictly only to the conditions existent at Kew. It has seemed on the whole best to apply no flexure correction to the results obtained during the Expedition, and to compare these results with those obtained at Kew, also uncorrected for "flexure." This is equivalent to the assumption that the "flexure" with the piers used at Winter Quarters, Christchurch, and Melbourne was the same in each case as that with the pier used at Kew. Judging by Mr. BERNACCHI's description and the photograph, the pier used at Winter Quarters was fairly similar to that used at Kew, so it is probable that the plan adopted will lead to but little error. The "flexure" tends to lengthen the time of swing, and so, if uncorrected or underestimated, leads to too low a value for g. Whether the method adopted is equivalent to an overestimate or an underestimate it is, of course, impossible to say. On the Kew pier, on the average of experiments with three pendulums, the flexure correction to the period was 69×10^{-7} second. The error in g corresponding to the total omission of a correction of this size is approximately 0·027 C.S.$^{-2}$, or about 1 part in 36,000. The error actually arising seems hardly likely to have exceeded a third of this, and may, of course, be absolutely nil.

§ 4. The last source of uncertainty to be mentioned is the fact that during their three years' absence on the Expedition the pendulums seem all to have altered slightly. The apparatus had really four pendulums, Nos. 36, 37, 38, 39, but with a view to possible changes in the Antarctic it was considered advisable to retain one pendulum, No. 36, at Kew. The times of swing observed at Kew in 1901 and 1904 were as follows, all the ordinary corrections—temperature, pressure, arc, and clock-rate—having been applied :—

	Flexure correction omitted.				Flexure correction applied.		
	No. 36.	No. 37.	No. 38.	No. 39.	No. 36.	No. 37.	No. 38.
1901	·5087654	·5087801	·5087745	·5088202	·5087586	·5087731	·5087675
1904	652	752	719	7925	583	683	650
Change (in 7th decimal place)	−2	−49	−26	−277	−3	−48	−25

The apparent change in No. 36 does not exceed the probable error of the observations. Thus the presumption is that during the Expedition no appreciable change took place except in the pendulums themselves. That some change actually took place in Nos. 37, 38, 39 can hardly be doubted. There is independent evidence of the fact from the observations at Christchurch, presently to be discussed. The changes in Nos. 37 and 38 are, fortunately, not large, but that in No. 39 appears much more serious. Comparatively few observations were made with this pendulum at Kew before the Expedition set sail, and it is quite possible that the change in it is overestimated, but in any case the results derived from it must be regarded as appreciably more uncertain than those derived from Nos. 37 and 38.

§ 5. Table I., p. 26, gives particulars of all the observations taken during the course of the Expedition. The reductions, involving a large amount of laborious calculation, were made by Mr. BERNACCHI. They were then done independently by Mr. E. G. CONSTABLE. The results obtained by Mr. BERNACCHI were accepted as correct unless Mr. CONSTABLE's differed by more than 1 in the seventh figure. In cases where larger differences existed I investigated the cause myself. I also revised the rates accepted for the chronometer during the observations. The usual set of observations gave four values for the period of each pendulum, two with the pendulum facing D (or direct), and two with it facing R (or reversed). But on February 6, 1903, at Winter Quarters, the R position alone was used, and at Melbourne, in 1901, the D position only was used. If one compares the results for the D and R positions in Table I., when both exist, one finds that on the average the R periods exceeded the D in pendulums 37 and 38 by 17×10^{-7} and 15×10^{-7} second respectively, whereas in No. 39 the D period exceeded the R by 9×10^{-7}. Individual differences, however, fluctuate largely, and corresponding results, based on a greater number of observations at Kew, make the difference much less for No. 37, and both numerically less and of opposite sign for No. 38. It has thus been decided to neglect any difference that may possibly have existed between the D and R positions in dealing with the observations at Melbourne, and those on February 6 at Winter Quarters.

Tables II., III., and IV. summarise the results of Table I.

TABLE II.—Results at Winter Quarters.

Date.	Observer.	Periods of Pendulums.		
		37.	38.	39.
1902 July 31, August 1	BERNACCHI SKELTON	·5083155 159	·5083077 103	·5083330 332
	Means . . .	·5083157	·5083090	·5083331
1903 February 1, 2	BERNACCHI SKELTON	·5083251 245	·5083202 183	·5083388 376
	Means . . .	·5083248	·5083192	·5083382
1903 February 6	BERNACCHI SKELTON	·5083287 249	·5083167 184	·5083341 347
	Means . . .	·5083268	·5083176	·5083344
1903 September 5, 6	BERNACCHI SKELTON	·5083135 143	·5083080 062	·5083299 301
	Means . . .	·5083139	·5083071	·5083300

TABLE III.—Results at Winter Quarters.

Date.	Periods of pendulums.		
	37.	38.	39.
July 31, August 1, 1902	·5083157	·5083090	·5083331
February 1, 2, 1903	248	192	382
„ 6 „	268	176	344
September 5, 6 „	139	071	301
Means, allowing half weight to observations on February 6, 1903 .	·5083194	·5083126	·5083339
„ from July 31, August 1, 1902, and September 5, 6, 1903 .	·5083148	·5083080	·5083316
„ „ February 1, 2, 6, 1903	·5083255	·5083187	·5083369

TABLE IV.—Results at Melbourne and Christchurch.

Place and date.	Periods of pendulums.		
	37.	38.	39.
Melbourne, November 10, 11, 1901	·5091079	—	·5091218
Christchurch, November 26, 27, 1901	·5089600	·5089538	·5089876
" May 30, 1904	580	477	738
	·5089590	·5089508	·5089807

§ 6. The periods observed at Kew in 1901 and 1904 have been already given. Their mean values, uncorrected for flexure, are

Pendulum	37	38	39
Period	0·5087776	0·5087732	0·5088064

It has been judged best to employ these mean Kew values for comparison with the results obtained at Winter Quarters and Christchurch, but to employ only the 1901 results for comparison with Melbourne.

The observations made at Christchurch in 1904 gave lower values than those obtained in 1901, the differences in the seventh place of decimals being −20 for No. 37, −61 for No. 38, and −138 for No. 39. The differences for Nos. 37 and 38 give a mean which is closely similar to the corresponding mean difference observed at Kew, thus suggesting that any change that took place in these two pendulums occurred at Winter Quarters, and so influenced the Kew and Christchurch observations alike, leaving the Melbourne observations unaffected. The comparative brevity of the interval between the observations made at Kew and Melbourne in 1901 is an argument pointing in the same direction.

§ 7. If t_1 and t_2 denote the periods of a pendulum at two places where g_1 and g_2 are the values of gravity, then, assuming the pendulums unchanged, and the conditions as to temperature, pressure, &c., the same at the two places, we have

$$g_1 t_1^2 = g_2 t_2^2,$$

or

$$g_2 = g_1 (t_1/t_2)^2.$$

Accepting 981·200 (centimetre/second²) as the value at Kew,* the values deduced by the above formula for Melbourne, Christchurch, and Winter Quarters are those given in Table V. under the heading "Observed values." In the probable mean the results from pendulum No. 39 have been allowed only half weight as compared to those from either 37 or 38.

TABLE V.

Place and date.	Observed values.				Theoretical sea-level value.
	37.	38.	39.	Probable mean.	
Melbourne	979·936	—	980·037	979·970	979·954
Christchurch	980·501	980·515	980·528	980·512	980·463
Winter Quarters:—					
July, August, 1902, and September, 1903.	982·987	982·997	983·034	983·000	—
February, 1903	982·946	982·955	983·013	982·963	—
All observations combined	982·970	982·979	983·025	982·985	982·963

* 'Roy. Soc. Proc.,' A, vol. 78, 1906, p. 245.

§ 8. As to the values to be expected by theory at these stations, the formula which at present has most claims to acceptance is that of VON HELMERT, viz. :—

$$g = 978 \cdot 000 \, (1 + 0 \cdot 00531 \sin^2 \phi) \left\{ 1 - \frac{2h}{R} + \frac{3h}{2R} \frac{\delta}{\Delta} - \frac{3h'}{2R} \frac{\delta - \theta}{\Delta} + y \right\} \quad . \quad . \quad . \quad . \quad (1),$$

where

ϕ is the latitude (north or south),
h the height above mean sea level,
h' ,, thickness of surface strata of low density,
R ,, Earth's mean radius,
Δ ,, ,, ,, density (5·6),
δ ,, ,, ,, surface density (assumed 2·8),
θ ,, actual density of surface strata at the place,
y an orographic correction, arising from mountain masses, &c.

It is possible that at Winter Quarters, Mt. Erebus, Mt. Terror, Mt. Discovery, and other mountain masses, and the proximity of McMurdo Sound with a considerable depth of water, might severally contribute sensibly to the y term in (1), but without much more complete information than exists, no value derived from this could make any claims to accuracy.

The observed rock densities at Winter Quarters would seem to indicate that the mean surface density did not differ much from 2·8.

At sea level, at a station where the surface strata have a density of 2·8, and there are no causes (such as high mountains or deep seas) in the neighbourhood for an orographic correction,

$$g = 978 \cdot 000 \, (1 + \cdot 00531 \sin^2 \phi),$$

or, more conveniently,

$$g = 978 \cdot 000 + 5 \cdot 193 \sin^2 \phi$$

$$= 980 \cdot 5966 - 2 \cdot 5966 \cos 2\phi \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

The values of g calculated from (2) for the latitudes of Melbourne (37° 49′ 53″), Christchurch (43° 31′ 50″), and Winter Harbour (77° 50′ 50″), are given in Table V. under the heading "Theoretical sea-level values." The values under this heading, it should be noticed, are not the exact theoretical equivalents of these observed values given in the table, because the latter have not been reduced to sea level. The reduction to sea level is at best only an approximation, and different views may be entertained regarding its application. If we suppose with VON HELMERT

$$\delta = 2 \cdot 8 = \Delta/2 \text{ in } (1),$$

we have

$$- \frac{2h}{R} + \frac{3h}{2R} \frac{\delta}{\Delta} = -5h/4R.$$

The corrections to the observed values answering to this would be

At Christchurch, 25 feet above sea level, +0·001 ;
,, Winter Quarters, 30 ,, ,, ,, +0·002.

The height of the station at Melbourne, in the cellars of the Observatory, was not exactly ascertained, but was about 75 feet, so the correction required there would be about +0·005.

These corrections are very trifling, considering the various sources of uncertainty.

§ 9. It will be noticed that the probable mean observed values are all slightly in excess of the theoretical, especially at Christchurch. This same phenomenon, it may be mentioned, appears, and to a greater extent, in the results obtained by Austrian observers in Australasia, using half-second pendulums.

According to the publications of the Pola Observatory,* the excesses in the observed over the theoretical values were as follows:—

g observed − *g* calculated (by von Helmert's formula).

Auckland	+0·111
Brisbane	+0·067
Hobart	+0·064
Melbourne	+0·062
Sydney	+0·097

The Austrian observations at Melbourne and Sydney were carried out in 1893 and 1897. Observations were also made at these two stations by Mr. P. Baracchi and Mr. E. F. J. Love in 1893–4, using Kater's pendulums. Mr. Love† gives only the times of swing, not the absolute values of *g*, but the differences in the times of swing observed at Sydney and Melbourne accord fairly well with the difference between these two stations deduced by the Austrian observers. Though he does not give absolute values of *g*, Mr. Love gives the time of swing of the Kater pendulums at Greenwich; from these one would deduce for Melbourne a lower value of *g* than that obtained by the Austrian observers, or by Mr. Bernacchi.

§ 10. An outstanding feature is the very considerable difference between the results obtained at Winter Quarters in July–August, 1902, and September, 1903, on the one hand, and those obtained in February, 1903, on the other. The most natural direction in which to seek an explanation of such a discrepancy is in error either in the observations themselves or in their reduction. The data have been so carefully checked that the possibility of observational error in the readings, or of arithmetic error in the reductions, may, I think, be dismissed. The mean values of the pressure and temperature during the series of observations at Winter Quarters were as follows:—

	Pressure (in millims.).		Temperature, ° C.	
July–August, 1902	83·2	78·6	−1·6	−1·1
September, 1903	74·0		−0·6	
February, 1903		87·1		−1·0

The differences in the mean pressure and temperature are so small that no conceivable error in the values accepted for the pressure and temperature coefficients could supply an adequate explanation. The same pillar was used throughout, so difference in the "flexure" is an impossible explanation unless the condition of the pillar in February predisposed to "flexure" immensely more than in July, August, or September. Such a difference would have appeared less improbable if the February mean temperature (in the hut) had been much higher than on the two other occasions, instead of occupying, as it did, an intermediate position. If the cause is observational, its most probable source would seem to be error in the rates deduced for the chronometer.

Mr. Bernacchi refers to this point in his introduction, and mentions as a possible explanation the large northward movement of ice occurring in the Antarctic summer prior to February. Exactly how the Earth behaves under the removal of a load, and what compensations may come into play under the conditions existent in the Antarctic, are matters about which we know too little at present to draw conclusions of value. At present, I am afraid, remembering the sources of uncertainty, the only prudent course is to reserve judgment. The point is one, however, to which the attention of future observers may well be directed.

* 'Veröffentlichungen des Hydrographischen Amtes der k. u. k. Kriegs-Marine in Pola,' Gruppe III.—Relative Schwere-bestimmungen, Heft III., Pola, 1902.

† 'Roy. Soc. Victoria Proc.,' March, 1894.

III. EARTHQUAKES

AND

OTHER EARTH MOVEMENTS RECORDED

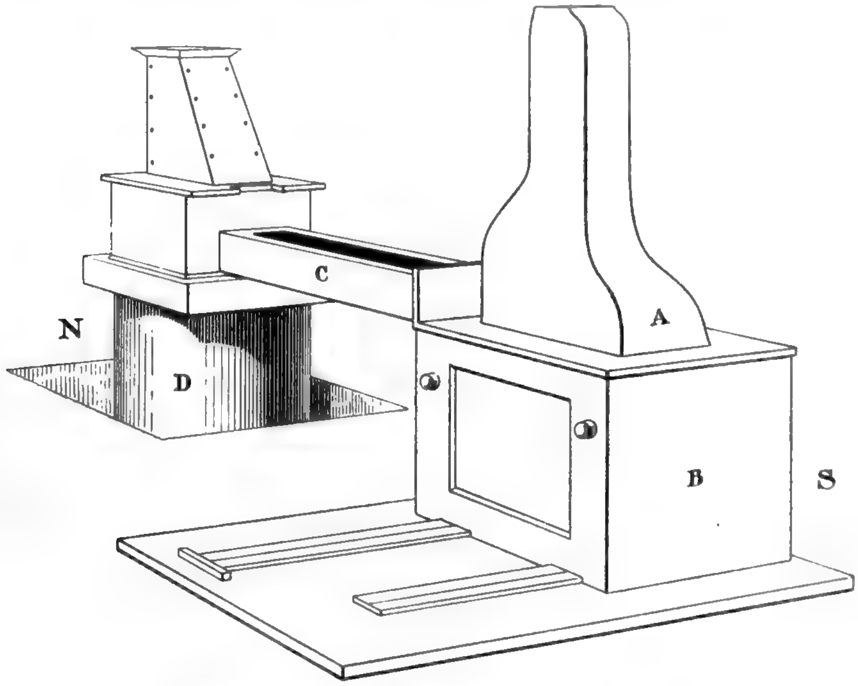
IN THE

ANTARCTIC REGIONS, 1902-1903

CONTENTS.

INTRODUCTORY NOTES TO SEISMIC OBSERVATIONS.

THE Milne seismograph supplied to the Expedition was erected at Winter Harbour in the Magnetic Variation House during March, 1902. This instrument (No. 37) was made by R. W. MUNRO, London, of non-magnetic materials. The drain-pipe upon which the bed-plate was tightly fixed was 1 foot 6 inches in diameter, and was sunk through a thin layer of ice until it rested upon a solid bed of frozen earth and stones. The height of the pipe above the ground was 19½ inches (see figure).



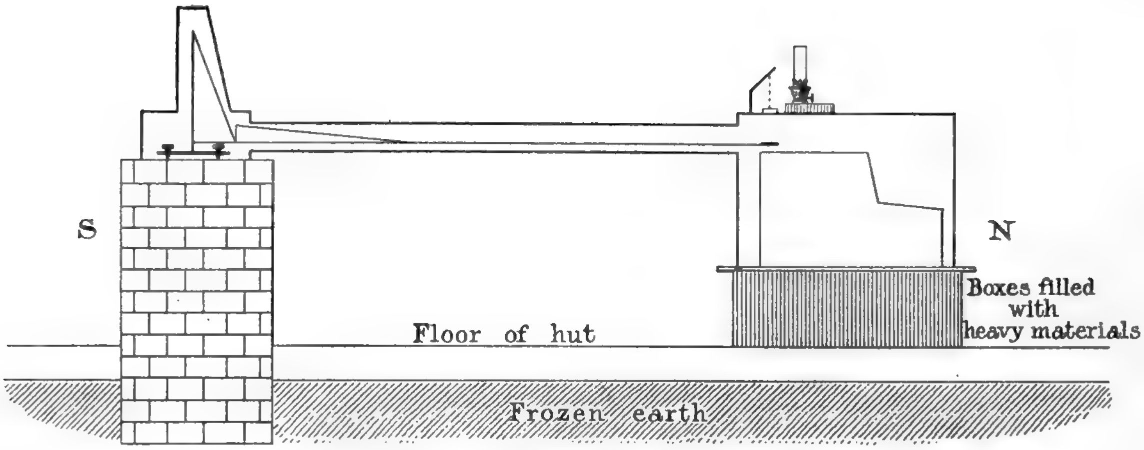
Seismograph No. 37—March to November, 1902.

A. Red lamp-shade.
B. Recording apparatus.
C. Boom case.
D. Drain pipe.

When the column had been made rigid, with bed-plate attached, the instrument was set up in the geographical meridian, the aluminium boom being N.—S., and the balance weight and attachment of tie at the regulation distance from the pivot, viz. 7 millims. and 125 millims. respectively. By means of the pivot and front levelling screw the boom was given a period of exactly 15 seconds. When deflected 8 or 9 millims. from its normal position, it took about 8 minutes before returning to rest. The instrument was kept going in this position from March 14 to November 9, 1902, when it was dismounted, removed to the large store hut, and erected on a masonry pillar (brick) of following dimensions :—

Depth sunk in ground . . .	12 inches.
Height above ground	3 feet.
Breadth	2 feet by 2 feet.

(See figure.)



Seismograph No. 37—November, 1902, to December, 1903.

The instrument was so placed that the boom pointed S.—N. true, thus in an opposite direction to its former position. The period of the boom was made exactly 15 seconds.

From January 29 until March 18, 1903, the seismograph was dismounted, the brick pillar being then employed for pendulum work, and was finally dismounted in December, 1903.

L. C. BERNACCHI.

Amongst the various records brought home by the ss. "Discovery" from the Antarctic Regions, a long series refer to the movements of a horizontal pendulum. This instrument, which is similar to a type adopted by the British Association and established at 38 widely separated stations in various parts of the world, was in charge of Mr. LOUIS BERNACCHI.

When we read Mr. BERNACCHI'S log we recognise the exceptional difficulties, meteorological and otherwise, under which he worked. This and the fact that a hurried departure only admitted of a few hours' instruction in the practical working of the instrument he had to use, entitle him to the sincerest congratulations on the results he has brought home.

The huts, to which Mr. BERNACCHI refers, were 30 to 50 feet above sea-level at a place in longitude 166° 44′ 45″ E. and latitude 77° 50′ 50″ S., about 15 miles distant from Mounts Erebus and Terror. The former of these volcanoes was always active.

The records obtained refer to Changes in the Vertical, Tremors, Pulsations, and Earthquakes. In many instances these records, when taken by themselves, have little value, but when analysed in conjunction with registers obtained by similar and similarly installed apparatus at very distant stations they throw light upon hitherto unsuspected phenomena which take place within and on the surface of our world.

In the following pages I give a register of the earthquakes recorded by the "Discovery." To this is appended a list of very large earthquakes which were not recorded by the "Discovery" seismograph, although at the time of their occurrence this instrument appears to have been in working order. Finally, I give a certain number of conclusions arrived at from an analysis of these various observations. The greater number of these are to be found in a paper on "Preliminary Notes on Observations made with a Horizontal Pendulum in the Antarctic Regions," see 'Proceedings of Royal Society,' Series A, vol. 76, May 29, 1905.

J. MILNE.

I. EARTHQUAKES RECORDED IN THE ANTARCTIC REGIONS.

77° 50′ 50″ S. Lat., 166° 44′ 45″ E. Long.

1902–1903.

D = The distance of a station from an origin.
C and *M* give in minutes the time taken by phases C and M to travel from an origin to a given station.

The time used in the following registers is Greenwich Mean *Civil* Time : Midday = 12 hours, Midnight = 24 or 0 hours.

C = Commencement. M = Maximum. D = Duration. A = Amplitude, or half of a complete swing.

P_1 refers to the commencement of the first phase.
P_2 refers to the commencement of the second phase.
P_3 refers to the maximum motion.

Towns printed in italics refer to instruments not of the Milne type.

1. *March* 14, 1902.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	21 36·6	—	0 25	0·5	
Bidston	22 10·0	22 50	—	—	Line tremulous.
Hamburg	21 55·8	—	1 0	—	

The difference in time between the "Discovery" records and M for Bidston suggests an origin to the S.W. of New Zealand.

The Bidston records probably respectively refer to P_2 and P_3, while that for Hamburg refers to P_1.

We apparently have here the first illustration of an earthquake being only recorded at its antipodes and not at intermediate stations.

2. *March* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	5 10·7	—	0 13	0·3	} A thickening.
Bidston	4 15·1	4 18·7	0 10	—	
Edinburgh	4 14·5	4 24·0	0 19	0·2	
Toronto	3 42·0	3 47·5	0 36	1·5	
Baltimore	3 41·0	3 46·0	1 5	2·3	
Victoria, B.C.	3 58·2	4 6·3	0 43	0·7	
San Fernando	3 59·9	4 15·6	0 45	1·5	
Christchurch	4 25·7	4 28·3	—	0·1	
Hamburg	3 54·0	—	1 0	—	
Nicolaiew	4 14·0	4 17·0	0 38	—	
Taschkent	4 18·4	—	—	—	
Tiflis	4 6·3	4 2·7	—	—	
Dorpat	4 4·0	—	0 28	—	

The identification of the hour marks on the "Discovery" film is uncertain. If, however, we take the first reading as 4h. 10·7m. the record is fairly in accord with those which follow and refers to a disturbance originating in or near to Central America. The area disturbed is similar to that given for No. 72.

3. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	5 42·1	5 47·2	0 13	0·5	A lenticular thickening.
Christchurch	5 46·8	5 47·4	0 22	0·6	
Wellington	5 48·7	5 51·0	—	1·0	

A possible approximate origin lies near to 150° E. Long., 50° S. Lat.

4. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	6 30·9	6 31·9	0 10	5·0	
Batavia	6 10·3	6 16·0	0 19	1·0	
Kodaikanal	6 16·3	—	0 20	—	
Irkutsk	6 6·0	6 35·7	0 38	0·1	
Tiflis	6 4·8	6 25·1	—	—	
Nicolaiew	—	7 19·0	—	—	
Dorpat	6 49·0	—	—	—	
Manila	6 3·1	6 5·7	0 15	—	

Slight tremors were felt at Zamboanga in Mindanao.

The "Discovery" record suggests an origin not more than 5° distant. The entries for Manila, Batavia, and Irkutsk, however, suggest a distinct disturbance of very large extent which originated in the Southern Philippines at about 6h. 0m. If this is the case, the second phase of motion, or P_2, would reach the Antarctic regions at 6h. 26m., or about the time the "Discovery" shock originated. Apparently, therefore, we may have a case of two shocks related to each other as a primary and a secondary.

5. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	9 37·0	—	0 10	0·5	A thickening.

As entries corresponding to this do not appear in the registers from Christchurch, Wellington, Batavia, and comparatively near stations, one inference is that the origin was local.

6. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m	h. m.	millims.	
"Discovery"	9 58 ·3	10 6 ·3	0 20	0 ·6	
Christchurch	9 42 ·0	10 3 ·0	0 55	1 ·0	
Wellington	9 48 ·7	10 3 ·0	0 24	1 ·5	
Batavia	9 29 ·4	9 40 ·2	0 55	5 ·2	
Bombay	9 34 ·5	10 3 ·3	0 40	0 ·5	
Kodaikanal	9 40 ·5	9 59 ·5	0 40	0 ·5	
Irkutsk	9 46 ·9	10 3 ·4	0 38	0 ·3	
Manila	9 28 ·1	9 32 ·4	0 8	—	

It was also recorded at Nicolaiew, Tiflis, and Hamburg. At Ternati and Halmaheira (Celebes), shocks were felt at 8.35 and 8.46 (see 'Natuurkundig Tijdschrift v. Ned.-Indië,' lxiii., p. 194). M – C for Batavia and Manila indicate an origin about 132° E. Long. and 3° N. Lat. A similar origin is obtained from the differences in the value of M, given for these stations. The time of the origin deduced from the observations made at these two places would be 9.23 or 9.22.

With an origin at 9.22 the times at which we should expect P_1, P_2, and P_3 to reach New Zealand and the "Discovery" would be as follows:—

New Zealand . . . . P_1 9.32, P_2 9.41, P_3 9.57.
"Discovery" . . . . P_1 9.36, P_2 9.47, P_3 10.15.

The inference is that P_2 and P_3 were recorded in New Zealand and P_3 only by the "Discovery."

7. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	14 47 ·1	15 26 ·8	2 50	2 ·0	
Wellington	14 34 ·0	15 19 ·0	1 9	4 ·0	
Christchurch	14 53 ·8	15 23 ·3	0 45	4 ·2	
Batavia	14 49 ·1	14 59 ·5	3 0	5 ·40	
Bombay	14 54 ·7	?	1 26	?	
Kodaikanal	14 53 ·4	15 20 ·0	3 0	1 ·5	
Cape Town	14 53 ·8	15 40 ·4	2 58	0 ·01	
Shide	14 23 ·8	15 20 ·7	2 20	1 ·2	
Kew	15 3 ·2	15 58 ·8	1 34	0 ·7	
Bidston	15 2 ·5	15 50 ·2	1 7	0 ·6	
Edinburgh	15 4 ·0	15 16 ·5	2 9	0 ·6	
San Fernando	15 3 ·5	16 7 ·0	4 34	2 ·5	
Toronto	15 7 ·0	16 12 ·5	1 53	0 ·4	
Baltimore	15 6 ·5	—	2 17	0 ·5	
Irkutsk	14 53 ·8	15 18 ·8	3 8	2 ·7	
Cordova	15 3 ·6	21 8 ·0	—	0 ·5	
Victoria, B.C.	15 3 ·5	16 7 ·0	4 36	2 ·5	
Mauritius	14 55 ·1	15 4 ·2	2 47	1 ·0	
Hamburg	14 58 ·9	15 4 ·1	4 30	—	
Tiflis	14 57 ·0	15 7 ·9	—	—	
Dorpat	14 59 ·0	—	—	—	
Nicolaiew	—	15 25 ·0	—	—	
Manila	14 47 ·9	14 53 ·7	1 4	—	

This shock, which was one of a series, was felt strongly in the Celebes. The time given for a heavy shock at Ternate is 14h. 45m.

M – C for Manila, Batavia, and Irkutsk indicates an origin about 132° E. Long. and 3° N. Lat. To reach Ternate, 3° distant, would take 2·5m. The time at the origin would therefore be 14h. 42·5m. This time calculated from the Manila maximum is 14h. 42m., and from the Batavia maximum 14h. 41m. The time adopted is 14h. 42m. The region disturbed embraces the whole world. The following table gives the distance, *D*, of various stations from the origin and the number of minutes occupied by *C* and *M* to travel from the origin to the station. The average velocity *D*/*C* may refer to P_1 or P_2, while *D*/*M* refers to P_3.

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Manila	18	6	11	3·0	—	1·6
Batavia	26	7	17	—	—	1·5
Wellington	51	—	37	—	—	1·4
Christchurch	52	11	41	4·7	—	1·2
Irkutsk	52	11	36	4·7	—	1·4
Kodaikanal	52	11	38	4·7	—	1·3
Bombay	60	12	—	5·0	—	—
Mauritius	72	13	22	5·5	3·2	—
"Discovery"	82	5	44	16·4	—	1·8
Tiflis	86	15	26	5·7	3·3	—
Nicolaiew	95	—	43	—	—	2·2
Dorpat	97	17	—	5·7	—	—
Victoria, B.C.	97	21	85	4·6	—	1·1
Hamburg	108	17	22	6·3	4·9	—
Cape Town	108	12	58	9·0	—	1·8
Kew	111	21	76	5·3	—	1·4
Edinburgh	111	22	34	5·0	3·2	—
Shide	112	—	38	—	2·9	—
Bidston	112	20	68	5·6	—	1·6
San Fernando	125	21	85	5·9	—	1·4
Toronto	130	25	30	5·2	4·3	—
Baltimore	131	24	—	5·4	—	—
Cordova	150	21	—	7·1	—	—

The times at which P_1, P_2, and P_3 would be expected to reach New Zealand and the "Discovery" would be as follows:—

New Zealand . . . . . P_1 14.51, P_2 15.0, P_3 15.17.
"Discovery" . . . . . P_1 14.56, P_2 15.7, P_3 15.35.

From this it appears that with a disturbance of greater intensity than No. 6, P_1 was recognisable at Christchurch.

8. *March* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	17 57·3	18 3·4	0 30	1·5	
Batavia	17 40·7	18 2·4	—	1·4	

In all probability the first entry refers to a shock which had an Antarctic origin. The relations between the times of these two disturbances as recorded in Batavia and by the "Discovery" are somewhat similar to those for No. 4, and one may be the secondary of the other.

9. *April* 1.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	9 19·2	—	0 8	0·3	

At Christchurch a very slight disturbance was noted at 9 12·7. The inference is that the shock after reaching Christchurch had about 9° to travel before reaching the "Discovery." A possible origin would be about 10° S.W. of New Zealand.

10. *April 7.*

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	2 41 ·2	—	0 8	0 ·5	

At Christchurch a slight earthquake was noted at 2.31, with a maximum at 2.34. The interval of time between the records at the two places suggests an origin like that for No. 9, namely on the line of the submerged New Zealand ridge.

11. *April 7.*

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	6 0	{ 6 5 ·1 6 17 ·3 6 26 ·5 }	0 26	1 ·0	The character is that of a bead-shaped group of waves followed by two thickenings.
Christchurch	5 39 ·0	5 52 ·2	1 4	1 ·0	
Perth	5 31 ·8	5 41 ·9	1 0	3 ·1	
Batavia	5 25 ·7	5 45 ·0	0 40	0 ·7	
Taschkent	5 39 ·9	6 5 ·4	—	—	
Dorpat	5 51 ·3	6 10 ·0	—	—	

Origin very uncertain, possibly S. Indian Ocean, or district G.

12. *April 9.*

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	8 24 ·9	—	0 21	0 ·2	Small serrations.
Christchurch	8 8 ·7	—	—	0 ·9	
Bidston	8 15 ·0	—	—	—	Doubtful.
Strassburg	8 10 ·0	—	—	—	
Tiflis	8 13 ·1	—	—	—	
Taschkent	8 57 ·2	9 3 ·2	—	—	
Dorpat	9 2 ·2	8 59 ·0	—	—	

Origin doubtful. Probably S. of New Zealand.

13. April 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	14 59 ·5	—	0 16	0 ·2	Small serrations.
Christchurch	14 43 ·7	14 51 ·0	—	0 ·2	
Irkutsk	14 37 ·6	—	0 29	—	
Strassburg	14 27 ·0	—	1 50	—	
Taschkent	14 29 ·1	14 52 ·2	—	—	
Dorpat	14 57 ·0	16 15 ·0	—	—	

Origin doubtful. District K ?

April 11 to 15, film lost.

14. *April* 17.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	0 23	—	0 10	0·5	

Origin local.

15. *April* 17.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	16 27·2	—	0 13	0·5	Small serrations.
Christchurch	17 22·0	17 24	0 8	0·1	

Origin local.

16. *April* 20.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	21 34·9	21 45·2	1 10	2·0	
Christchurch	21 42·0	21 45·0	—	1·3	(See facsimile of trace, Plate 4.)
Wellington	21 44·5	—	0 7	—	
Perth	21 49·0	—	0 46	0·2	

By the method of circles an origin is arrived at in 160° E. Long. and 65° S. Lat.

17. *April* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	17 34·4	17 54·7	1 28	1·0	Duration of P_1=4m., P_2=10m.
Christchurch	—	18 0·2	—	1·0	
Perth	17 38·6	17 50·0	1 38	2·2	
Batavia	18 37·3	18 46·7	1 20	1·6	
Kodaikanal	17 40·2	17 57·4	1 30	1·0	
Bombay	17 44·7	18 3·0	1 6	1·7	
Irkutsk	18 52·1	18 28·1	1 23	0·7	
Bidston.	18 37·3	18 48·2	0 24	0·3	
Edinburgh	18 44·5	18 57·0	0 18	0·2	
Strassburg	17 45·3	—	—	—	(See facsimile of trace, Plate 4.)
Mauritius	17 37·0	17 39·0	—	—	
Cape Town	17 42·2	17 50·5	0 16	0·3	
Calcutta	17 55·1	—	1 24	—	
Nicolaiew	17 53·0	18 23·0	—	—	
Taschkent	17 49·3	18 14·8	—	—	
Tiflis	17 39·3	18 0·8	—	—	
Dorpat	17 55·0	18 17·5	—	—	

From the values C – M, and from those of M, an origin is indicated in district G, possibly in 70° E. Long. and 40° S. Lat. The area disturbed is a hemisphere embracing Europe, Asia, Africa, and Australia.

18. *April* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	11 23·1	11 46·5	0 43	0·2	Serrations.
Christchurch	11 44·0	12 0·5	0 32	0·1	
Taschkent	12 19·8	12 37·3	—	—	

The last record probably refers to P_3. Origin S. of New Zealand.

19. *April* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	23 44·5	—	—	—	A slight thickening.
Cordova	22 52·9	22 54·9	1 3	17·0	
Bidston	23 38·4	23 50·0	0 27	0·3	
Victoria, B.C.	23 46·0	—	0 7	0·2	
Mauritius	23 53·0	—	—	—	
Strassburg	23 15·0	—	—	—	
Irkutsk	24 25·1	—	—	—	
Taschkent	23 26·6	24 26·3	—	—	

The disturbance probably originated in district D off the W. coast of South America at 22h. 50m. The large waves would reach the Antipodean region at the times specified for the last two stations, respectively 150° and 180° distant.

20. *April* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery" . . . . {	3 9·6	—	0 5	0·2	} Slight ripples.
	5 43·2	—	0 5	0·2	
	13 48·3	—	0 5	0·2	
Taschkent	13 26·8	—	0 20	—	

Origin local.

21. *April* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	18 48·3	—	0 6	0·2	Slight ripples.
Christchurch	18 15·2	—	—	0·4	

Origin near New Zealand.

22. *April* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	19 5·6	—	0 6	0·2	

23. *April* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	3 30·0	—	0 6	0·2	
Kodaikanal	3 46·6	—	—	—	Earthquake?

24. *May* 1.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	17 57·0	—	0 30	1·5	Earthquake?

25. *May* 2.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery" . . .	11 49·0 and 12 10·0	12 35·0 and 13 4·0	—	—	Slight tremors.
Christchurch	11 55·0	12 17·0 and 12 31·0	1 6	0·2	
Bombay	11 51·7	12 10·9	0 47	0·4	
Calcutta	11 46·3	12 6·6	0 57	1·2	
Edinburgh	11 52·0	12 31·5	1 5	0·3	
Bidston	11 52·3	12 32·2	0 36	0·5	
Tokyo	11 32·0	11 33·4	1 50	16·0	
Manila	11 4·4	11 5·6	0 1	—	2 out of a series of 10 recorded on May 2.
	11 37·2	11 38·6	0 24	—	
Shide	11 55·1	12 31·9	1 5	0·2	
Kew	11 58·5	12 32·0	0 26	0·7	
Baltimore	12 27·6	12 39·4	0 39	0·4	
Irkutsk	11 36·6	11 49·2	1 39	2·4	
Nicolaiew	11 45·0	12 12·0	0 49	—	
Taschkent	11 40·2	11 54·9	0 14	—	
Tiflis	11 42·8	12 19·9	—	—	
Dorpat	11 51·7	12 18·9	0 45	—	
Hamburg	11 42·7	12 22·5	—	—	
Strassburg	11 43·1	—	1 40	—	

This earthquake originated off the N.E. coast of Japan, in about 144° E. Long. and 40° N. Lat. The time of origin would approximately be 4 minutes before the arrival of M at Tokyo, or at 11h. 29·4m.

The following table gives the velocity for C which may refer to P_1 or P_2, and M, which refers to P_3 in the form $\frac{\text{degrees}}{\text{minutes}}$:—

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Irkutsk	29	7·0	19·8	4·14	—	1·46
Calcutta	50	16·9	32·7	—	3·12	1·34
Bombay	62	22·3	41·5	—	2·82	1·49
Tiflis	70	13·0	50·5	5·38	—	1·38
Hamburg	79	13·3	53·1	5·9	—	1·48
Edinburgh	80	22·6	62·0	—	3·54	1·29
Bidston	81	22·9	62·8	—	3·53	1·29
Christchurch . . .	82	25·6	62·6	—	3·20	1·31
Strassburg	83	13·0	—	6·4	—	—
Shide	84	25·7	62·5	—	3·26	1·34
Baltimore	91	—	70·0	—	—	1·30
"Discovery" . . .	116	19·0	94·0	6·10	—	1·23

It will be observed that the entries for C chiefly refer to P_2, which, with the exception of a slight increase in the equatorial regions, has a constant arcual velocity. For P_1 there are five entries. If we express these velocities in kms. per second in the form $\frac{\text{chord}}{\text{time}}$, they become 7·5, 9·3, 10·1, 10·8, and 9·3.

The value for P_3 as an arcual velocity is fairly constant, with a possible slight rise in value 62° to 70° distant from the origin (see Time Curve No. 25, Plate 1).

26. *May* 2.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	13 50 ·0	14 14 ·0	14 37 and 14 46	—	Slight tremors.
Calcutta	13 44 ·3	14 28 ·0	0 36	0 ·7	Earthquake ?
Manila	13 51 ·2	13 52 ·1	0 1	—	

27. *May* 7.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	6 34 ·5	—	0 10	0 ·2	Slight ripples.
Christchurch	6 16 ·0	—	—	0 ·1	

Origin near New Zealand.

28. *May* 7.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	10 26 ·3	—	0 3	0 ·2	

Origin local.

29. *May* 8.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	2 13 ·4	—	0 6	0 ·5	Bead-like line.
Christchurch	2 55 ?	3 12 ·0	0 45	0 ·2	
Wellington	2 57 ·7	—	0 14	0 ·7	
Batavia	2 33 ·7	2 34 ·0	0 15	0 ·8	
Irkutsk	2 25 ·5	2 38 ·7	0 51	1 ·5	
Tokyo	2 20 ·9	2 24 ·6	1 10	4 ·0	
Shide	2 49 ·5	3 21 ·8	1 12	1 ·7	
Kew	3 8 ·5	3 18 ·2	0 32	0 ·6	
Bidston	3 0 ·4	3 21 ·6	0 44	0 ·8	
Edinburgh	3 0 ·0	3 16 ·5	0 47	0 ·6	
Calcutta	2 36 ·1	2 46 ·7	0 38	2 ·0	
Bombay	2 46 ·1	2 56 ·5	0 23	1 ·0	
Manila	2 23 ·5	2 23 ·7	0 12	—	
Nicolaiew	2 41 ·5	3 3 ·0	—	—	
Taschkent	2 34 ·6	2 59 ·8	—	—	
Tiflis	2 18 ·2	2 55 ·7	—	—	
Dorpat	2 40 ·4	2 57 ·4	—	—	
Hamburg	2 30 ·9	3 4 ·7	—	—	
Strassburg	2 31 ·9	—	1 15	—	

This earthquake was felt in Southern Japan, and its origin is given by Mr. A. IMAMURA as 9° distant from Tokyo, off the south-eastern coast of Kiusiu. From the observations made in Kiusiu (see 'B.A. Circular,' No. 6, p. 270), the value M – C for Tokyo and the Manila record, I should place this origin further S.W. from Tokyo, and deduce 2h. 16m. as the time of origin.

The following table gives the average arcual velocity of propagation:—

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Tokyo	12	5 ·0	8 ·5	—	2 ·4	1 ·41
Irkutsk	28	9 ·5	22 ·7	—	2 ·9	1 ·23
Calcutta	37	20 ·0	30 ·7	—	—	1 ·85
Batavia	40	17 ·5	18 ·0	—	2 ·29	—
Bombay	50	30 ·0	40 ·0	—	—	1 ·66
Taschkent	51	18 ·6	43 ·0	—	2 ·78	1 ·19
Tiflis	66	2 ·2 ?	49 ·0	30 ·0 ?	—	1 ·34
Dorpat	72	24 ·0	43 ·0	—	3 ·0	1 ·67
Nicolaiew	74	25 ·0	47 ·0	—	2 ·96	1 ·57
Wellington	76	41 ·0	—	—	—	1 ·85
Christchurch	77	39 ?	56 ·0	—	2 ·0	1 ·34
Hamburg	80	15 ·0	48 ·0	5 ·33	—	1 ·66
Strassburg	84	16 ·0	—	5 ·23	—	—
Edinburgh	85	44 ·0	60 ·0	—	—	1 ·93
Bidston	87	44 ·0	65 ·0	—	—	1 ·97
Kew	87	52 ·0	62 ·0	—	—	1 ·67
Shide	88	33 ·0	65 ·0	—	2 ·66	1 ·35
"Discovery"	110	3 ·0	—	—	—	—

The values for P_3 approximate to what we should expect from other analyses. P_2 was only observed at comparatively few places, while P_1, unless we accept the two low values of 5·3 kms. per second, has not been recorded.

The earthquake is essentially one that only exhibits one type of wave motion, and this was propagated across Europe and Asia, and southwards beyond Australia.

30. *May* 10.

"Discovery," 22h. 20m. A series of thickenings commencing on May 9 at 15h. 52m. and ending May 11 at 19h. 34m.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
Irkutsk	22 16 ·5	—	0 36	—	
Taschkent	22 22 ·8	22 36 ·6	—	—	
Tiflis	22 24 ·5	22 30 ·9	1 8	—	
Dorpat	22 35 ·0	—	0 15	—	
Batavia	22 20 ·7	22 23 ·0	0 25	0 ·3	
Perth	22 25 ·1	22 42 ·1	0 37	0 ·9	This is entered in 'B.A. Register' for May 11.
Strassburg	22 23 ·1	—	0 37	—	
Hamburg	22 24 ·6	—	—	—	

31. *May* 19.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	12 23 ·9	—	—	0 ·2	Two bead-like thickenings.
Batavia	12 31 ·0	12 31 ·7	0 4	0 ·8	
San Fernando	11 50 ·8	—	2 29	—	Small serrations.

The occurrence of this earthquake, although it may have been local, is possibly connected with three heavy shocks which on the night of May 19–20 shook Amboina in the Moluccas.

May 24. The clock ceased to drive the paper several times, with the result that the times of five thickenings cannot be obtained.

32. *May* 26.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	10 59·6	11 5·7 11 9·8	0 37	3·5 2·5	
Hamburg	11 40·8	11 43·4	0 20	—	(See facsimile of trace, Plate 4.)
Strassburg	11 37·3	—	0 12	—	
Tiflis	10 53·7	—	1 39	—	

The "Discovery" record refers to an earthquake with an origin about 15° distant from that station. The time of origin would, therefore, be at about 10.50. At 11.40 we should expect P_2 to have reached Europe, which is the time at which records were obtained there.

33. *May* 31.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	5 12·1	5 18·2	0 24	0·5	
Christchurch	5 8·7	5 20·0	0 18	0·2	
Kodaikanal	4 54·4	4 54·4	0 5	1·0	

Origin S. or S.W. of New Zealand.

34. *May* 31.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 7·1	7 17·2	0 32	0·7	
Christchurch	7 9·7	7 12·2 7 18·2	0 32	0·5 0·6	
Taschkent	8 21·2	8 44·0	—	—	
Tiflis	8 28·9 ?	—	—	—	
Dorpat	8 26·0	—	—	—	

M – C for the first two entries suggest an origin 25° distant from the "Discovery" and 22° distant from Christchurch, or 140° E. Long. and 55° S. Lat. The time of origin would be approximately 7h. 4m. The anticipated times of arrival of P_3 at the last three stations, respectively 115°, 125°, and 145°, would be 8.14, 8.19, and 8.29.

June 2, 4.30 to 23.52 the light was out. On June 8 for a portion of the day the clock stopped, while the record for June 9 has been lost.

35. *June* 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	3 35·9	3 39·1	0 18	0·5	
Christchurch	3 37·2	3 46·0	0 21	0·3	

Origin to S. or S.W. of New Zealand.

June 10, 11h., to June 11, 3h., the light was out.

36. *June* 13.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	9 22·6	—	0 10	0·5	

Origin local.

June 13, 21h. 0m., to 15, 1h. 26m., the light was out.

37. *June* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	12 47·2	—	0 20	0·2	Ripples.
Wellington	12 26·5	12 31·0	0 6	2·6	
Batavia	12 50·7	13 8·0	0 30	0·8	
Perth	12 35·4	12 54·6	0 46	0·5	
Bidston	13 33·0	13 36·6	0 22	0·3	
Taschkent	12 54·0	13 35·5	—	—	
Tiflis	12 24·4 ?	—	2 25	—	
Dorpat	13 2·9	13 28·3	1 12	—	
Nicolaiew	13 17·0	13 37·0	0 40	—	
Hamburg	12 34·8	—	1 26	—	
Strassburg	12 44·0	—	1 50	—	

The records from Wellington and Perth indicate an origin in the vicinity of 155° E. Long. and 50° S. Lat. The time of origin would be about 12.21.

The following table gives approximate values for the arcual velocities of propagation in degrees per minute:—

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
"Discovery" . . .	25	26	?	—	—	0·96
Batavia	60	39	47	—	1·54	1·28
Taschkent	120	33	74	—	3·63	1·62
Nicolaiew	135	56	76	—	2·41	1·77
Dorpat	146	41	67	—	3·56	2·18
Hamburg	156	11	—	14·1	—	—
Strassburg	157	23	—	6·82	—	—
Bidston	164	72	76	—	2·27	2·15

The inference to be drawn from this table is that in all cases but two C refers to P_2.

38. *June* 17.

"Discovery," 21 42·6, a slight thickening. Origin local.

39. *June* 17.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	23 49·9	24 50·0	0 30	0·5	
Christchurch	24 17·2	24 28·2	0 35	0·2	
Taschkent	24 34·7	24 47·9	—	—	
Tiflis	23 53·3	24 8·7	1 26	—	
Dorpat	24 11·0	24 35·0	0 57	—	
Hamburg	23 3·5	—	0 57	—	
Strassburg	23 3·7	—	0 60	—	

40. *June* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	6 53 ·6	—	0 26	0 ·2	Ripples.
Christchurch	6 51 ·5	6 59 ·0	—	0 ·7	
Perth	7 16 ·1	7 20 ·0	0 32	0 ·2	
Taschkent	7 28 ·1	7 48 ·5	—	—	
Dorpat	7 6 ·7	—	—	—	

The records from Christchurch and Perth indicate an origin S.W. of New Zealand in 140° E. Long. and 65° S. Lat. The approximate time of origin would be 6h. 44m.

The arcual velocity of propagation would be as follows :—

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	C.	M.	P_1.	P_2.	P_3.
	°					
Taschkent	120	44	62	—	2 ·72	1 ·93
Dorpat	145	22	—	6 ·60	—	—

June 22, 12.45 to 24.0, the light was out. The record for June 23 has been lost.

41. *June* 26.

"Discovery," 23h. 17·7m., a slight thickening. Origin local.

June 30, after 18h. the light was out.

July 5, 17.30 to 24.0 the light was out.

42. *July* 6.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	13 8 ·6	—	2 50	1 ·0	Thickenings.
Christchurch	13 7 ·8	13 18 ·0	—	7 ·1	
Wellington	13 5 ·2	13 15 ·2	2 14	2 ·8	
Perth	13 14 ·8	13 50 ·2	2 14	2 ·8	
Irkutsk	13 27 ·7	14 34 ·7	2 25	0 ·3	
Batavia	13 15 ·0	13 50 ·8	1 40	2 ·0	
Mauritius	13 30 ·0 (abt.)	—	—	—	
Victoria, B.C.	13 25 ·8	14 27 ·3	1 51	0 ·4	
Toronto	13 28 ·6	14 20 ·5	1 51	2 ·0	
Kodaikanal	13 27 ·7	14 11 ·0	2 6	0 ·6	
Baltimore	13 29 ·3	14 14 ·0	1 53	0 ·6	
San Fernando	13 20 ·7	—	2 9	—	
Edinburgh	13 44 ·8	14 40 ·7	2 8	0 ·7	
Bidston	13 38 ·7	14 28 ·5	1 58	0 ·7	
Kew	13 40 ·7	—	0 25	0 ·2	
Shide	{12 20 ·0 and 13 40 ·0}	—	—	—	
Tiflis	13 21 ·9	13 48 ·8	2 56	—	
Nicolaiew	13 40 ·0	14 0 ·0	1 20	—	
Dorpat	13 32 ·3	14 27 ·9	1 45	—	
Strassburg	13 22 ·6	—	2 18	—	
Hamburg	13 23 ·1	—	3 7	—	

The position of the origin appears to have been to the N.E. of New Zealand at a distance of 25° to 30°, but it cannot be determined with any accuracy. The time of origin would be about 13h. 0m.

The following table of velocities indicates the character of motion which reached distant stations :—

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	C.	M.	P_1.	P_2.	P_3.
	°					
"Discovery" . . .	60	9	—	5·55	—	—
Victoria, B.C. . .	90	25	87	—	3·60	1·03
Kodaikanal . . .	95	27	71	—	3·52	1·33
Toronto	115	28	80	—	4·10	1·43
Baltimore	115	29	74	—	4·00	1·55
Tiflis	132	22	48	6·00	2·74	—
Dorpat	142	32	87	—	4·43	1·63
Nicolaiew	145	40	60	—	3·62	2·41
Strassburg	158	22	—	7·18	—	—
Bidston	162	38	88	—	4·26	1·84
San Fernando . .	175	20	—	8·75	—	—

From this table it appears that, with the exception of three stations, the character of the movement recorded refers to P_2 and P_3.

July 7, 0h. 30m. to 19h. the light was out.

43. *July* 13.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	12 9·6	—	0 7	0·5	Time uncertain.
Bidston	12 9·0	12 18	0 9	—	
Cordova.	11 59·0	12 6	0 9	0·5	
Trinidad	12 2·0	—	0 16	—	
Strassburg	12 2·0	—	0 37 ?	—	
Hamburg	12 3·0	—	1 42	—	

This disturbance probably originated in the South Pacific to the E. of New Zealand, and spread in a north-easterly direction as far as the western side of Europe. The area disturbed is similar to that given for No. 123.

July 29, 0h. 30m. to 30, 0h. 30m., the light was out.

August 1, 11h. 30m., to end of day the light was out.

44. *August* 2.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	14 45·0	—	1 0	0·5	
Perth	14 29·3	14 43·3	1 33	12·0	
Irkutsk	14 40·9	14 55·3	0 55	0·4	
Batavia	14 28·6	14 41·5	1 5	2·5	
Mauritius	14 45·1	15 12·4	0 49	0·09	
Bidston	14 42·0	15 27·0	1 48	0·3	
Edinburgh.	15 32·5	15 36·5	0 17	0·3	
Strassburg	14 42·1	—	1 55	—	
Taschkent	14 33·9	15 21·3	—	—	
Tiflis	14 39·4	15 1·9	—	—	
Nicolaiew	14 48·0	15 17·0	0 59	—	
Dorpat	14 46·4	15 28·0	1 14	—	

A possible origin is 150° E. Long. and 10° N. Lat. With this supposition, however, a very much smaller amplitude would be expected for Perth, and the disturbance should have been noted at Tokyo, Victoria, Christchurch, and Wellington, which was not the case. Another possible origin is that given for No. 46.

45. *August* 7.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	11 32·6	11 37·7	0 40	2·0	
Perth	12 3·2	12 6·7	0 40	0·4	
Irkutsk	12 22·6	12 25·0	0 11	0·2	
Batavia	{ 11 50·0 ? or 11 48·1 }	11 51·0 ?	0 42	25·0	
Kodaikanal	12 0·7	12 11·1	0 19	1·0	
Mauritius	12 4·2	12 15·0	0 21	0·4	
Cape Town.	12 29·0	12 36·0	0 9	0·2	
Bidston.	12 50·6	12 54·4	0 20	Small	

At Palembang, in Sumatra, where the shocks were severe, the time given is 11.49, and for Benkoelen 11.35.

From these notes the inference is that the origin was nearer to the S.E. extremity of Sumatra, about 5° N.W. from Batavia.

With the assumption that the largest waves travelled at a rate of 3 kms. per second, the time at the origin as derived from the records from Batavia would be 11.48, and from the Perth record 11 47·6, results which accord with the time noted at Palembang. For P_3 to reach the "Discovery," 80° distant, would take 49 minutes. The Antarctic record for maximum motion, if it refers to the Sumatra earthquake, instead of reading 11.37, should read 12.37. As the "Discovery" observation appears to be correct, it is interesting to note that 16 minutes after the commencement of a somewhat severe earthquake in the Antarctic, a large earthquake originated near Sumatra, 80° distant. And 16 minutes is the time which preliminary tremors would take to traverse the path of that length.

August 8, 6h. 0m. to end of the day the light was out.

46. *August* 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	13 48·4	13 51·5	0 26	1·2	Time approximate.
Batavia	12 47·7	12 59·5	0 20	0·7	
Perth	12 47·6	12 58·6	0 53	3·6	
Bidston	13 35·2	13 47·0	0 32	0·2	

From the time observations the inference is that this earthquake, like No. 44, originated at a spot about 50° distant from Perth and Batavia. The amplitude records, however, suggest that the origin was much nearer to the former station than to the latter. It might also be at a spot nearly equally distant from Bidston and the "Discovery." The duration of the preliminary tremors at Batavia and Perth suggests an origin about 50° distant from these two places. A position roughly in accordance with these conditions would be about 50° E. Long. and 30° S. Lat.

August 16, 2.30, to 18, 3.51, light cut off by snow, which filled the slit.

47. *August* 16.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	8 12·11	{ 8 24·4 8 28·5 }	1 0	1	Seen on edge of paper.
Perth	8 12·0	8 35·0	—	—	
Batavia	8 39·0	—	1 10	2·1	Three shocks here.
Cape of Good Hope. .	8 35·0	9 11·0	—	—	
Toronto.	8 36·0	—	—	—	
Victoria.	8 27·0	—	—	—	
San Fernando. . . .	9 24·0	10 1·0	—	—	
Bidston	8 42·0	9 12·0	—	—	
Edinburgh	—	8 45·0	—	—	
Irkutsk	8 25·0	8 49·0	—	—	
Christchurch	8 11·0	8 25·0	—	—	
Wellington	8 11·0	8 22·0	—	—	

47*b*. *August* 18.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	18 39·0	—	0 5	0·2	

Local origin.

48. *August* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	11 35·3	—	0 6	0·2	
Perth	11 30·0	11 43·8	1 3	0·9	
Irkutsk	11 32·0	11 41·7	0 59	0·5	
Batavia	11 20·7	11 27·7	1 0	4·6	
Kodaikanal	11 30·7	11 35·0	0 38	0·6	
Mauritius	11 40·9	11 41·5	0 9	—	
Calcutta	11 24·3	11 44·1	0 50	0·7	
Shide	—	12 19·1	—	—	
Bidston	11 39·7	11 48·2	1 5	0·6	
Edinburgh.	12 10·0	12 23·0	0 33	0·5	
Manila	11 17·3	11 19·2	1 29	—	

It was noted at many stations in Mindanao and at Minado in the Celebes at 11.21. The real origin was in the central region of Mindanao, where there were great upheavals of the ground and destruction of buildings, 122° 25′ E. Long., 10° 56′ N. Lat. Records obtained in Manila and Batavia each indicate 11.14 as the time of origin. The time taken to reach the "Discovery," 90° distant, was therefore 21 minutes.

The time taken by preliminary tremors, the second phase of motion, and the large waves to traverse such a distance, would be approximately 16, 25, and 55 minutes. The suggestion, therefore, is that the "Discovery" record may refer to the first or second phase of the Mindanao disturbance, but this, however, fails to explain the absence of records at Wellington and Christchurch. Another suggestion is that the "Discovery" record refers to a disturbance of local origin, resultant on tremors which originated in the Mindanao area.

48*b*. *August* 24.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	5 49·0	—	0 11	—	Slight.
Bidston	5 33·0	5 47·0	0 8	0·3	
Strassburg	5 53·8	—	0 50	—	
Hamburg	5 33·3	5 53·5	0 37	—	

48*c*. *September* 1.

"Discovery," about 14.30, a small earthquake. Time uncertain. Local origin.

August 24, 17.30, to 25, 0.44, the light was out.

August 28, 6.30, to 29, 0.30, the light was out.

No records up to September 10.

September 11, about 11.30, light out, and no records up to the 17th, 2h. 6·7m.

September 19, 6.30, to 20, the light was out.

On the afternoon of September 20, Mr. Bernacchi says that large volumes of smoke and a fire-like glow were seen emanating from the crater of Mount Erebus, which, as a rule, is very quiescent.

49. *September* 22.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	1 59·1	2 14·2	1 55	2·5	
Christchurch	1 57·3	2 6·4	4 0	14·3	
Wellington	1 42·0	{ 2 8·2 2 55·8 }	4 20	10·0	
Perth	1 57·7	2 16·9	2 32	9·7	
Batavia	1 55·3	2 6·0	3 41	11·0	
Tokyo	1 51·3	1 57·3	2 20	20·0	
Cordova	2 6·8	{ 2 12·7 2 43·2 }	2 44	1·5	
Irkutsk	1 55·0	2 8·7	3 0	13·9	
Victoria	1 58·5	2 10·5	2 48	7·1	
Mauritius	2 0·0	2 12·8	—	3·2	
Bombay	1 57·7	2 14·8	2 1	2·7	
Kodaikanal	1 57·5	2 22·8	1 59	1·0	
Calcutta	1 55·8	2 18·2	2 8	7·5	
Paisley	2 5·2	2 20·6	2 7	2·5	(See facsimile of trace, Plate 4.)
Shide	2 5·4	2 49·0	2 40	8·0	
Kew	2 5·3	2 48·6	2 54	8·5	
Bidston	1 59·6	2 46·3	2 32	7·9	
Edinburgh	2 2·0	2 50·2	3 8	3·5	
Toronto	2 6·4	2 17·4	2 29	4·4	
San Fernando	2 5·2	2 54·2	3 16	10·0	
Cape Town	2 6·3	2 55·6	2 40	1·9	
Trinidad	2 4·0	3 20·0	2 19	1·5	
Cairo	2 4·0	2 17·0	1 44	1·0	
Nicolaiew	2 0·0	2 22·0	—	—	
Taschkent	1 59·2	2 26·6	—	—	
Tiflis	2 0·1	2 12·2	—	—	
Dorpat	1 59·6	2 13·7	—	—	
Manila	1 54·4	1 57·4	—	—	
Strassburg	2 1·9	—	3 40	—	
Hamburg	2 1·2	2 15·5	—	—	

In Guam, 145° E. Long., 13° 36′ N. Lat., there was a great destruction of buildings, while in the Island of Saypan buildings were also shattered. An origin in this region approximates to one dependent upon values for M – C at the four nearest stations.

From the hours of maxima as recorded at Batavia, Irkutsk, Tokyo, and Manila, by the method of circles a district is arrived at, the centre of which is in 13° N. Lat. and 130° E. Long., about 6° W.N.W. of Guam.

As the maximum was recorded in Manila and in Tokyo at the same time the origin should be found on a line all points in which are equidistant from these two stations. For similar reasons it should be on a line equidistant from Batavia and a point about 480 kms. from Irkutsk, on a line drawn from that place in the direction of Guam. These two lines intersect in the region indicated. Guam and Saypan were, therefore, about 300 miles distant from the origin, and that this might well be the case is testified by the destruction which took place. Had these islands been much nearer to the origin of a disturbance which was so definitely recorded at stations all over the globe, it is likely that the destruction in Guam would have been greatly intensified.

The time of origin as deduced from the time of arrival of the maximum motion at Tokyo and Manila is 1.44, at Batavia 1.43, and at Irkutsk 1.40. The local times given for Guam are 1.35, 1.45 and 2.5. As a close approximation to time of origin we shall adopt 1.44.

In the following table velocities are expressed in degrees per minute. The eighth column indicates the proportion of the wave path between the origin and the various stations which was suboceanic, while the last column gives the amplitudes recorded at these stations:—

	Distance.	Minutes.		On arc.	On chord.	On arc.	Path.	Amplitude.
	D.	*C.*	*M.*	P_1.	P_2.	P_3.		
	°							millims.
Manila	20	10	13	2·00	1·98	1·54	1·0	—
Tokyo	24	7	13	2·85	2·84	1·54	1·0	20·0
Batavia	37	8	22	4·62	4·54	1·68	0·9	11·0
Irkutsk	45	11	24	4·09	3·99	1·87	0·5	13·9
Calcutta	46	11	33	4·18	4·07	1·39	0·5	7·5
Perth	51	13	32	3·92	3·80	1·59	0·7	9·7
Kodaikanal	55	12	38	4·58	4·41	1·44	0·3	11·0
Wellington	—	—	—	—	—	—	1·0	10·0
Bombay	62	13	30	4·77	4·54	2·08	0·3	4·3
Christchurch	62	12	21	5·16	4·91	2·95	1·0	14·3
Taschkent	67	15	42	4·46	4·21	1·59	0·3	—
Victoria, B.C.	80	13	25	6·15	5·66	3·20	1·0	7·1
Tiflis	83	16	28	5·19	4·74	2·96	0·2	—
Mauritius	85	18	30	4·72	4·27	2·83	1·0	3·2
Dorpat	88	15	29	5·88	5·30	3·03	0·2	—
"Discovery"	92	14	29	6·57	5·88	3·17	1·0	2·5
Nicolaiew	92	16	38	5·75	5·15	2·42	0·2	—
Cairo	95	19	32	5·00	4·44	2·97	0·2	1·0
Hamburg	102	17	31	6·00	5·23	3·29	—	—
Strassburg	103	18	—	5·72	4·98	—	—	—
Edinburgh	105	17	65	6·17	5·34	1·61	0·2	8·5
Kew	105	20	14 (?)	5·25	4·54	1·64	0·2	8·5
Bidston	106	15	61	7·06	6·10	1·73	0·2	7·9
Paisley	106	20	36	5·30	4·57	2·94	0·2	2·5
Shide	106	20	65	5·30	4·57	1·63	0·2	8·0
Toronto	112	21	32 (?)	5·33	4·52	3·50 (?)	0·7	4·4
San Fernando	120	21	69	5·71	4·72	1·74	0·2	10·0
Cape Town	120	21	71	5·71	4·72	1·68	1·0	1·9
Trinidad	146	20	95	7·30	5·47	1·53	0·9	1·5
Cordova	160	21	59	7·61	5·37	2·71	1·0	1·5

An inspection of the above table shows that the values for P_1 are such as might be expected, and also that the velocity of propagation on an arcual path is not constant. The average velocity along a path corresponding to a chord when the length exceeds 50° is more nearly constant. P_3 shows a fairly constant arcual velocity to stations at less distances than 60° from the origin. To stations 60° to 90° distant the rate of propagation increases to values that suggest a rate of transmission for P_2. Beyond this distance the rate decreases to values approximating to those obtained at the nearer stations.

In the middle regions it may be noted that the increased rate is derived not only from records of Milne pendulums, but from others adjusted to have different periods. It is likely, therefore, that the maxima recorded by different types of instruments refer to the same phase of motion, and we are not dealing with apparent maxima occasioned by coincidences of the period of the pendulum and that of its foundations.

There does not appear to be any relationship between P_3 and the nature of the path, nor is anything clearly shown with regard to decreasing amplitudes. (See Time Curve No. 49, Plate 1.)

50. *September* 23.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	20 33·0	20 47·2	2 20	1·0	
Christchurch	—	21 16·9	4 18	18·0	
Wellington	20 33·1	21 14·0	3 40	15·0	
Perth	20 40·0	20 53·6	2 33	4·0	
Trinidad	20 24·0	20 34·0	2 13	10·0	
Batavia	19 40·5	{ 19 56·0 21 10·7 }	2 45	{ 3·0 5·0	
Manila	20 38·7	20 44·3	1 46	—	
Tokyo	20 36·4	20 48·4	1 20	3·0	
Irkutsk	20 34·1	21 34·2	2 58	4·8	
Cordova	20 28·0	20 42·2	2 39	2·5	
Kodaikanal	20 39·0	21 46·0	2 8	1·1	
Bombay	20 39·3	{ 21 2·0 21 46·0 }	2 15	{ 1·6 2·0	
Calcutta	20 39·5	21 45·6	2 4	2·7	
Mauritius	20 39·1	20 54·3	—	2·0	
Cape Town	20 38·7	21 22·9	2 51	4·1	
Victoria, B.C.	—	20 44·4	—	>20·0	
Toronto	20 24·2	20 34·0	2 35	>20·0	
San Fernando	19 33·7	20 00·0 ?	3 25	10·0	
Shide	20 30·9	21 7·0	3 27	>17·0	
Kew	20 31·2	21 10·0	3 26	>17·0	
Bidston	20 27·5	21 3·0	2 53	>17·0	
Edinburgh	—	21 8·0	3 19	22·0±	
Paisley	20 30·5	21 5·5	2 0	6·0	
Cairo	20 32·0	20 45·3	2 20	2·0	
Nicolaiew	20 33·0	20 38·0	—	—	
Taschkent	19 59·6	21 33·2	—	—	
Tiflis	20 34·1	20 48·8	—	—	
Hamburg	20 31·9	20 43·8	4 39	—	
Strassburg	20 32·5	—	4 30	—	

The origin was near Guatemala City, 15° N. Lat. and 90° W. Long.

The shock was also severe in British Honduras.

The values for M at Trinidad, Victoria and Toronto give times of origin 20.16, 20.19 and 20.17. The time adopted is 20.16.

The following table is similar to that given for Earthquake No. 49. Velocities are expressed in degrees per minute :—

	Distance.	Minutes.		On arc.	On chord.	On arc.	Path.	Amplitude.
	D.	*C.*	*M.*	P_1.	P_2.	P_3.		
	°							millims.
Toronto	29	8	18	3·62	3·50	1·61	0·0	20·0
Trinidad	29	8	18	3·62	3·50	1·61	0·9	10·0
Victoria	41	—	28	—	—	1·46	0·0	20·0
Bidston	73	11	47	6·63	6·18	1·55	1·0	17·0
Edinburgh	74	—	52	—	—	1·42	1·0	22·0
Paisley	74	14	49	5·28	4·92	1·51	1·0	6·0
San Fernando	74	17	—	4·35	4·05	—	1·0	10·0
Shide	75	15	51	5·00	4·60	1·47	1·0	17·0
Kew	76	15	54	5·06	4·66	1·41	1·0	17·0
Strassburg	80	16	—	5·00	4·56	—	1·0	—
Hamburg	80	15	27	5·33	4·86	2·96	1·0	—
Nicolaiew	99	17	22	5·82	5·11	4·50	0·8	—
Cairo	105	16	29	6·56	5·62	3·62	0·9	2·0
Tiflis	107	18	33	5·94	5·05	3·24	0·7	—
Wellington	108	17	58	6·38	5·35	1·86	1·0	15·0
Tokyo	110	20	32	5·50	4·65	3·43	1·0	3·0
"Discovery"	110	17	31	6·47	5·47	3·55	1·0	1·0
Christchurch	112	—	61	—	—	1·83	1·0	18·0
Irkutsk	118	18	78	6·55	5·44	1·51	0·7	4·8
Cape Town	119	22	66	5·43	4·45	1·80	0·6	4·1
Taschkent	120	—	77	—	—	1·55	0·6	—
Manila	140	22	28	6·36	4·86	5·00	1·0	—
Mauritius	152	23	38	6·60	4·82	4·00	0·8	2·0
Perth	155	24	37	6·45	4·66	4·18	0·7	4·0
Calcutta	155	23	89	6·73	4·87	1·74	0·8	2·7
Batavia	162	24	54	6·75	4·70	3·00	1·0	3·5
Kodaikanal	165	23	90	7·17	4·91	1·83	0·8	1·1
Bombay	165	23	46	7·17	4·91	3·58	0·8	2·0

Like the table for the preceding earthquake, the arcual values for P_1 increase with the length of the wave path, while chordal values approximate to a constant value. From 99 to 110 the values for P_3 are above the average. Where wave paths have been suboceanic, amplitudes recorded in Western Europe and in New Zealand have been high, which suggests that an ocean load has a less damping effect than a continental load. (See Time Curve No. 50, Plate 1.)

September 26, 16.0, to October 3, 2.30, the clock was stopped.

51. *October* 5.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	15 2·9	—	0 10	0·2	Slight ripple.
Perth	15 20·0	15 27·2	0 40	0·4	
Strassburg	15 7·5	—	0 40	—	

An Antarctic disturbance also noted near to its antipodes.

52. *October* 6.

"Discovery" 8.30 to the 7th, 16.0. A rhythmic succession of 5 or 6 large and 9 or 12 small bead-shaped wave groups. Whether these are connected with a severe earthquake which originated in Ferghana, 40° N. Lat. and 72° E. Long., and which was recorded at the Cape of Good Hope, Perth, and many other stations, is doubtful.

53. *October* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	8 40·0	time approximate		—	A slight thickening.
Bidston	8 24·4	8 32·1	0 19	0·3	
Hamburg	7 59·5	8 9·5	—	—	
Strassburg	8 9·2	—	—	—	
Nicolaiew	8 39·0	—	—	—	
Taschkent	8 36·3	9 3·6	—	—	
Dorpat	8 1·0	8 35·3	0 51	—	

October 13. From 10.0 to 16.0 the trace was very faint.

54. *October* 14.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	16 44·0	17 26·0	2 30	0·5	Time uncertain.
Bidston	—	16 10·0	—	—	
Batavia	17 43·7	17 49·3	0 21	1·0	
Manila	17 37·5	17 38·5	—	—	
Taschkent	17 56·3	18 12·2	—	—	

The Manila record refers to an earthquake which was felt at Zamboanga and Joló Island.

The "Discovery" record relates to an earthquake of local origin, but it is very doubtful whether the time of its occurrence is connected with the disturbance in the Philippines.

October 18 to 22, the line is very faint. From 16.0 to 23.30 on the 21st it is invisible.

55. *October* 28.

	C.	D.	A.	Remarks.
	h. m.	h. m.	millim.	
"Discovery"	3 59·4	0 10	0·5	

Of local origin.

56. *November* 1.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	11 5·9	11 10·9	0 18	0·5	

Of near origin.

On November 2 disturbances commenced at Tokyo and Batavia at 11.19 and 11.48 respectively.

57. *November* 4.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	12 44·0	—	—	—	A slight thickening.
Perth	12 5·0	12 23·0	0 34	0·3	
Kodaikanal	11 44·0	11 47·0	—	4·5	Sudden.
Bombay	11 17·8	11 46·0	1 35	3·8	
Calcutta	11 22·8	—	0 2	—	Slight.
Mauritius	11 55·8	12 4·1	0 46	0·6	
Cape Town	12 9·0	12 27·8	0 36	0·5	
Victoria	12 25·6	—	0 10	0·1	
Irkutsk	11 37·6	11 48·1	1 33	6·3	
Shide	12 5·7	12 12·7	0 25	0·5	
Kew	12 9·2	12 20·0	0 29	0·5	
Bidston	12 7·2	12 18·7	0 24	0·5	
Nicolaiew	11 49·5	12 3·0	1 8	—	
Taschkent	11 37·9	11 48·4	—	—	
Tiflis	11 47·4	12 4·4	—	—	
Dorpat	11 50·9	12 8·3	1 25	—	
Hamburg	11 52·3	12 12·3	2 10	—	
Strassburg	11 53·0	—	—	—	

Approximate position of origin, 85° E. Long., 35° N. Lat. This shock does not appear to have been recorded in New Zealand, Batavia, Tokyo, or Cordova. From the values of M at Kodaikanal and Bombay the time of origin would be 11.35. Large waves would arrive at the "Discovery," 125° distant, about 12.49. It would seem, therefore, that the "Discovery" record relates to P_3.

November 9 to 13 the instrument was dismounted.

58. *November* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	10 41·2 or 10 34·2	11 21·8 or 11 14·8	1 20	1·5	
Perth	9 34·8	9 44·1	1 38	10·5	
Batavia	9 28·1	9 41·2	1 3	1·6	
Tokyo	9 32·5	9 37·0	0 30	1·4	
Irkutsk	9 28·9	9 48·5	1 12	0·2	
Kodaikanal	—	9 58·9	—	—	
Mauritius	9 39·5	10 10·8	1 11	0·5	
Toronto	10 12·0	—	0 51	0·05	
Victoria	9 58·7	—	0 59	0·1	
Cape Town	10 6·0	10 23·0	0 30	0·3	
Bidston	10 29·4	10 40·0	0 22	0·1	
Manila	9 24·1	9 40·0	1 7	—	
Nicolaiew	9 50·0	10 25·0	1 0	—	
Taschkent	9 40·0	9 59·2	—	—	
Tiflis	9 18·2	9 37·9	—	—	
Dorpat	9 48·0	—	—	—	
Strassburg	9 41·9	—	2 30	—	
Hamburg	9 38·5	10 1·9	1 35	—	

It is interesting to note that this earthquake does not appear to have been recorded in New Zealand, whilst it was recorded to the N. and to the S. of the same. At Perth the movement was pronounced, from which it may be inferred that the origin was nearer to that station than to any other. In the publications of the Earthquake Investigation Committee of Tokyo, No. 16, p. 99, Mr. A. IMAMURA analyses this earthquake on the assumption that its origin was probably near Manila, where it is said to have been registered at 9 21·2. This, however, does not correspond with the entry in the 'Bulletin of the Philippine Weather Bureau,' November 1902, p. 281.

The recorded amplitudes and the values for M for Perth, Batavia, and Tokyo indicate an origin near to the centre of a circle which would pass through these three stations, or 160° E. Long. and 0° N. or S. Lat. The values M – C for these three stations suggest an origin near New Guinea, while the values of M together with that for Irkutsk place the origin about 130° E. Long. All that we can say about the origin is that it appears to be in the eastern portion of district F.

59. *November* 18.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	2 12·3	—	0 10	—	A slight thickening.
Strassburg	2 2·4	—	0 16	—	
Hamburg	—	2 12·5	—	—	

Antipodean disturbance.

59*b*. *November* 19.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	20 47·0	—	—	—	Slight, local.

November 20. Instrument not working.

60. *November* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	7 24·3	—	1 35	0·2	A series of thickenings.
Christchurch	7 23·6	—	1 25	0·8	
Wellington	Air tremors				
Perth	7 20·7	7 36·8	1 20	1·0	
Batavia	7 7·5	7 29·2	1 20	8·0	
Irkutsk	7 11·3	7 25·0	1 26	4·3	
Calcutta	—	7 27·0	—	—	Trace faint.
Mauritius	7 12·7	7 48·1	3 25	1·9	
Bombay	7 11·5	7 35·5	1 14	2·8	
Tokyo	7 8·3	7 20·3	1 20	3·5	Origin in Formosa.
Kodaikanal	7 10·0	7 33·3	0 51	0·7	
Victoria	7 26·7	—	1 11	0·2	
Toronto	7 32·7 ?	8 18·5	0 52	0·1	
Baltimore	7 30·0	—	2 0	—	
Cape Town	7 29·5	8 4·2	1 35	0·8	
Cordova	7 29·0	—	0 48	—	
Shide	7 29·0	7 59·0	0 52	2·5	
Kew	7 28·2	7 59·4	1 20	1·8	
Bidston	7 20·5	8 3·2	1 12	1·2	
Edinburgh	7 23·5	7 56·0	1 30	1·1	
Paisley	7 50·0 ?	—	—	—	Obscured.
San Fernando	7 55·5	8 3·2	0 52	3·0	
Manila	7 4·9	7 7·9	2 1	—	Felt at Santo Domingo (Batanes I.) at 7 6·5.
Nicolaiew	7 24·5	7 46·0	1 23	—	
Taschkent	7 12·9	7 40·7	—	—	
Tiflis	7 13·6	7 44·9	1 45	—	
Dorpat	7 15·0	7 45·0	1 45	—	
Hamburg	7 15·8	7 27·0	2 45	—	
Strassburg	7 16·1	—	3 0	—	

In the publication of the Earthquake Investigation Committee of Tokyo, No. 16, p. 100, Mr. IMAMURA says that this earthquake originated off the southern coast of Formosa, and that in Manila the initial movement was registered at 7h. 1·8m. This hour, it will be observed, is not in accord with the one just given, which was obtained from 'The Bulletin of the Philippine Weather Bureau,' November, 1902, pp. 280 and 281. Neither is it in accord with observations made at meteorological stations in Formosa, which were as follow: Taito, 7 12·0; Tainan, 7 4·2; Koshun, 7 6·7; Taichu, 7 2·8; and Taihoku, 7 3·0. At the two latter places, which are in Northern Formosa, the motion was slight, whilst at the three former places, in the southern part of the island, the movement was strong, houses were shaken, and at Koshun clocks were stopped. At Tainan there was vertical movement. The inference is that the origin was the S. of that city and its time would be at least 2 minutes earlier than that recorded in Tainan.

From the times of arrival of maximum motion at Manila, Tokyo, and Irkutsk, an origin is arrived at a point about midway between the northern end of Luzon and the southern extremity of Formosa, or approximately at 120° E. Long. and 21° N. Lat. The values M – C for these three stations also indicate an origin in this district.

From the times taken for large waves to travel from such an origin to the above three places it would appear that the time at the origin would lie between 7h. 2m. and 7h. 4m. As the former of these is more nearly in accord with observations made in Formosa and at other stations than the latter, it is the one adopted and used in the construction of the following table:—

	Distance.	Minutes.		Average arcual velocity in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Manila	6	3	6	2·0	—	1·0
Tokyo	25	6	18	4·1	—	1·4
Batavia	29	5	27	5·8	—	1·0
Calcutta	30	—	25	—	—	1·2
Irkutsk	35	9	23	3·9	—	1·5
Kodaikanal . . .	39	8	31	4·8	—	1·2
Bombay	44	9	33	4·9	—	1·3
Taschkent	50	10	38	5·0	—	1·3
Perth	52	18	34	—	2·9	1·5
Tiflis	65	11	42	5·9	—	1·5
Mauritius	73	10	46	7·3	—	1·6
Dorpat	74	13	43	5·7	—	1·7
Nicolaiew	74	22	44	—	3·3	1·7
Christchurch . . .	77	21	—	—	3·6	—
Hamburg	85	13	25	6·5	3·4	—
Strassburg	87	14	—	6·2	—	—
Kew	90	26	57	—	3·4	1·5
Edinburgh	90	21	54	4·3	—	1·6
Shide	92	27	57	—	3·4	1·6
Bidston	93	18	61	5·1	—	1·5
Paisley	93	—	48 ?	—	—	1·9 ?
Victoria	93	24	—	—	3·8	—
"Discovery" . . .	100	22	—	4·5	—	—
San Fernando . .	105	—	53 ?	—	2·0 ?	1·9
Cape Town . . .	110	27	62	4·1	—	1·7
Toronto	115	30	76	—	3·8	1·5
Baltimore	118	28	—	—	4·3	—
Cordova	175	27	57	6·5	3·0	—

See Time Curve No. 60, Plate 1.

61. *December* 7.

	C.	M.	D.	A.	Remarks.
"Discovery"	h. m. 8 52·2	h. m. —	h. m. 0 10	millim. 0·5	A thickening.

Local origin.

62. *December* 23.

	C.	M.	D.	A.	Remarks.
"Discovery"	h. m. 4 26·0	h. m. —	h. m. 0 11	millim. 0·5	Irregular thickenings.

Local origin.

63. *December* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	5 32·7	{ 5 42·9 5 45·9 }	0 49	2·0	
Christchurch	5 32·7	—	1 1	1·7	
Perth	5 43·0	5 51·0	0 54	0·7	

Origin 160° E. Long. and 60° S. Lat. On the continuation of the New Zealand fold.

64. *December* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	9 14·4	9 22·5	1 10	7·0	

The sudden commencement indicates a near origin.

65. *January* 4 *or* 5, 1903.

An earthquake with a duration of 50 minutes and an amplitude of 1 millim. was recorded, but the times are not given. It probably refers to a disturbance recorded at many stations round the world. In the Shide register it is numbered 668 (see 'Brit. Assoc. Circular,' No. 8). An approximate position for the origin is 130° E. Long. and 30° N. Lat., from which the maximum motion would reach the "Discovery" on January 4 about 5.45 a.m.

66. *January* 14.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	1 14·6	—	0 46	0·2	No central line, and the record is only just visible on the edge of the film. Time uncertain.
Christchurch	2 4·8	2 38·8	2 39	16·5	
Wellington	2 4·8	2 38·8	2 39	16·5	
Perth	2 8·8	3 55·8	2 52	3·1	
Batavia	3 7·4	3 38·7	2 40	2·2	
Calcutta	2 8·5	2 58·8	2 32	11·0	
Madras	2 11·4	2 58·2	1 45	2·0	
Bombay	2 7·9	2 54·9	2 36	24·0	
Mauritius	2 18·8	{ 2 24·7 3 21·4 }	4 7	4·0	
Tokyo	2 3·0	2 19·0	2 40	1·0	
Irkutsk	2 7·4	3 15·9	2 2	3·0	
Victoria	1 55·6	2 18·5	2 36	6·7	
Toronto	1 54·4	2 11·2	2 34	>18·0	
Cairo	2 12·0	2 15·0	2 30	2·0	
Cape Town	2 7·4	2 52·3	3 0	7·5	Times approximate.
Cordova	0 57·3	1 5·1	2 0	3·5	
Shide	1 59·1	2 36·7	2 0	3·0	Large waves also at 3.34.
Kew	1 59·3	2 37·4	3 4	>17·0	
Bidston	1 54·6	2 6·7	2 9	14·7	Recrudescence at 5.24.
Edinburgh	2 0·5	2 37·0	2 51	11·0	
Paisley	1 57·5	2 34·0	2 0	12·5	
San Fernando . . .	1 58·1	2 19·1	2 57	6·0	
Trinidad	1 57·0	2 17·0	1 39 ?	8·0	
Manila	2 7·2	2 11·0	1 56	—	
Taschkent	2 3·2	3 48·6	1 35	—	
Tiflis	2 2·7	3 7·6	3 7	—	
Dorpat	2 1·4	2 11·2	3 42	—	
Strassburg	3 0·0 ?	—	—	—	
Hamburg	2 1·1	—	—	—	

Values for M and M – C indicate an origin about 100° W. Long. and 10° S. Lat.

January 29 to March 18 the seismograph was dismounted.

67. *March* 20.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 12·5	—	0 5	0·2	Local origin.

68. *March* 20.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	10 35·8	—	0 5	0·2	

This was followed by slight ripples with approximate periods of 60 seconds. The total duration is 65 minutes. At 10.31 an earthquake was recorded at Kodaikanal. The "Discovery" record probably refers to a shock of local origin.

69. *March* 21.

Between 10.30 and 12.30 the trace is slightly irregular, but whether this has any connection with an earthquake recorded at Bidston at 10.57, Tokyo 10.40, and Irkutsk at 10.45 is very doubtful.

70. *March* 22.

From 14 to 16 hours a series of slight thickenings were recorded. It is possible that these refer to an earthquake which was noted at Shide, Bidston, Edinburgh, Paisley, Mauritius, Bombay, Calcutta, Tiflis, Irkutsk, Cordova and Cairo. The origin of the disturbance was to the N. of Bombay, 78° E. Long., 30° N. Lat.

71. *March* 26.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	9 5·3	—	0 53	0·2	Series of thickenings.
Christchurch	8 54·7	9 6·2	0 42	2·0	
Perth	8 56·0	9 7·9	0 31	0·8	
Irkutsk	8 58·8	9 2·8	0 21	—	
Batavia	8 55·7	9 6·5	0 30	0·5	
Shide	9 42·2	9 59·6	0 25	0·2	
Kew	9 41·0	—	0 15	0·2	
Manila	8 47·5	8 45·8	0 35	—	
Taschkent	9 5·0	9 32·9	—	—	
Dorpat	9 8·9	9 45·7	—	—	

The time intervals between C and M at Christchurch, Perth, and Batavia, and the practical identity in the times at which C and M arrived at these three stations, suggest an origin in the eastern portion of the East Indies. The Manila and Batavia records suggest an origin to the N. of the Celebes.

72. *March* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	16 47·7	—	0 50	0·5	A series of thickenings decreasing in amplitude.
Cordova	16 30·0	16 32·5	1 20	4·0	
Mauritius	16 42·4	17 26·2	1 42	4·0	
Trinidad	16 56·0	17 8·0	0 35	1·0	
Baltimore	16 49·0	—	0 7	0·3	
Toronto	16 49·0	—	0 11	0·1	
Victoria, B.C.	16 51·8	16 55·5	0 3	0·1	
San Fernando	16 47·0	17 29·0	1 11	0·5	
Shide	17 19·5	17 26·7	0 30	0·5	
Kew	17 19·5	17 28·0	0 24	0·4	
Bidston	16 55·0	17 26·2	0 42	0·4	
Edinburgh	17 20·0	17 27·5	0 21	0·2	
Tiflis	16 53·9	16 59·7	—	0·4	
Irkutsk	16 48·4	18 18·5	3 28	—	
Taschkent	16 44·4?	17 48·3	2 0	—	
Dorpat	16 55·8	17 23·9	—	—	
Strassburg	16 46·5	—	1 15	—	
Hamburg	17 1·9	—	—	—	

A well-defined seismogram obtained at Cordova indicates an origin about 12° distant from that place. The probability is that the same lies to the W. of Cordova off the West Coast of South America, or 75° W. Long. and 30° S. Lat. The approximate time at the origin would be about 9 minutes earlier than the time of arrival of M at Cordova, or 16.23. The area over which it was recorded may be represented by a radius of 100°. In New Zealand and at the Cape of Good Hope, which lie within this distance, however, it does not appear to have been noted.

	Distance.	Minutes.		Average arcual velocity in degrees per minute.		
	D.	C.	M.	P_1.	P_2.	P_3.
	°					
Cordova	12	7	9	1·7	—	1·3
Trinidad	45	33	45	—	—	1·3
"Discovery"	65	24	—	—	2·7	—
Baltimore	70	26	—	—	2·7	—
Toronto	72	26	—	—	2·7	—
Victoria, B.C.	90	28	33	—	3·2	2·8
San Fernando	90	24	66	—	3·7	1·3
Shide	102	56	63	—	—	1·8
Kew	102	56	65	—	—	1·8
Bidston	103	32	63	—	3·2	1·6
Edinburgh	104	57	64	—	—	1·9
Strassburg	105	23	—	4·6	—	—
Hamburg	108	38	—	—	—	2·8
Dorpat	120	32	60	—	3·7	2·0
Tiflis	130	30	36	4·3	3·6	—
Taschkent	145	21	85	6·9	—	1·7
Irkutsk	178	25	55	7·1	3·2	—

As already noted for Earthquake No. 50, the values for P_1 increase with the length of the arc, while the values for P_2 and P_3 are fairly constant.

73. *March* 30.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	3 31·4	3 40·5	2 13	0·5	A series of thickenings and bead-formed groups of waves. Times approximate.
Christchurch	3 38·6	4 1·1	2 5	1·5	
Perth	3 28·6	3 43·2	1 4	5·2	
Tiflis	3 36·4	3 46·0	—	0·8	
Batavia	3 26·7	3 35·8	1 6	7·0	
Bombay	3 38·4	4 2·6	0 40	0·6	
Calcutta	3 37·3	3 42·0	0 45	1·5	
Mauritius	3 42·5	4 3·4	0 33	0·6	
San Fernando	4 32·0	4 56·0	0 37	0·5	
Shide	3 55·0	—	—	—	
Irkutsk	4 59·2	4 59·6	0 6	0·6	
Kew	4 25·0 ?	—	—	—	
Bidston	3 43·0	3 52·6	0 27	—	
Edinburgh	4 22·5	—	0 9	—	
Manila	3 26·4	3 26·9	2 21	—	
Taschkent	3 19·9	3 40·9	—	—	
Dorpat	3 46·7	4 26·3	—	—	
Strassburg	3 41·6	—	1 20	—	
Hamburg	3 46·3	—	2 14	—	

The records from Batavia, Manila, and Irkutsk point to an origin near Ceram and 25° distant from Batavia. At Amboina three heavy shocks were felt at 3h. 5m. There was also a heavy shock at 3h. 32m. The former was immediately followed by a disturbance in the sea. The time of origin deduced from the Batavian records is 3h. 19m., from the Manila maximum 3h. 15m., and from the Calcutta maximum 3h. 14m., which neither accord amongst themselves or with local observations.

The disturbance did not reach Cape Town, or Victoria, B.C., but travelled westwards across Asia and Europe.

74. *April* 3.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	4 24·3	—	0 44	0·2	
Batavia	4 45·7	4 56·6	0 30	0·6	

It is possible that these entries refer to distinct disturbances.

75. *April* 3.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	8 58·9	—	0 50	0·2	Minute irregular serrations.
Irkutsk	9 57·4	10 5·5	0 31	0·7	
Tiflis	10 6·8	10 28·7	—	1·0	
Calcutta	10 18·7	—	0 24	—	
Mauritius	8 5·8	—	0 3	—	
Victoria, B.C.	9 40·6	9 46·8	0 22	1·0	
Toronto	9 51·0	9 57·1	0 42	1·1	
Baltimore	9 58·5	—	0 42	—	
San Fernando	10 14·5	10 27·5	0 13	—	
Bidston	10 1·9	10 12·0	0 27	0·2	
Kew	10 17·0	—	0 11	0·2	
Shide	10 17·5	10 21·5	0 20	0·3	
Strassburg	9 43·1	—	—	—	
Hamburg	9 43·7	—	—	—	
Taschkent	9 53·5	10 8·3	—	—	

A possible origin is in District B, 160° W. Long. and 40° N. Lat.

76. *April* 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 32·7	7 44·0	0 21	0·5	
Cordova	7 22·9	7 24·0	0 30	0·4	

The commencement and end of the record from Cordova is not clear, otherwise it is well defined. It is possible that the origin was off the West Coast of South America, in the same region as No. 72.

77. *April* 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	15 12·2	15 18·4	1 10	4·2	Commencement and end hidden by tremors.
Wellington.	15 16·0	15 20	0 13	1·5	
Perth	15 19·9	15 23	0 34	1·1	
Mauritius	15 40·0 ?	—	0 18	—	
Shide	16 4·0 and 16 29·6	—	—	—	(See facsimile of trace, Plate 5.)
Bidston	16 34·8	16 39·2	0 17	0·1	
Taschkent	15 33·5	16 1·7	—	—	
Tiflis	15 32·9	15 50·1	—	—	
Dorpat	16 20·0	—	—	—	

From the times of the arrival of M at the first three stations an origin is arrived at on the S.W. continuation of the New Zealand axis, or approximately at 140° E. Long. and 55° S. Lat. The times of arrival of the larger waves at Shide and Bidston, roughly 160° distant from the origin, indicate they refer to the disturbance recorded by the "Discovery." The superficial area disturbed by this earthquake was apparently a band 50° in width running from its origin in a N.W. direction to its antipodes. It does not appear to have reached the continent of North and South America to the N.E. and E., Java, Manila, or Japan to the N., India to the N.N.W., or the Cape of Good Hope to the W.N.W.

78. *April* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	23 10·8	23 48·3	1 18	1·0	P_1 lasts 16 minutes.
Mauritius	23 2·7	23 4·2	0 6	0·2	
San Fernando. . . .	23 44·7	23 51·7	0 10	0·7	
Tiflis	23 0·4 ?	23 21·6	—	—	

Assuming that these records refer to the same earthquake, the inference is that the area disturbed is similar to that given for No. 77.

79. *April* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	3 16·8	—	0 24	0·2	

Origin local.

80. *April* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	12 1·4	—	0 6	0·5	
Perth	11 49·3	11 50·5	0 6	0·3	

The origin is probably on a line joining these stations 125° E. Long., 50° S. Lat.

81. *April* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	2 49·4	—	0 25	0·2	
Cordova	2 51·4	—	0 10	0·1	
Cape Town	2 1·7	2 14·0	4 20	0·5	
Taschkent	3 6·6	3 25·5	—	—	Probably local.

The above records suggest an origin 60° distant from the first two stations, and about 6° S.S.W. from Cape Town, or 18° E. Long. and 40° S. Lat.

82. *April* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	4 21·1	4 30·3	2 15	1·0	Groups of bead- and gourd-shaped waves.
Wellington	{ 3 8·0 or 4 15·2 }	4 22·0	5 20	11·0	
Christchurch	4 10·8	4 28·8	2 6	8·5	
Perth	4 24·3	4 45·3	1 37	2·5	
Tiflis	4 24·5	5 28·8	1 35	0·5	
Cordova	4 33·1	4 43·2	0 12	0·5	
Irkutsk	4 32·6	—	0 53	—	
Batavia	4 15·2	5 5·5	1 30	2·1	
Bombay	4 38·8	5 23·5	2 9	1·5	
Mauritius	4 10·7	5 14·8	3 6	1·4	
Cape Town	5 9·5	—	—	—	Boom not free.
Baltimore	4 41·0 ?	5 30·0	1 30	1·2	
Victoria	4 32·0	—	0 29	0·1	Boom partly anchored.
Toronto	4 40·0	5 24·0	1 38	1·0	
San Fernando . . .	4 44·3	5 54·0	1 48	2·0	
Paisley	—	5 48·0	—	—	
Edinburgh	5 32·0	5 50·0	1 6	0·5	
Bidston	5 0·0	5 52·7	1 3	1·0	
Kew	5 33·5	5 48·5	2 2	1·6	
Shide	5 26·5	5 53·1	2 0	1·5	(See facsimile of trace, Plate 5.)
Manila	4 20·0	—	4 8	—	
Taschkent	4 31 4	5 23·6	—	—	
Dorpat	4 28·4	5 27·6	2 0	—	
Strassburg	4 29·6	—	1 40	—	
Hamburg	4 29·1	4 39·8	2 22	—	

From the amplitude of movement and the time of arrival of the large waves at Wellington it is evident that the origin of the disturbance was nearer to that station than to any other. This is one of the largest earthquakes which has been recorded with its origin in district M. It disturbed the whole world. The time of origin based on the value of M – C for the nearer stations would be 4h. 5m., or half-an-hour after the occurrence of a disastrous earthquake in Caucasia, distant 150°. If we read this time of origin 4h. 0m., this is the time at which the preliminary tremors from Caucasia, generated at 23h. 40m. on April 28, reached their antipodes, or the district in which the earthquake we are discussing took place.

83. *April* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	13 10·1	—	1 0	0·2	
Christchurch	13 17·0	—	—	1·3	
Taschkent	13 39·0	14 41·2	—	—	
Tiflis	14 52·7	14 53·2	—	—	

This shock originated at no great distance from Christchurch, and is in all likelihood an aftershock for No. 82. As confirmatory of this it appears that the times given for M at the two latter stations approximately accord with expectations. We have here another illustration of a disturbance only being recorded near to its origin and at its antipodes.

84. *May* 4.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	10 48·4	—	0 6	0·2	

Local origin.

May 11 to 18, the clock stopped.

85. *May* 19.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 52·7	—	0 15	0·7	
Christchurch	8 14·0	—	0 16	1·0	

Origin between these two stations.

86. *May* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	1 39·9	—	0 4	0·2	

Local origin.

87. *May* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	17 57·9	—	0 5	0·2	

Local origin.

88. *May* 23.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	22 32·4	—	0 50	0·4	Series of thickenings.
Perth {	20 16·2	20 21·0	0 19	0·3	
	22 22·9	22 31·6	0 38	1·3	
Mauritius {	20 31·1	—	0 11	—	
	22 30·0	22 50·9	0 41	0·5	
Calcutta	22 17·0	22 28·0	0 56	2·2	
Kodaikanal	21 20·0	21 25·7	0 15	0·3	
Batavia {	20 8·0	20 10·2	0 20	0·7	
	22 14·7	22 20·1	0 55	3·7	
Tokyo	22 16·6	22 19·8	0 30	0·5	
Irkutsk	22 28·0 ?	22 31·0 ?	0 37	—	
Tiflis	22 21·0	22 58·4	1 22	0·6	
Shide	23 3·8	23 19·0	0 25	0·2	
Kew	23 8·5	—	0 20	0·2	
Edinburgh	22 53·5	23 9·0	0 39	0·2	
San Fernando	23 1·5	23 14·0	0 44	0·6	
Manila	22 10·9	—	1 13	—	
Taschkent	22 19·6	22 44·9	—	—	
Dorpat	20 56·4	23 3·5	—	—	
Hamburg	22 27·7	—	—	—	
Strassburg	22 28·3	—	2 10	—	

This earthquake recorded by the "Discovery" apparently refers to the one recorded in Manila by the Vicintini seismograph. It originated in the island of Mindanao (see Earthquake No. 48), near to Davao and Caraga, at the head waters of the Rio Augusan (see 'Bulletin Philipp. Weather Bureau,' May, 1903, p. 115). Westwards across Europe and Asia the disturbance extended to Great Britain, 105° distant, but it does not appear to have reached Victoria, B.C., or Cape Town, respectively distant 95° and 105° along paths which would be suboceanic. The area covered closely resembles that for Nos. 73 or 88. The first entries for Perth, Mauritius, Batavia, and that for Kodaikanal refer to a distinct shock which may or may not be related to the one noted by the "Discovery."

The Manila record indicates the time of origin at a distance of 14° as 22h. 7m. The entries for M at Batavia, Perth, and Calcutta respectively give 22h. 7m., 22h. 6m., and 22h. 5m. as the times for the origin. The following table is constructed on the assumption that the time of origin was 22h. 7m. :—

	Distance.	Minutes.		Average arcual velocity in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Manila	9	4	—	2·2	—	—
Batavia	22	7	13	3·1	—	1·7
Tokyo	31	9	13	3·4	2·4	—
Calcutta	36	10	21	3·6	—	1·7
Perth	40	14	24	—	2·9	1·7
Kodaikanal	43	13 ?	19 ?	3·3	—	1·7
Irkutsk	46	21 ?	24 ?	—	2·2	1·9
Taschkent	61	12	37	5·0	—	1·6
Mauritius	70	23	43	—	3·0	1·6
Tiflis	76	14	51	5·4	—	1·5
Dorpat	86	—	56	—	—	—
Hamburg	100	20	—	5·0	—	—
Strassburg	101	21	—	5·0	—	—
Kew	105	—	61	—	—	1·7
Edinburgh	105	46	62	—	2·3	1·7
Shide	106	56	72	—	—	1·9
San Fernando	115	54	67	—	2·1	1·7

(See Time Curve No. 88, Plate 1.)

May 28 to 31, clock stopped.

89. *May* 31.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	6 52·9	—	0 25	0·4	
Wellington	6 32·0	6 39·0	0 20	3·5	
Perth	6 54·3	7 0·9	0 18	0·3	
Shide	7 54·9	—	0 5	0·2	
Irkutsk	6 40·8	7 15·8	1 50	—	

After reaching Wellington the shock had about 35° to travel to reach Perth, and 31° to reach the "Discovery," which indicates an origin 152° E. Long. and 48° S. Lat., or on the continuation of the New Zealand axis. The time at the origin deduced from the value M – C at Wellington would be 6h. 24m. The time taken for large waves to reach Shide, 162° distant, would be 1h. 30m. The actual arrival and the anticipated time for the same are in accordance, and we have another marked instance of antipodean reappearance.

June 1 to 5, clock stopped.

90. *June* 8.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	5 30·5	5 48·8	1 55	3·5	P_1 lasts 5m. 30s.
Perth	5 34·0	5 37·1	0 31	3·3	
Wellington	5 31·0	5 49·0	1 8	1·5	
Christchurch	5 34·5	5 49·5	1 34	2·0	
Batavia	5 31·1?	5 41·9	0 10	0·6	
Mauritius	5 45·9	5 56·4	0 46	0·6	
Calcutta	5 58·5	—	0 43	—	
Bombay	5 58·4	6 12·3	0 34	1·0	(See facsimile of trace, Plate 5.)
Kodaikanal	5 47·2	6 10·7	0 32	0·3	
Bidston	6 47·3	6 57·9	0 16	0·3	
Irkutsk	5 24·8	6 0·8	—	—	
Taschkent	5 54·0	—	—	—	
Tiflis	5 46·6	6 3·4	—	—	
Dorpat	5 11·8	6 22·3	—	—	
Hamburg	5 49·6	5 57·4	1 3	—	
Strassburg	5 45·1	—	1 0	—	

From the times given for M at the first four stations we should expect to find an origin at the centre of a circle which passed through Perth and touched a circle of 15° to 18° radius which passed through Wellington, Christchurch, and the "Discovery." This indicates a locality 120° E. Long. and 42° S. Lat. The probability, however, is that the same is to be found 10° farther eastwards on the line of the New Zealand axis. That the time of arrival for M at Bidston is 80 minutes later than Perth accords with this supposition. The area shaken closely resembles that for No. 88.

91. *June* 8.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	14 39·2	—	0 16	0·5	Time approximate.
Shide	12 44·4 and 14 34·1	—	0 6	0·2	Both shocks are similar.
Kew	14 46·2	14 56·0	0 15	0·4	

Antipodean disturbances which are nearly simultaneous.

92. *June* 9.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	11 22·3	—	1 20	0·2	A series of thickenings. Times approximate.
Christchurch	11 16·6	11 18·7	0 22	3·0	
Perth	11 35·4	11 45·2	0 32	0·6	
Batavia	11 37·7	11 54·7	0 30	0·4	
Mauritius	11 51·6	12 9·1	0 35	0·4	
Paisley	—	12 42·5	—	—	
Shide	12 7·1	—	0 14	0·2	
Tiflis	11 7·6	11 19·8	—	0·6	
Strassburg	11 38·7	—	0 50	—	

The differences in time between C and M at Christchurch, Perth, and Batavia indicate an origin on the S.W. continuation of the New Zealand axis, or approximately 150° E. Long. and 50° S. Lat. The area shaken practically resembles that for 77.

93. *June* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	22 30·8	22 40·1	0 30	0·5	
Christchurch	22 18·1	22 22·9	—	2·1	
Perth	22 38·9	22 43·7	0 50	2·1	
Irkutsk	22 33·6	23 0·4	2 0	—	
Strassburg	22 29·6	—	—	—	

Although this disturbance was not recorded in Britain, it was noted in Strassburg. The area shaken is, therefore, similar to that given for No. 92. Also certain time intervals; for example, the interval between C and M at Christchurch approximates to those for No. 92. From resemblances like these it may be concluded that these disturbances had their origins in the same district.

94. *June* 17.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	20 6·9	—	0 10	0·2	
Cordova.	19 34·1	19 36·1	0 8	0·5	
Mauritius	20 28·4	20 37·7	0 9	—	
Bidston	20 21·8	20 31·5	0 19	0·3	
Shide	20 29·2	—	—	0·2	
Taschkent	20 42·6	20 55·2	—	—	
Dorpat	20 46·4	—	—	—	
Strassburg.	20 10·6	—	—	—	

The origin was evidently nearer to Cordova than to any other station, and at a distance of about 10° from that city measured westwards. The time taken for phase M to travel such a distance would be 6 minutes. The time at the origin would, therefore, be about 19h. 30m. With this assumption the times at which P_3 would be expected to reach the "Discovery," Mauritius, and Britain would be 20h.10m., 20h. 40m., 20h. 35m., which are not widely different from the observations. The area disturbed is somewhat similar to No. 72, which had an origin in the same region.

95. *June* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	8 6·5	—	0 10	0·2	
Christchurch	7 43·9	—	0 33	0·3	
Bidston	8 58·7	9 2·9	0 21	0·2	
Shide	9 0·6	—	0 45	0·2	
Taschkent	8 20·3	8 29·0	—	—	

There is also a record from Cordova at 7 16·8, but as the duration is 8 hours, it suggests a tremor storm. If it is assumed that the shock originated a few minutes before 7.43, and at no great distance from Christchurch, the times of arrival for P_3, as noted at the other stations, approximate to what would be expected. It is, however, difficult to understand why records were not obtained at stations lying between New Zealand and its antipodes.

96. *June* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	13 13·1	—	0 45	0·3	
Bidston	14 17·3	14 24·0	0 33	0·2	
Shide	14 18·2 and 14 30·5	—	0 35	0·2	

A disturbance was also noted at Strassburg at 13.24 by a Rebeur-Ehlert pendulum, and at 14.22 by a Milne pendulum. In Taschkent there was a record at 13 27·7.* The time interval for M between the "Discovery" and the English station lies between 71 and about 96 minutes. If the shock originated in the Antarctic region, we should expect the interval to have been about 90 minutes (see Nos. 91 and 95).

97. *June* 27.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	4 35·6	—	0 10	0·2	

Local origin.

98. *June* 27.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	6 16·3	—	0 25	0·2	

Local origin.

* This is in the Strassburg register for June, but not in the 'Russian Bulletin,' April to June, 1903. For June 24 in the 'Bulletin' there is a shock, recorded at Irkutsk 13.6, Taschkent 13 0·5, Tiflis 13.8, which may correspond with a record for Mauritius 13.49 with a maximum at 14.4.

99. *June* 28.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	13 23 ·9	—	0 5	0 ·2	

Local origin.

100. *July* 2.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	21 32 ·4	—	0 55	0 ·5	
Christchurch	21 21 ·6	21 30 ·5	0 13	1 ·4	
Batavia	21 33 ·1	21 57 ·5	0 40	0 ·5	B.A. Register gives date as July 3.
Mauritius	21 37 ·1	22 16 ·1	0 54	0 ·3	
Bidston	21 52 ·9	22 2 ·0	0 27	0 ·4	
Shide	21 40 ·2	22 2 ·5	1 15	0 ·2	
Manila	21 24 ·4	21 25 ·1	0 47	—	
Tiflis	21 36 ·1	21 54 ·7	—	—	
Strassburg	21 34 ·5	—	1 30	—	
Hamburg	21 32 ·5	—	2 0	—	

The records from Christchurch, Batavia, and Mauritius indicate an origin 150° E. Long. and 50° S. Lat., or on the submerged New Zealand axis. The area disturbed is similar to that for No. 73, &c.

101. *July* 3.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	21 24 ·5	—	0 12	0 ·2	
Batavia	21 33 ·1	21 57 ·5	0 40	0 ·5	

The seismic character of the "Discovery" record is doubtful.

102. *July* 8.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	2 58 ·0 (abt.)	—	0 25	0 ·5	
Batavia	2 58 ·0	2 59 ·1	0 7	0 ·6	

A shock was felt at Bantam, Java, at about 2h. 56m.

103. *July* 9.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	4 40 ·6	5 11 ·1	>0 50	0 ·7	Time of commencement and end uncertain.
Christchurch	4 52 ·2	5 19 ·3	—	—	

Approximate origin, 150° E. Long. and 60° S. Lat.

104. *July* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	5 38 ·7	6 7 ·2	1 12	0 ·5	The first entry probably refers to a maximum phase.
Christchurch	4 28 ·3	4 46 ·7	0 24	2 ·5	
Perth	5 34 ·5	5 49 ·9	0 50	2 ·1	
Irkutsk	5 13 ·1	5 14 ·6	1 36	0 ·4	
Tiflis	5 36 ·8	5 45 ·6	—	0 ·4	
Mauritius	5 40 ·6	6 15 ·9	1 4	0 ·2	
Cape Town	5 37 ·0	6 23 ·5	0 51	0 ·05	
Baltimore	6 23 ·2	6 43 ·1	1 0	0 ·6	
Victoria, B.C.	5 42 ·0	6 34 ·0	1 1	1 ·0	
San Fernando	6 35 ·2	6 53 ·9	—	—	
Bidston	6 15 ·1	6 26 ·8	0 28	0 ·3	
Kew	6 11 ·7	—	0 6	0 ·3	
Shide	5 48 ·1	6 44 ·0	1 55	0 ·7	
Taschkent	5 21 ·0	5 50 ·3	—	—	
Dorpat	4 29 ·0	6 24 ·0	—	—	
Strassburg	5 38 ·8	—	1 20	—	
Hamburg	5 39 ·9	—	2 20	—	

The records from Christchurch, Perth, and Irkutsk indicate an origin 150° E. Long. and 5° S. Lat., or E. of New Guinea.

It does not appear to have been recorded at Batavia, Manila, and three Indian stations which are comparatively near or at Cordova in South America. With these exceptions it was noted all over the world.

105. *July* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	13 27 ·6	13 35 ·7	0 18	0 ·5	

Local origin.

106. *July* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	4 0 ·0(abt.)	—	0 23	0 ·2	
Christchurch	4 35 ·0	—	0 12	—	
Victoria, B.C.	4 8 ·0	4 12 ·0	0 13	0 ·4	
Toronto	4 1 ·2	—	0 4	0 ·1	
Edinburgh	4 31 ·0	—	0 4	0 ·2	
Bidston	4 21 ·0	4 28 ·3	0 20	0 ·3	
Kew	4 30 ·5	—	0 4	0 ·2	
Shide	4 24 ·5	—	0 10	0 ·5	
Strassburg	4 3 ·0	—	—	—	
Taschkent	4 19 ·6	4 45 ·3	—	—	
Dorpat	4 14 ·7	4 14 ·3	—	—	

All these entries excepting that for the "Discovery" refer to July 28.

We have here a small disturbance which seems to have extended round the northern hemisphere N. of latitude 30°, and to have also been recorded at Christchurch and possibly by the "Discovery" in the southern hemisphere.

107. *August* 11.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	4 40 ·8	5 11 ·6	2 20	0 ·4	
Irkutsk	4 46 ·5	5 10 ·7	0 50	0 ·3	
Tiflis	4 37 ·1	4 41 ·7	2 4	2 ·7	
Taschkent	4 32 ·1	4 51 ·6	—	1 ·0	
Kodaikanal	—	4 50 ·7	—	0 ·5	
Bombay	4 48 ·0	4 51 ·9	0 33	1 ·4	
Mauritius	4 53 ·2	4 54 ·3	—	0 ·5	
Cape Town	4 52 ·9	5 9 ·8	0 40	0″ ·48	
Victoria, B.C.	4 56 ·0	—	0 48	0 ·2	
Toronto	4 53 ·5	—	0 32	0 ·2	
San Fernando	4 39 ·2	4 43 ·8	1 7	4 ·0	A tremor at Lisbon.
Cairo	4 33 ·5	4 42 ·0	0 52	2 ·5	
Paisley	4 42 ·0	4 44 ·0	0 43 ?	3 ·0	
Edinburgh	4 38 ·5	4 43 ·8	0 51	3 ·7	
Bidston	4 37 ·0	4 43 ·6	0 57	2 ·3	
Kew	4 37 ·8	4 42 ·0	0 42	3 ·3	
Shide	4 35 ·9 ?	4 44 ·1	0 40	2 ·0	
Manila	4 45 ·5	4 46 ·3	0 24	—	
Dorpat	4 17 ·1	4 45 ·9	—	—	
Hamburg	4 36 ·3	—	2 28	—	
Strassburg	4 36 ·8	—	1 20	—	

This earthquake originated in the eastern part of the Mediterranean and was felt in Southern Italy, Cairo and Constantinople. At about 4.25 it was severe in the Island of Cerigo which was near the epicentre. In Athens there were heavy shocks at 4 31·7 and 4 33·0. The time of origin deduced from the first records in Athens would be 4h. 30m. ± 30s.

The time of origin deduced from observations made at comparatively near stations is shown by the following table:—

	Distance.	Time to travel.	Time at origin.
	°	m.	h. m.
Tiflis	18 ·0	11 ·0	4 30 ·7
Kew	20 ·0	12 ·0	4 30 ·0
Shide	21 ·0	13 ·0	4 31 ·1
San Fernando	22 ·0	14 ·0	4 29 ·8
Bidston	23 ·5	14 ·5	4 29 ·1
Edinburgh	24 ·0	15 ·0	4 28 ·8
Taschkent	33 ·0	20 ·5	4 31 ·1
		Mean value	4 30 ·08

The following velocity table is constructed on the assumption that the shock originated near Cerigo at 4.30. (See Time Curve No. 107, Plate 1, and Map, Plate 2.)

	Distance.	Minutes.		Average arcual velocities in degrees per minute.		
	D.	*C.*	*M.*	P_1.	P_2.	P_3.
	°					
Cairo	12	3·5	12	3·43	—	1·0
Strassburg	17	6·5	—	—	2·5	—
Tiflis.	18	7·0	12	—	2·57	1·50
Hamburg	19	6·0	—	3·16	—	—
Kew	20	7·8	12	—	2·56	1·66
Shide	21	6·0 ?	14	3·50 ?	—	1·50
Dorpat	21	−13·0	16	—	—	1·31
San Fernando . .	22	9·0	14	—	2·44	1·56
Bidston	23	7·0	14	3·28	—	1·64
Edinburgh	24	8·0	14	3·0	—	1·71
Paisley	24	12·0 ?	14	—	2·00 ?	1·71
Taschkent	33	2·0	21	16·5	—	1·56
Bombay	46	18·0	22	—	2·55	2·09
Kodaikanal . . .	56	—	21	—	2·66	—
Irkutsk	59	16·0	40	—	3·68	1·47
Mauritius	65	23·0	24	—	2·82	2·70
Cape Town . . .	69	23·0	40	—	3·00	1·72
Toronto.	70	23·0	—	—	3·04	—
Manila	85	15·0	16	5·66	5·31	—
Victoria	90	26·0	—	—	3·45	—
"Discovery" . . .	140	10·0	42	14·0	3·33	—

If we omit the values for P_1 for Taschkent and the "Discovery," as they are abnormally large, and that for Manila as being too small, the inference is that this phase of motion did not announce itself at stations more than 24° distant from its origin. P_2 reached a distance of 90° or 140°, whilst P_3 was lost at a distance of 70°. For area disturbed see Map (Plate 2).

108. *August* 11.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	10 50·1	—	0 5	0·2	
Hamburg	11 5·3	—	0 47	—	
Strassburg	11 1·5	—	0 20	—	

This is probably a shock which originated in region M some time before 10.50. If a phase P_1 had been transmitted to Europe it would reach the German stations at about the time records were obtained.

109. *August* 12.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	0 50·9	—	0 20	0·2	
Perth	0 53·7	1 1·6	0 18	0·5	

Records of a small disturbance were also obtained in Strassburg at 0.48 and Hamburg at 0.47. The origin which would accord with the first two records would lie on the S.W. extension of the New Zealand axis.

110. *August* 12.

"Discovery" 17 2·6 and 17 39·0. Each with a duration of 5m. and an amplitude of 0·2 millim Local origin.

111. *August* 17.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	18 21·9	18 29·0	0 20	0·4	
Cordova	18 9·2	18 10·2	0 19	0·1	
Irkutsk	18 44·2	18 45·0	0 5	0·4	
Taschkent	18 36·8	19 31·1	0 31	—	
Dorpat	18 52·0	—	—	—	

The first two records suggest an origin off the South American coast, W. of Cordova, to which Irkutsk and Taschkent are antipodean.

112. *August* 19.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	9 21·2	9 44·5	1 50	0·5	
Christchurch	9 43·6	9 55·0	0 32	0·5	
Calcutta	10 4·3	—	0 29	—	
Cape Town	8 58·6	9 19·7	0 38	0·1	
San Fernando	9 48·8	9 57·4	0 31	0·4	
Bidston	—	10 40·0	—	—	
Shide	10 0·1	—	0 25	0·2	
Taschkent	9 25·1	10 5·4	—	—	
Irkutsk	9 23·5	9 42·0	2 12	—	
Strassburg	9 22·9	—	1 15	—	

The position of the origin is very uncertain. A possible origin would be 20° to 40° S.E. from Cape Town.

113. *August* 21.

	C.	M.	D.	A.	Remarks.
	h. m.		h. m.	millim.	
"Discovery"	14 16·0	—	0 5	0·2	

The absence of other records and the sudden commencement indicate a local origin.

114. *August* 25.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	12 16·7	12 33·8	0 30	0·2	Times of beginning and end are uncertain.
Taschkent	12 35·7	12 42·3	—	—	

It is probable that the "Discovery" record refers to a disturbance of Antarctic origin.

115. *August* 26.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	13 14·2	13 33·5	0 30	0·5	
Perth	13 17·0	13 28·0	0 28	0·2	
Bidston	13 58·2	14 5·3	0 18	0·2	
Taschkent	13 30·0	13 45·9	—	—	

The origin probably lies in the S.W. extension of New Zealand axis, nearly equidistant from the "Discovery" and Perth. The interval between C at Perth and C at Bidston suggests that the record at the latter station refers to P_2.

As there are no records from intermediate stations, the Bidston entries suggest an antipodean reinforcement or resurgence.

116. *August* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	16 57·5	—	0 5	0·2	
Cordova	15 20·9	15 24·4	0 17	1·5	
Irkutsk	15 35·5	16 16·0	4 5	—	
Taschkent	15 59·6	16 43·7	0 11	—	
Bidston	15 59·5	16 6·3	0 18	0·3	
Strassburg	15 37·7	—	—	—	
Hamburg	15 38·0	—	1 8	—	

The Cordova record refers to a disturbance that was felt at that city and in Tinogusta at 14h. 43m. The great difference in time between the times given for these localities suggests that they may refer to distinct disturbances.

From the value M – C for Cordova the inference is that the disturbance originated at a spot about 15° distant from that city, and from this it follows that the time of origin would be about 15h. 16m.

The records for Strassburg and Hamburg may refer to P_1 or P_2, but most likely the latter. The value for M at Bidston indicates a time at which P_3 might be recorded.

The record for Taschkent is suggestive of an antipodean focal effect.

The disturbed area is not unlike those for Nos. 94 and 111.

Instrument dismounted August 31 until September 22.

117. *September* 23.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	0 26·1	0 27·1	0 25	0·8	
Christchurch	0 17·0	0 21·7	0 32	0·8	
San Fernando	1 37·3	1 49·3	0 21	0·6	
Paisley	1 52·7	1 53·3	0 6	0·5	
Edinburgh	1 53·5	1 54·5	0 5	0·4	
Kew	1 50·8	—	0 6	0·4	(See facsimile of trace, Plate 5.)
Shide	1 49·4	1 50·4	0 7	0·5	
Tiflis	1 23·1	1 22·7	—	0·5	
Strassburg	1 46·3	—	0 35	—	
Hamburg	1 46·8	1 55·7	—	—	
Irkutsk	1 28·6	1 37·9	1 0	—	
Taschkent	0 44·6	1 28·9	—	—	
Dorpat	1 27·4	1 34·3	—	—	

At 1.45 a shock was felt in Algiers. There were two heavy shocks in Blidah, near Algiers, and also about this time there were two in the Canaries. The time records indicate that the origin was about 12° distant from Christchurch, and after the shock reached this station it had yet 10° to travel before arriving at the "Discovery." The probability, then, is that it lies approximately in 160° E. Long. and 52° S. Lat. The time at the origin would be about 0.14. Large waves or P_3 would reach Western Europe at 1.44 to 1.45, indicating that the C and M records for European stations both refer to this particular phase. That shocks should have been felt in Northern Africa at the time when these waves arrived is worthy of note as also is the absence of records at stations lying between the origin and Europe.

We have here a case not only of antipodean convergence, but possibly also of wave convergence resulting in the relief of seismic strain.

The area over which it was recorded extends as a band from New Zealand in a N.W. direction over Western Asia and Europe, which band might possibly be continued round the world.

118. *September* 23.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 27·7	7 33·7	0 30	0·5	
Christchurch	7 19·1	7 23·2	0 31	0·5	

Origin like No. 117.

119. *September* 26.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	5 53·8	5 56·9	0 25	4·5	
Christchurch	6 15·0	6 17·8	0 24	1·3	(See facsimile of trace, Plate 6.)
Taschkent	6 32·8	—	—	—	

The value M – C at the first two stations indicates an origin about 14° distant from each. The two values for M and the great difference between the two amplitudes, however, indicate that the origin was nearer to the "Discovery" than to Christchurch. A possible and extremely likely origin lies on the continuation of the New Zealand axis or in Long. 145° E. and 52° S. Lat. With a time of origin at 5.50 we should expect P_2 to reach Taschkent at 6.24, and P_3 at 7.2. The record at that place may therefore refer to a local shock, and is not connected with the "Discovery" observations.

120. *October* 4.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	5 6·2	—	0 20	0·2	Time approximate.
Christchurch	5 2·4	5 5·7	0 27	1·0	
Baltimore	5 55·0	6 4·5	0 14	0·3	
Bidston	6 7·2	6 12·7	0 23	0·4	
Kew	6 19·2	—	0 11	0·2	
Shide	6 0·3	6 4·4	0 45	0·5	

The origin was apparently about 14° distant from Christchurch and nearer to that station than to any other. The time of origin would be about 4.57, and if the position of this origin is on the S.W. continuation of the New Zealand axis we should expect the time of arrival of phase P_3 at British stations to be about 6.27, which, when we consider the durations given for these stations, might well be the case.

Baltimore and the British stations, it may be remarked, are about equidistant from the antipodes of the supposed origin. (See No. 117.) It may be noted that this disturbance was not recorded at Hamburg, Strassburg, or Russian stations, at all of which there are instruments of much greater sensibility than the Milne type.

121. *October* 8.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	11 17·4	11 19·5	0 38	1·0	(See facsimile of trace, Plate 6.)
Cordova	11 12·2	—	0 27	0·5	

Origin about 15° distant from the "Discovery," probably in the direction of Cordova.

122. *October* 14.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	3 40·1	4 8·6	0 50	0·4	
Christchurch	3 32·2	3 52·8	0 37	0·8	
Perth	3 20·0	3 29·0	0 25	—	
Irkutsk	3 32·3	3 46·7	0 25	—	
Tokyo	3 32·7	3 33·4	0 8	0·4	
Batavia	3 9·7	3 33·5	0 45	0·8	
Calcutta	3 35·4	—	0 29	—	
Shide	4 4·5	—	0 15	0·2	
Manila	3 18·0	3 18·5	0 27	—	
Taschkent	3 35·0	3 49·3	0 24	—	
Tiflis	—	3 42·9	—	—	
Dorpat	3 41·8	4 5·8	—	—	
Strassburg	3 33·4	—	1 5	—	
Hamburg	3 35·4	—	—	—	

By the method of circles, with Manila as zero, an origin is indicated in or near the Carolines, 130° E. Long. and 10° N. Lat. The determination is, however, vague.

It may be noted that the disturbance does not appear to have passed beneath the Pacific Ocean to stations in North America, whilst it has been transmitted to a great distance across the continents of Asia and Europe. Whether this indicates an oceanic damping effect, or results from the direction of the initial impulse, is open to conjecture. (See map.)

123. *October* 14.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	7 26·9	7 35·2	0 25	0·5	
San Fernando	7 24·1	7 49·4	0 45	0·8	

The two values for C suggest an origin somewhat nearer to San Fernando than to the "Discovery." The interval M – C for San Fernando indicates an origin some 60° distant from that station. An origin may, therefore, be sought in the western part of the Southern Atlantic in about 35° W. Long. and 20° S. Lat. This shock could not have been recorded at Cordova, because at the time of its occurrence a tremor storm was in progress at that station. It is not likely to have disturbed the instruments in Cape Town, as shocks spreading in this direction have not so far made themselves sensible at that place (see Nos. 72, 94, and 116, &c.).

The suggested origin, although it does not accord with the value M – C for the "Discovery," is quite in accordance with the amplitude and duration noted at that station.

124. *October* 20.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	2 58·5	3 22·9	1 10	0·5	
Perth	3 6·8	3 21·7	0 42	1·8	
Irkutsk	3 15·7	3 17·2	0 5	—	
Batavia	3 9·0	3 25·0	0 50	0·6	
San Fernando	4 19·4	4 38·7	0 37	1·0	
Bidston	4 12·5	4 22·0	0 38	0·2	
Shide	4 1·5	4 16·9	0 50	0·5	
Taschkent	3 18·0	3 53·3	—	—	
Tiflis	—	3 34·7	—	—	
Dorpat	3 29·5	4 2·8	2 13	—	
Strassburg	3 10·0	—	—	—	

The area disturbed resembles that for number 122, but the position of the origin beyond being in the eastern seas is very uncertain. It does not appear to have reached North America, but, avoiding India, it has travelled westwards across Asia and Europe.

125. *October* 21.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	10 15·9	10 35·2	1 40	3·5	C refers to P_2.
Perth	10 14·1	10 21·1	1 7	3·1	
Tiflis	10 13·7	10 47·8	0 47	1·9	
Tiflis	10 8·9?	10 28·9	—	—	
Cordova	—	10 21·9	1 19	0·1	
Irkutsk	10 24·4	11 7·8	1 24	—	
Irkutsk	10 15·0	10 37·0	—	—	
Kodaikanal	10 14·1	10 20·7	0 51	1·9	Local shock.
Bombay	10 1·3	10 27·5	1 7	1·2	
Calcutta	10 19·1	10 45·5	0 54	1·0	
Cape Town	10 3·0	10 9·7	0 59	0·3	
Victoria, B.C.	10 42·0	—	0 27	0·1	
Toronto	10 40·5	—	0 54	0·1	
San Fernando	10 19·6	10 52·6	2 13	4·0	
Paisley	10 30·0	—	0 55	1·5	
Edinburgh	10 24·5	10 30·5	0 24	0·3	
Bidston	10 24·0	10 57·7	1 25	1·4	(See facsimile of trace, Plate 6.)
Kew	10 23·5	11 0·0	0 48?	0·8	
Shide	10 20·9	10 54·4	1 15	0·2	
Azores	10 27·2	10 54·7	1 4	0·5	
Cairo	10 16·0	10 37·0	1 20	2·2	
Taschkent	8 41·4	10 33·5	—	—	
Strassburg	10 10·5	—	2 0	—	
Hamburg	10 11·8	10 24·9	—	—	

Approximate origin 50° to 60° E. Long. and 30° S. Lat., S.E. of Madagascar. The area disturbed is represented by the surface of the globe.

126. *October* 24.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	1 22·1	1 34·2	0 40	0·5	
Cape Town	1 10·0	1 15·7	0 19	0·07	
Bidston	2 2·8	2 7·1	0 16	0·2	
Shide	2 3·7	—	0 5	0·2	
Taschkent	1 36·0	3 0·2	—	—	
Tiflis	1 56·7	—	—	—	
Dorpat	2 8·0	—	0 34	—	
Strassburg	1 30·0	—	0 60	—	

Possible origin, 35° E. Long. and 55° S. Lat., but this is very uncertain.

127. *October* 29.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	14 35·9	{14 51·0, 14 57·3}	2 20	2·7	
Irkutsk	{14 42·6 and 14 33·7}	{15 47·1, 14 49·5}	1 32	0·9	
Batavia	14 30·3	14 56·3	1 40	1·6	
Kodaikanal	14 44·1	15 16·1	1 5	0·5	
Cape Town	—	15 32·5	0 36	—	
Baltimore	14 19·0	15 44·5	1 27	0·6	
Victoria	14 43·5	15 41·0	1 11	0·2	(See facsimile of trace, Plate 6.)
Toronto	15 25·2	16 0·0	1 3	0·5	
San Fernando	12 17·0	16 0·2	4 22	1·1	
Edinburgh	15 51·5	16 3·0	0 52	0·4	
Bidston	15 1·3	15 48·6	1 20	0·8	
Kew	15 2·0	15 51·5	1 11	0·5	
Shide	15 2·5	15 49·2	1 35	0·5	
Azores	14 41·1	15 1·1	0 56	0·2	
Taschkent	14 46·8	14 59·3	—	0·5	
Tiflis	14 41·9	15 40·8	—	0·5	
Strassburg	14 39·5	—	2 30	—	
Hamburg	14 39·8	14 59·1	—	—	

In the register for Christchurch, Earthquake No. 158, an earthquake is entered with C for large waves at 14 29·9, M 14 36·5, and with A = 11·5 millims., for October 20. It appears likely that this is a misprint for October 29. If this correction is accepted, an origin is arrived at near to 140° E. Long. and 55° S. Lat., in the extension of the New Zealand axis. The time of origin would be about 14.21, and from this origin the large waves would reach Batavia, India, the Cape, and England close upon the times they were noted to arrive. The area disturbed is represented by the surface of the globe.

128. *October* 30.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	3 47·0	{4 22·7, 4 30·9}	2 15	2·0	P_1 lasts 24·4m. P_2 lasts 11·2m.
Christchurch	3 30·1	{4 10·0 to 4 20·0}	>1 0	>6·0	
Perth	3 53·4	4 28·3	1 20	5·2	
Batavia	4 13·8	4 43·9	1 20	1·2	
Kodaikanal	4 44·1	4 55·8	0 40	0·5	
Bombay	4 51·6	5 10·2	0 35	0·5	
Cape Town	4 45·0	—	0 40	—	
Azores	4 25·2	—	0·30	0·05	
Baltimore	5 3·0	5 14·4	1 6	0·9	
Victoria	4 21·5	5 8·0	0 40	0·2	
Toronto	4 41·0	5 13·0	1 29	0·5	(See facsimile of trace, Plate 6.)
Paisley	5 5·0	5 43·0	1 18	0·2	
Edinburgh	5 27·0	6 6·0	1 3	0·3	
Bidston	4 39·6	5 28·4	1 32	0·7	
Kew	5 22·0	5 32·5	0 42	0·5	
Shide	5 14·7	5 21·8	0 50	0·5	
Tiflis	4 19·4	5 35·5	2 15	0·3	
Irkutsk	3 56·1	4 45·1	—	—	
Irkutsk	5 16·9	5 21·5	0 21	0·5	
Taschkent	4 19·4	4 39·5	—	—	
Hamburg	4 14·0	—	—	—	
Strassburg	4 15·5	—	2 30	—	

The records for M and A at the first four stations suggest an origin in the same district as No. 127. The values M − C for the first three entries, however, are far greater than would be expected. The disturbance spread all over the world.

129. *October* 30.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	15 12 ·6	15 25 ·7	1 5	0 ·5	
Christchurch	12 0±	15 7 ·3	—	1 ·3	
Perth	15 14 ·6	15 26 ·1	0 30	0 ·7	
Bidston	16 24 ·2	16 28 ·8	0 13	—	
Shide	16 20 ·7	—	0 5	0 ·2	
Taschkent	15 32 ·5	15 57 ·4	—	—	

The quantities M - C for the "Discovery" and Perth records, and the difference between M for each of these two stations and that for Christchurch, each point to an origin in the southern extension of the New Zealand axis, or 150° E. Long. and 50° S. Lat. The time of origin would be about 14h. 57m. Large waves would be expected to reach England, 162° distant, at 16.27, from which it may be inferred that the entries for Shide and Bidston refer to this phase of motion.

It may be noted that there are no records from stations in Germany and Russia. We therefore have here another illustration of antipodean convergence.

130. *November* 1.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	18 8 ·8 or 18 11 ·9	18 38 ·0 / 18 41 ·0	1 5	0 ·2	
Christchurch	18 2 ·5	18 7 ·7	0 34	1 ·0	
Strassburg	18 13 ·0	—	1 40	—	

The entries for Christchurch suggest an origin at a distance of 15° to the S.W. of New Zealand. With a time of origin at 17.57, the anticipated arrival of P_1 at Strassburg, 155° distant, would be 18h. 17m.

131. *November* 10.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millims.	
"Discovery"	17 24 ·2	17 37 ·4	1 22	0 ·5	
Christchurch	17 23 ·0	17 29 ·2	0 57	3 ·5	
Irkutsk	17 59 ·9	18 9 ·7	0 28	0 ·1	
	17 23 ·6	18 47 ·0	—	—	
Tiflis	17 36 ·9 ?	17 38 ·0	?	0 ·3	
Bombay	18 2 ·8	18 20 ·3	0 36	0 ·4	
Baltimore	18 14 ·5 ?	18 32 ·0	0 35	0 ·4	
Victoria	17 44 ·8	18 33 ·5	1 0	0 ·3	
Toronto	18 13 ·0	18 34 ·0	0 36	0 ·3	
San Fernando	18 26 ·7	—	0 43	0 ·6	
Bidston	18 41 ·6	18 52 ·0	>0 25	0 ·9	
Kew	18 47 ·7	—	0 28	0 ·2	
Shide	18 40 ·2	—	0 35	0 ·3	
Taschkent	17 41 ·2	17 52 ·7	—	—	
Manila	18 10 ·9	18 11 ·0	—	—	
Strassburg	17 33 ·5	—	—	—	
Hamburg	17 44 ·8	—	—	—	

The values M – C for the first two stations suggest an origin like that for 129 and 130. The time at this origin would be 17h. 17m., from which it would be anticipated that the times of arrival in England would for P_3 be 18.47, at Victoria, B.C., 18.37, at Bombay 18.11, and at Manila 18.2, which are not widely different from what was observed.

With the exception of an area which would include Cape Town, Mauritius, Kodaikanal, Calcutta, Batavia, and Perth, and a second area represented by South America, this earthquake was recorded all over the world.

132. *November* 15.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	17 0 (abt.)	—	0 30	0·5	

Origin local.

133. *November* 22.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	14 11·0	14 28·0	0 49	0·5	

Local origin.

134. *November* 22.

	C.	M.	D.	A.	Remarks.
	h. m.	h. m.	h. m.	millim.	
"Discovery"	—	21 17·0	0 4	0·2	

Local origin.

November 23 to 25, no record.

135. *November* 26.

"Discovery," about 13.20 or 13.26 there is a slight thickening of the trace which may correspond to a disturbance which was recorded at nearly all stations, the only marked exceptions being Christchurch, Perth, and Cordova (see No. 789 in the Shide register). Origin, 95° E. Long., 35° N. Lat.

II. EARTHQUAKES NOT RECORDED BY THE "DISCOVERY."

In the following list dates are given for a few very large earthquakes. These disturbances, although the "Discovery" seismograph appears to have been in good working order, were not recorded by the same. The stations at which the records were obtained are indicated by their initial letters, a key to which will be found on p. 96. The time of commencement is given for the first-mentioned station only. This is noted in Greenwich Mean Civil Time (24 or 0h. equals midnight). Details respecting the observations made at the stations mentioned are contained in British Association Seismological Circulars Nos. 6, 7, 8, and 9. The only earthquakes considered are those of which the origins are at least approximately known.

1902.

March 17, Bi. 12.3, S., V., T., Bal., I., St., H., *Central Mexico.*
„ 20, Bi. 2.28, S., K., SF., C., Ba., Bal., I., St., H., *Caucasia.*
„ 22, Bi. 22.54, S., K., E., SF., T., V., CT., C., B., Ko., Tr., Bal., Ch., I., St., H., *West of Victoria or North Mexico?*
„ 24, Bi. 18.28, S., K., E., SF., T., V., Tr., Bal., I., St., H., *North Mexico or West Indies.*
April 19, Bi. 2.35, S., K., E., SF., T., V., CT., C., B., Ko., Ba., P., Bal., Ch., W., I., Cor., To., *Guatemala.*
May 25, S. 17.28, Bi., E., SF., V., CT., C., B., Ba., Bal., I., St., H., *W. Asia?*
June 11, Bi. 6.30, S., K., E., SF., T., V., CT., C., B., Ko., Ba., Bal., I., To., *East of Japan.*
„ 16, Bi. 2.16, K., B., Ko., I., St., *North-West India.*
July 5, Bi. 14.59, S., K., E., SF., T., V., CT., Ko., Cai., I., St., *East of Greece.*
„ 9, Bi. 4.2, S., K., E., SF., CT., C., B., Ko., Ba., Cai., I., St., *Bunder Abbas.*
August 3, Bi. 17.2, S., K., E., V., B., Ko., Ba., I., St., *Central Asia?*
„ 7, To. 9.22, I., St., Bi., *North-East Japan.*
„ 22, Bi. 2.56, S., E., SF., T., V., CT., B., Ko., Ba., P., Bal., I., W., Ch., Cor., To., *Kasgaria.*
„ 22, S. 15.56, Bi., E., C., Ko., Tr., I., St., *Kasgaria.*
„ 23, Bi. 13.24, E., C., Ko., I., *Kasgaria.*
„ 24, Bi, 2.12, S., E., C., Ko., Ba., I., *Kasgaria.*
September 20, Bi. 6.44, S., K., E., V., C., B., Ko., P., I., St., *North-West India.*
„ 24, Ch. 5.31, I., K., Bi., E., T., V., St., *West Indies.*
November 17, V. 19.57, T., S., K., Bi., E., Cai., I., St., *near Victoria, B.C.*
December 12, V. 23.14, T., S., K., E., SF., Tr., Bal., I., Cor., W., St., *West of Southern California.*
„ 13, C. 17.7, B., Ko., Ba., P., Cai., V., T., S., K., E., SF., I., To., St., *Central Asia.*
„ 16, B. 5.12, C., Ko., Ba., Cai., S., K., Bi., E., SF., T., V., I., To., St., *North-West India.*

1903.

January 5, To. 22.4, Ti., Ba., B., C., K., Bi., E., Pa., SF., Ta., *near Formosa.*
„ 17, V. 16.11, S., K., Bi., E., Pa., Bal., Tr., CT., I., Cor., W., Ch., P., Ti., Ta., *West Indies.*
„ 19, P. 12.44, I., Ti., Ba., Ta., S., K., Bi., Pa., *North of New Guinea.*
„ 24, V. 5.33, T., Bal., S., K., Bi., E., SF., I., Cor., P., Ti., *West of Mexico.*
„ 24, V. 15.45, T., Bal., S., K., Bi., E., Pa., SF., B., Ko., Ba., Cor., Ch., Ta., *West of Mexico.*
March 28, I. 8.3, Ti., C., S., K., Bi., E., Pa., *Ferghana.*
April 28, B. 23.52, Ko., I., Ti., S., K., Bi., E., P., SF., Cai., St., *near Tiflis.*
May 28, Ti. 3.58, Mau., S., K., Bi., E., St., *near Tiflis.*
„ 29, Bi. 9.8, S., K., E., Pa., SF., I., Ti., St., *Ionisches Meer.*

1903.

June 7, Ba. 8.49, I., CT., Mau., C., S., K., Bi., E., Pa., SF., T., St., Ho., *95° E., 30° N.*

„ 10, Ch. 16.49, W., P., I., Ba., CT., Mau., C., S., K., Bi., SF., T., V., Ho., St., *East of Philippines.*

July 27, T. 10.46, V., Bal., S., K., Bi., E., Pa., SF., Az., *North-West Atlantic.*

„ 28, Ch. 4.35, T., V., S., K., Bi., E., St., *Mid Atlantic.*

August 6, Bi. 3.59, S., E., SF., I., Ti., St., *Caucasia.*

October 10, C. 17.3, B., To., I., Ti., S., K., Bi., E., SF., St., *Coast of Japan ?*

„ 23, I. 2.40, Ti., B., S., K., Bi., E., Pa., SF., Cai., St., *90° E., 45° N.*

November 17, Ma. 20.18, Ba., I., S., K., Bi., Ho., *Philippines.*

An inspection of the above list shows that 37 large earthquakes, which without exception originated in the northern hemisphere, did not transmit motion sufficiently far south to be recorded by the "Discovery." Inasmuch as many of these were recorded over areas represented by the three northern continents, the fact that they failed to reach the Antarctic regions can hardly be attributed to want of intensity in originated impulses. The more probable explanation for the lacunæ in the "Discovery" register is that the unrecorded earthquakes represent initial efforts or blows which were not delivered in a southerly direction. Isoseists which have been drawn for earthquakes originating between New Zealand and the "Discovery" find an explanation for their form by a supposition of this description (see pp. 91 and 92) and observations on certain recent earthquakes give strength to this idea. For example, the Californian earthquake of April 18, 1906, which originated from a fault parallel to the coast of that country, gave pronounced seismograms in countries lying to the east and west of the same. With the Jamaica earthquake of January 14, 1907, where the originating line or lines of fracture were apparently east and west, the opposite took place. In Toronto a fairly marked record was obtained while a corresponding record in Europe was small.

III. CONCLUSIONS.*

(a) Changes in the Vertical.

Changes in the position of the outer end of the pendulum, which is an aluminium boom three feet in length, have been measured on the seismographic films at intervals of four hours, and in certain instances every 30 minutes. These films are strips of bromide paper each 2 inches in width and 35 feet in length. They moved beneath the end of the boom at a rate of 60 millims. per hour. The total length of film brought home by Mr. Bernacchi is about 3000 feet. One millimetre deflection of the photographic trace of the outer end of the boom is approximately equivalent to a tilt of 0·5″.

The measurement of the displacement of these traces was undertaken by my assistants, Mr. Shinobu Hirota, and Mr. Howard Burgess, of Newport, and it is in consequence of their assistance that the analyses of these records have reached their present stage. The results are at present in two forms—as a manuscript register and as a series of curves drawn on squared paper. They are in charge of the Royal Society. Before the analyses of these can be completed they must be supplemented with corresponding records from barographs and thermographs. The times of total darkness, continuous light, sunrise and sunset have already been entered on the squared paper. Also, as Mr. Bernacchi remarks, tidal fluctuations, ice movements, changes in volcanic activity may also hold some relation to the wanderings of the pendulum. It is, therefore, desirable that information relating to these phenomena should be obtained.

An examination of the curves indicates that there have been many comparatively large and rapid deflections of the pendulum, particularly after its removal from the magnetic observatory to the living hut. For example, subsequent to the removal, tiltings of 10″ have taken place in 20 hours. Displacements of this magnitude suggest a yielding of the foundations or parts of the brick column on which the instrument was installed. My own experience is that in England it takes about 12 months for a masonry pier to become stable. A pier made with a glazed earthenware drain-pipe has only its foundation to settle, and becomes stable more quickly.

There are other deviations which may be seasonal, whilst others have accompanied marked barometric fluctuations. At certain periods there have also been changes in position of the boom, indicating tilts of 0·5″ to 1·0″ which have approximately a diurnal periodicity.

In "Discovery" local time the western excursion of the pendulum was most frequently completed about 11 p.m., whilst it was usually farthest east about 3 p.m., and this took place whether there was sun or no sun. To explain these changes, possible distortions produced by sun heat on the earth's surface have been suggested.

That an accumulation of a water load in a valley apparently causes its two sides to approach each other, whilst a body of men approaching an observatory will cause a pendulum inside the same to swing towards the advancing load, have strengthened the suggestions that changes of level observed at a station might be influenced by differences in evaporation or of vegetable transpiration on opposite sides of such a building. These suggestions, although they do not directly bear upon work carried out in the Antarctic regions, have received attention.†

Another suggestion which I venture to make, and it is one which, for many reasons, I think deserves

* This section is reprinted, with alterations, from 'Proceedings of the Royal Society,' series A, vol. 76, 1905.

† See 'British Association Reports,' 1895, pp. 115–139, and 1896, pp. 212–218.

consideration, is that the observed movements are not necessarily due to tilting, but are due to electrical attractions or repulsions. Factors to be taken into account when discussing this possibility are to be found in 'Proceedings of the Royal Society,' vol. A 76, 1905, p. 286.

(*b*) Tremors and Pulsations.

As shown in the films brought home by the "Discovery," tremors usually commence as intermittent slight thickenings. The thickenings recur at shorter and shorter intervals until there is a thickened line. This may have a width of 0·2 millim. The period of the movements they represent is probably near to that of the pendulum, or 15 seconds. The duration of a storm usually lies between 6 and 20 hours. These thickenings may develop into serrations when we see that the period has been that of the pendulum. Regular movements with amplitudes of about 0·5 millim., and periods of 60 or 120 seconds, are evidently forced vibrations, and are referred to as pulsations. These various movements have been tabulated as a register, and also entered on squared paper, with the curves showing changes in the vertical. They have been placed in the charge of the Royal Society.

(*c*) Earthquakes.

Between March 14, 1902, and December 31, 1903, although there were many days when the instrument was not working, 136 earthquakes were recorded. As none of these were felt by the staff of the "Discovery," it may be assumed that none of them originated within 50 miles of the station on Ross Island. A certain number were recorded all over the world, whilst many were noted at very distant observatories. These latter must have originated at distances greater than 500 miles. The measurements of the various seismograms are contained in the accompanying register, which, as far as possible, also contains corresponding information from 43 other stations, 38 of which have seismographs similar to that used by the "Discovery."

The results of analyses point to the following conclusions :—

1. *Distributions of Origins.* (See Plate 2.)

Out of the 136 records, 73 refer to disturbances which originated in a sub-oceanic region lying between New Zealand and the "Discovery." A certain number of these were only recorded by the "Discovery," and the exact location of their origin is very doubtful; others were recorded at Christchurch and Wellington, others again reached Perth, while some travelled as far as their antipodes.

On the maps published annually by the British Association to indicate the positions of origin of large earthquakes, 12 districts are shown. These are named by the letters of the alphabet from A to L. Districts J, I, L are not of great importance. The extremely active locality, the existence of which has been made known by the work of the "Discovery," I propose to call District M. The high frequency in the relief of seismic strain in the latter region indicates pronounced brady-seismical movement, an inference which is quite consistent with the existence of the active Erebus and many other recent volcanic peaks. It also suggests that New Zealand may be continued towards the south-west as a sub-oceanic ridge, accelerations in the changes of which are announced by sudden yieldings along its base. The islands of Auckland, Macquarie, and others, may indicate the existence of such a ridge, but I am not aware that there are any soundings to confirm the suggestion.

Sixteen records refer to shocks which originated near Japan—the Philippines and the Celebes. Five had their centres in the Himalayan region, and six off the West Coast of South America. (See Map, Plate 2.)

2. *Seasonal Frequency of Antarctic Earthquakes.*

The relative frequency of disturbances with an Antarctic origin in different seasons and months for the years 1902 and 1903 is shown in the following table. The numerals in the body of the table are the index numbers of earthquakes in the "Discovery" register :—

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	Seismograph only working in 1903.	Seismograph not working.		9	28		43	108	117	51	56	61
			1	10	31	33	100	110	118	54	130	62
			3	12	32	35	103	113	119	55	131	63
			4	15	34	36	105	114		120	132	64
			5	16	67	40		115		127	133	
			8	18	68	41				128	134	
			27	20	84	90				129		
			28	21	85	92						
						95						
				77	86	97						
				78	87	98						
				79	89	99						
				80								
				82								
Number of earthquakes	0	—	7	13	11	11	4	5	3	7	6	4
,, distinct seismic effects	0	—	4	12	9	11	4	5	2	6	5	3

Earthquakes which are bracketed occurred within a few hours of each other, and, therefore, may possibly refer to the same relief of seismic strain. In the lower line of totals each of the groups has been regarded as a single disturbance. Whichever line we take, it seems that the greatest frequency has been in April, May and June, or the first part of the winter months. The seasonal distribution of Antarctic earthquakes is, therefore, similar to the distribution noticed in many other countries. Dr. OMORI, however, has shown that earthquakes with a sub-oceanic origin off the coast of Japan have their greatest frequency in the summer, during which season a higher average sea level more than counterbalances a diminution of load on the sea bed, due to a lower barometric pressure. The seasonal difference in load amounts to 18·3 millims. of mercury. Whether similar conditions prevail in the Antarctic regions remains to be determined.

3. *On the Form of Areas Disturbed by Large Earthquakes.* (See Plate 3.)

For local earthquakes, such, for example, as are from time to time noted in Great Britain, we are prepared to see isoseists occasionally in the form of circles, but more frequently in the form of ellipses. The major axis of any one of these ellipses is usually parallel to the strike of a fault, the sudden yielding on the face of which gave rise to the shaking. If the movement originates at no great depth, the epifocal area where motion is most pronounced has been shown by Dr. CHARLES DAVIDSON to lie on the side of the fault towards which it hades.

With very large earthquakes, which are not sufficiently strong to be recorded over the whole surface of the world, but which may reach stations near to their antipodes, the idea of elliptical isoseists requires modification.

For example, earthquakes originating in District M to the S.W. of New Zealand have been recorded to the S.E. by the "Discovery," and along a band at least 20° in width, extending in a N.W. direction as far as Britain. They may or may not be recorded in India, whilst at comparatively near places like Batavia, Manila, and Japan, lying northwards from the origin, they have been seldom noted. Also it may be added that they have not been noted at Cape Town, or at Cordova in Argentina, each about 80° distant, nor anywhere on the American continents. It would appear, therefore, that recordable earthquake motion originating in District M may be propagated as a band running in a N.W. direction as far as its antipodes. When more stations have been established in South America, it may be found that the motion proceeds to great distances in two directions round the world. This, however, is doubtful.

Earthquakes originating off the West Coast of South America have been recorded by the "Discovery" to the S.W., but the greatest length of recognisable wave-path is found towards the N.E., in which direction they have been recorded in Western Europe and also near to their antipodes in Siberia. They have not been recorded at stations we should expect them to affect were they propagated with equal intensity in an opposite direction round the world.

Disturbances with origins in Japan, the Philippines, and the East Indies have been recorded as far S.

as the "Discovery" and westwards across Asia and Europe, whilst they do not appear to have reached nearer stations in North America. On the westward route it may be noticed that the path would be sub-continental, whilst in going eastwards it would be sub-oceanic.

The loudness of the sound made by a gun depends in part upon the direction in which the gun is trained with regard to the observer. In a somewhat similar manner, if we hold the blade of a spade in water and then suddenly move it, the largest waves are forced in the direction of the primary impulse.

If these analogies may be used to explain why earthquakes from District M are propagated more vigorously in a N.W. direction rather than in any other, one inference is that the fault or faults from which these disturbances spring strike in a N.E. and S.W. direction, that is, they are parallel to the New Zealand axis, and they hade towards the direction of the longest path along which movement is recorded. Similar inferences may be made with regard to the origins of movements in other districts. (See Map, Plate 3.)

4. *Velocity Determinations.*

In a few instances, when accurate data have been obtainable, calculations have been made of the speeds with which earthquake motions have been transmitted in various directions round and through the world.

Speeds along paths which are continental have been compared with those which are sub-oceanic. For example, for earthquakes with origins off the coast of Eastern Asia, the rate at which waves have been transmitted across Asia and Europe may be compared with the rate at which the same travelled beneath the Pacific Ocean to New Zealand and the "Discovery." The material at my disposal does not show that there is any certain difference in speeds. Certain tables relating to speed strengthen the suggestion that, for particular phases of earthquake motion, velocity is not constant. The large waves, or P_3, apparently increase in speed in quadrantal regions. Other tables relating to rate of propagation are only of value as indications of the character of motion which has reached distant stations. To this I refer in the next section.

A knowledge of the time taken by earthquake waves to travel from one seismic region to another occasionally leads to the conclusion that one earthquake may be regarded as the cause of a second disturbance. Illustrations of earthquakes having originated in a district at the times when teleseismic movement reached that district are to be found in earthquakes numbered 4, 8, 45, 48, and 117.

5. *The Surviving Phase of Earthquake Motion.*

With exceptionally large earthquakes we may obtain at very distant stations seismograms which exhibit all three phases of earthquake motion. More frequently, however, at such stations the record is a mere thickening of the photographic trace, a small fraction of a millimetre in amplitude, and with a duration of 3 or 4 minutes. Near to its origin the maximum motion of the same earthquake may have been pronounced, while its total duration may have extended over at least 1 hour.

The test which has been used to determine the phase of motion to which the surviving tremors represented by a thickening are to be referred has been determinations of the speed with which they have been transmitted from their origin to the station at which they were observed. In a few instances the times of origin and the positions of epifocal districts have been obtained with a fair amount of accuracy, and the results relating to earthquake speeds may be regarded as reliable determinations of the same.

This, however, is not the case with the majority of velocity tables which have been compiled, the reason being that they have been dependent upon data relating to times of origin and positions of centres which in all probability may in certain instances deviate by 5° in distance and 5 minutes in time from the truth.

Notwithstanding this, as the velocities of P_1, P_2, P_3 for long arcs are respectively about 12, 6, and 3 kms. per second, although the velocities deduced for surviving phases may want in accuracy, they seem to be sufficient to suggest the type of wave to which they belong. The type determined appears to be P_3, which at stations comparatively near to the origin is announced as an undulation of the earth's surface.*

* For list of shocks showing these survivals, see 'Antipodean Recurrences,' p. 292.

6. *On a Suspected Quadrantal Acceleration in Earthquake Speed.*

The earthquakes here referred to are those which have been recorded at stations situated at distances of at least 90° from their origins. In well-defined seismograms these disturbances show three phases of motion. The preliminary tremors, or P_1, reach stations 60° to 180° distant from origins with average chordal velocities increasing from 11 to 12 kms. per second. These may be compressional waves. Following these, but with larger amplitudes, we find a second phase, P_2. These, which are regarded as distortional waves, have over paths from 30° to 160° in length average arcual velocities increasing from 4·2 to 6·4 kms. per second. Lastly, there is the maximum motion, or P_3, which has an approximately constant arcual velocity of 3 kms. per second.

For the commencement of this phase, which is apparently recorded as an undulating movement of the surface of the earth, and may therefore be regarded as being partially gravitational in character,* the velocity becomes 3·3 kms. per second. With regard to P_3, this, however, is a general statement. Within 10° of an origin, the value for P_3 appears to be less than 3 kms. per second, whilst in the quadrantal region it may exceed 4 kms. per second. There are also indications of variation in velocity in the antipodean regions. The values for P_2 also appear to be increased in the quadrantal region. These velocity changes were first discussed in a British Association Report for 1900, p. 64 *et seq.*, but the data then at hand were not sufficient to sustain any definite conclusion.

The observations made by the "Discovery," taken in conjunction with observations referring to the same earthquakes made at other stations, have added to the material illustrating the phenomena here considered, and it is for this reason that I again call attention to the same

The speed acceleration, particularly for P_3, is shown in the eleven time curves (Plate 1), six of which refer to the "Discovery" register. The flattening in these curves indicates an increased speed. This usually commences at a distance of from 40° to 70° from an origin.

Something analogous to these movements recorded on the surface of the earth is seen in WHEWELL'S Oceanic Cotidal Chart.† In the narrowest part of the Atlantic, between Africa and South America, the lines representing the hourly change in the position of the tidal crest are crowded together. As these travel northwards into the broader, and in places somewhat deeper, water, they are more widely separated. In other words, the tidal wave travels more quickly in the broader and deeper portions of ocean than in the narrower portions, where it is retarded. Although the chart may not be "perfectly trustworthy," ‡ it at least suggests that a seismic wave of the type P_3 may be less constrained, and therefore travel more quickly in its quadrantal than in its polar region. This comparison is only intended to illustrate a form of progress, and not to suggest that the factors governing the variations in speed of the tidal and seismic waves are altogether identical. Further, the seismic wave at its antipodes shows an apparent increase in its velocity, which is the reverse of that which would be expected by a tidal wave when approaching the head of an oceanic inlet.

It might be assumed that the earthquake wave passes beneath a crust and over a nucleus, into which it merges. The upper portion of such a wave would be more retarded than its lower portion. It may also be imagined that the more swiftly moving lower portion on the first 90° of its path fails to give a surface indication of its existence because its external boundaries are widening. In the quadrantal region the periphery of the boundaries is fairly constant, and it is here that we find apparent acceleration in its speed. Still farther on its journey excessive contraction of the boundaries results in retardation of the waves.

7. *Antipodean Re-appearances.*

For some years past I have noticed that earthquakes which had their origin in the vicinity of New Zealand, and were recorded in that country, have also been recorded in Britain, particularly at Bidstone, but had not necessarily been recorded at intermediate stations. The "Discovery" records, taken in

* The influence of gravitation has been discussed by BROMWICH, in 'Proc. Lond. Math. Soc.'

† See 'The Tides,' by G. H. DARWIN, p. 172.

‡ *Ibid.*, p. 173.

conjunction with those from Christchurch, Wellington, and Perth, have confirmed this observation, and we have now a number of instances where the movement from an epifocal area has travelled round and through the world, to re-appear as a recordable quantity at its antipodes.

It is not affirmed that in the region between an epicentral district and its pole seismic movement did not reach the surface of the earth, but only that even with instruments very much more sensitive than the Milne type motion has not been detected. The phenomena under consideration might also be described as antipodean resurgences, convergences, focal effects or *contrecoups*, each of which, however, might be objected to as implying an explanation for this antipolar relationship.

In the preceding registers we find the following 19 illustrations of possible re-appearances, viz.:—Numbers 1, 32, 34, 51, 53, 59, 83, 89, 91, 93, 95, 96, 108, 111, 115, 117, 120, 129, and 130.

Out of these it seems that with earthquakes Nos. 1, 34, 83, 89, 95, 96, 117, 120, and 129, the surviving phase has been P_3. At Hamburg, Strassburg, and other stations where there are pendulums with a shorter period and a higher multiplication than those of the Milne type, P_1 has occasionally been recorded, *e.g.*, this is the case with Nos. 1, 93, 111, and 130. In other instances the polar responses have been nearly simultaneous, a conclusion, however, which for many reasons may be more apparent than real.

The interpolar transit of a wave of the P_3 type may be compared with that of a deep-sea wave down a rapidly widening and then up a similar but rapidly narrowing estuary. The dimensions of these estuaries are assumed to be large. When half-way on its journey the height of the wave and its energy per unit area would be less than at its commencement or its terminus. It might, therefore, traverse the central area and not be noticed, but because of subsequent convergence it might become recognisable at points still farther from its origin.

With very large earthquakes the movements were recorded all over the globe, and from experiments now in progress at Pribram, in Bohemia, the seismograms obtained at a depth of 1150 metres, although they show a diminished amplitude, differ but little from those relating to the same disturbances recorded on the surface. The earthquakes we have to consider are of this type, but less in magnitude. Let us imagine one of these smaller efforts to start over an epifocal cap subtending 10° at the centre, and that this expands as a ring 5° in width until it reaches the quadrantal region. The area of the cap or ring in the two positions will be approximately as 1 to 11, and if we neglect loss due to friction and assume constant energy, the intensity will be diminished in like ratio. With such conditions it seems conceivable that a disturbance might be missed in the quadrantal region and recorded at its antipodes. The distance to which motion would invade the superficial region between the focus and the quadrantal region would depend upon the intensity of the disturbance at its origin.

The reappearance of P_1, which is probably a condensational wave, may be accounted for by assuming that reflections are focussed in an antipodean region.

8. *Seismograms, Pulsations, Magnetograms, and the Value of* g.

It is now well known that at certain observatories magnetic needles are frequently disturbed by unfelt earthquake motion. To throw light upon the consequent irregularities which from time to time are shown in the magnetograms at particular stations, horizontal pendulums have been established. The records given by the latter instruments are due to mechanical movements, but whether the corresponding perturbations shown in the magnetograms are due to a similar cause is by no means certain. At one station teleseismic movement may disturb surrounding and subjacent magnetic materials, with the result that needles at that station may respond to magnetic effects, which would not be the case at stations where the neighbouring materials which had been equally disturbed were non-magnetic.

At Ross Island the basalts are distinctly magnetic, while Mount Erebus and other recent cones indicate that physical and chemical characters, and also the arrangement of magnetic materials, have suffered change.

The varying activity of Erebus suggests that these hypogenic processes have not yet ceased, and with seismic disturbances it seems probable that large bodies of magnetic magmas and rocks are, at least temporarily, disturbed and altered. We might, therefore, anticipate that the larger seismograms obtained by the "Discovery" would be accompanied by corresponding perturbations in the magnetograms. That a slight relationship of this description exists has already been noticed by Mr. BERNACCHI, but now that the register of the "Discovery" has been extended this may be more clearly established.

When making this enquiry, large earthquakes which for various reasons were not recorded by the "Discovery" should not be overlooked. A list of these is given (p. 87). Also that the time at which disturbances of magnetic needles might be expected would probably correspond with the arrival of phase P_3 must be kept in mind.

To strengthen the assumption that "pulsations" are actual movements of the earth's surface, it would be of interest to compare the times when these were frequent with the periods when magnetic needles were unsteady or showed oscillatory movements.

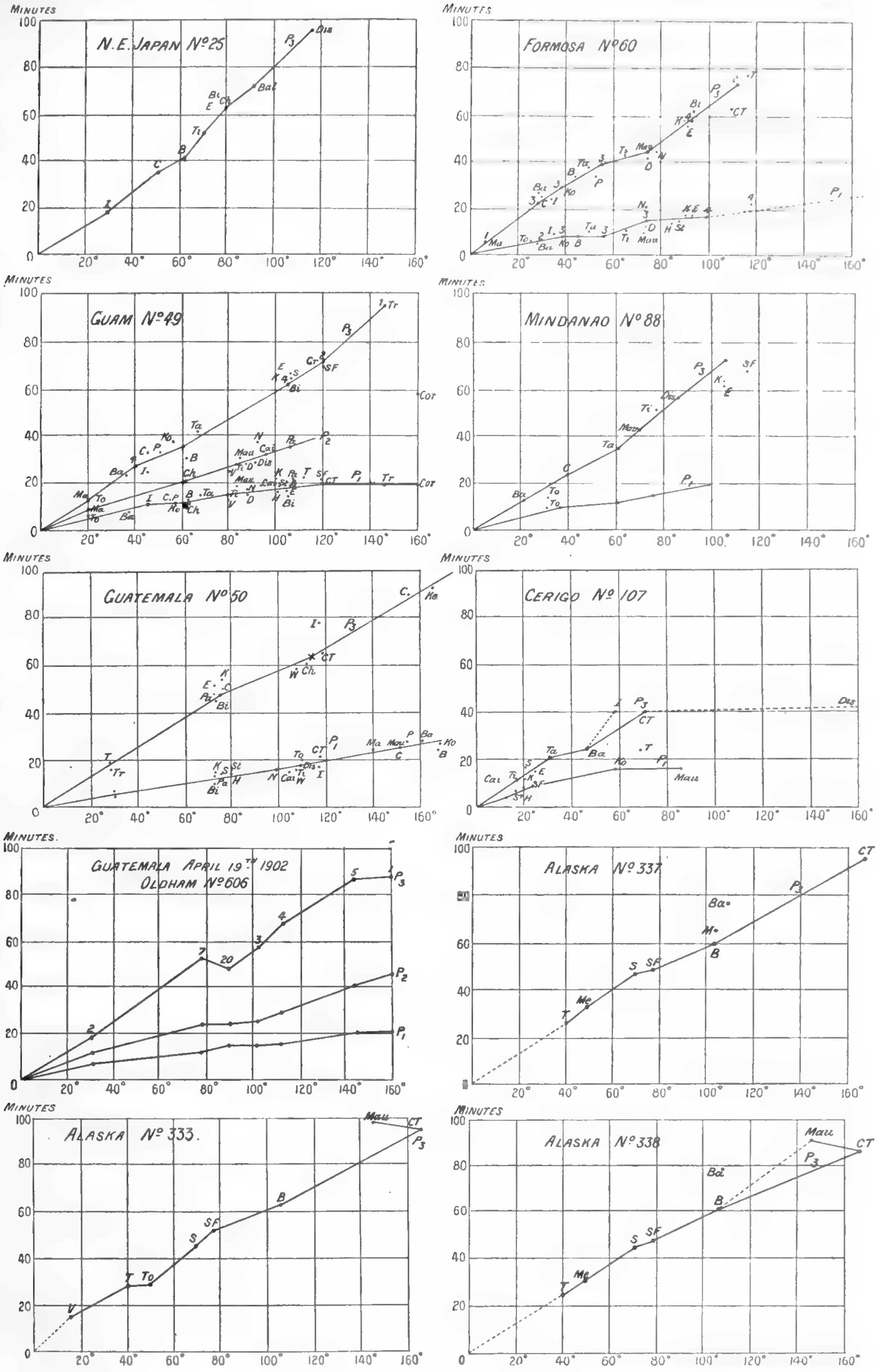
The fact that the magnetic rocks on Ross Island have a high density is one reason which would lead us to expect a marked difference between the observed and calculated values for g.

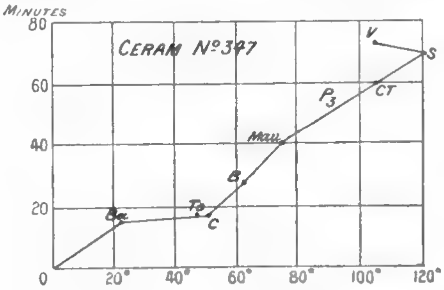
KEY TO ABBREVIATIONS USED IN SECTION III. AND IN VELOCITY DIAGRAMS.

The small figures on curve, fig. 606, *indicate the number of observations made to obtain the points to which they are attached.*

P_1 = commencement of first phase.
P_2 = commencement of second phase.
P_3 = maximum of third phase or large waves.

Az. = Azores.
B. = Bombay.
Ba. = Batavia.
Bal. = Baltimore.
Bi. = Bidston, near Liverpool.
C. = Calcutta.
Cai. = Cairo.
Ch. = Christchurch, New Zealand.
Cor. = Cordova, Argentina.
CT. = Cape Town.
D. = Dorpat.
Dis. = Discovery.
E. = Edinburgh.
H. = Hamburg.
Ho. = Honolulu.
I. = Irkutsk.
K. = Kew.
Ko. = Kodaikanal.
M. = Madras.
Ma. = Manila.
Mau. = Mauritius.
Me. = Mexico.
N. = Nicolaiew.
P. = Perth, W. Australia.
Pa. = Paisley.
S. = Shide, Isle of Wight.
St. = Strassburg.
St.H. = St. Helena.
SF. = San Fernando, Spain.
T. = Toronto.
Ta. = Taschkent.
Ti = Tiflis.
To. = Tokio.
Tr. = Trinidad.
V. = Victoria, B.C.
W. = Wellington, New Zealand.



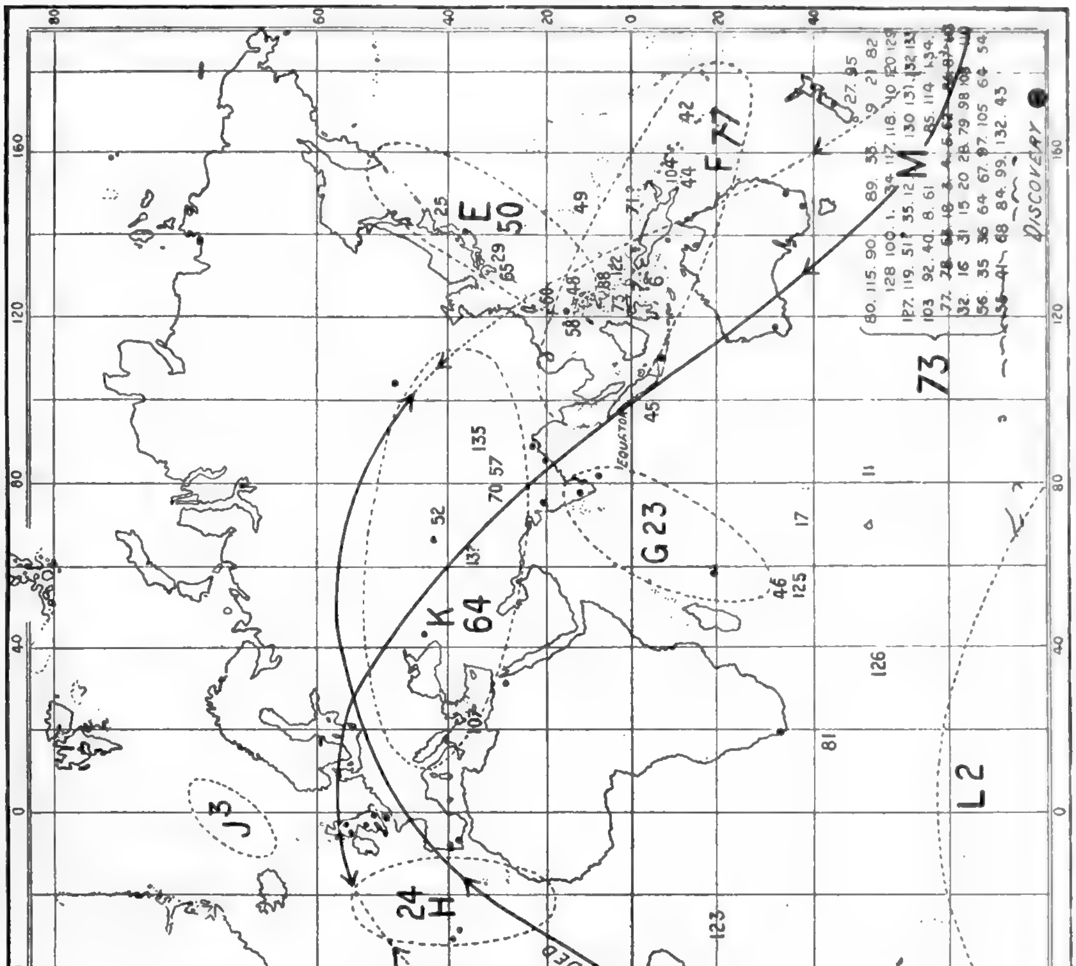


Time curves of earthquakes.

Nos. 25, 49, 50, 60, 88, and 107 refer to the "Discovery" register.

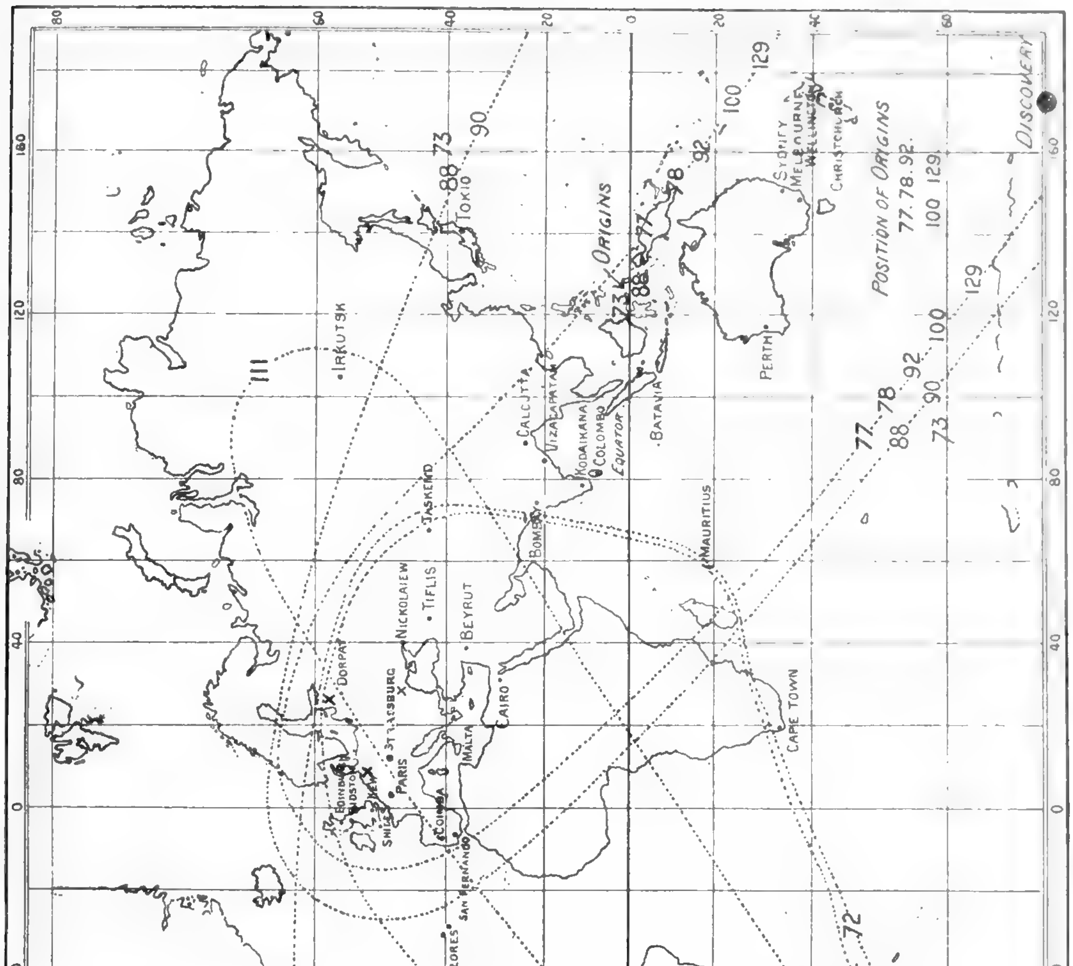
Nos. 606, 333, 337, 338, and 347 refer to the Shide register.

Origins of Earthquakes recorded by the "Discovery," 1902-3.—J. Milne, 1905.

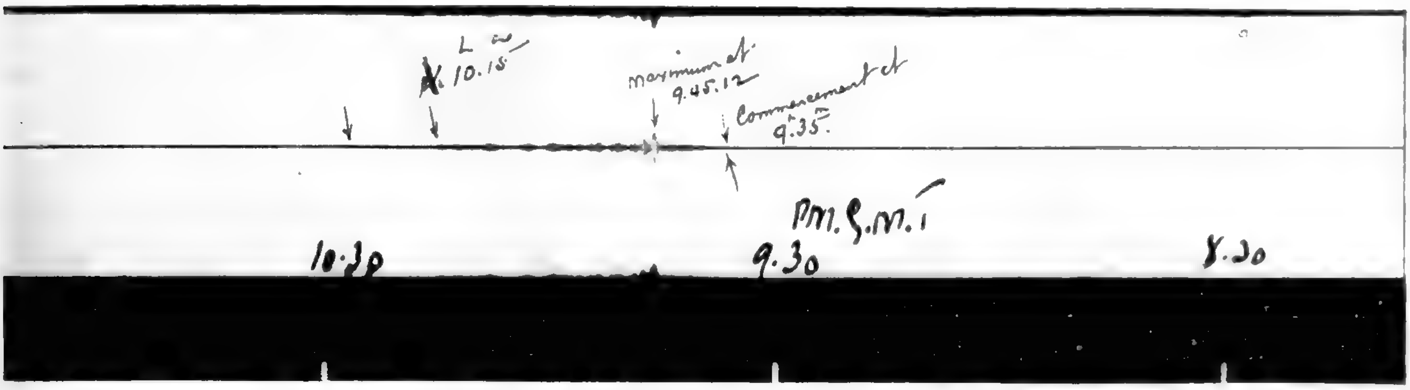


Small numerals refer to "Discovery." Large numerals give the number of large earthquakes originating (1899 to 1903) in districts, A, B, C, &c. M 73 refers to the "Discovery" only. Observing stations are indicated by black dots.

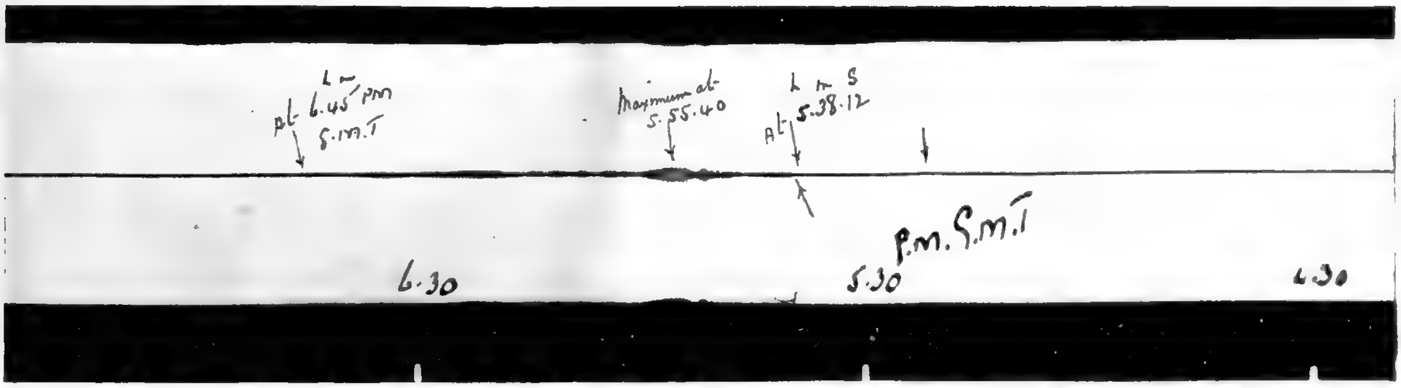
Isoseists of certain "Discovery" records.—J. Milne, 1905.



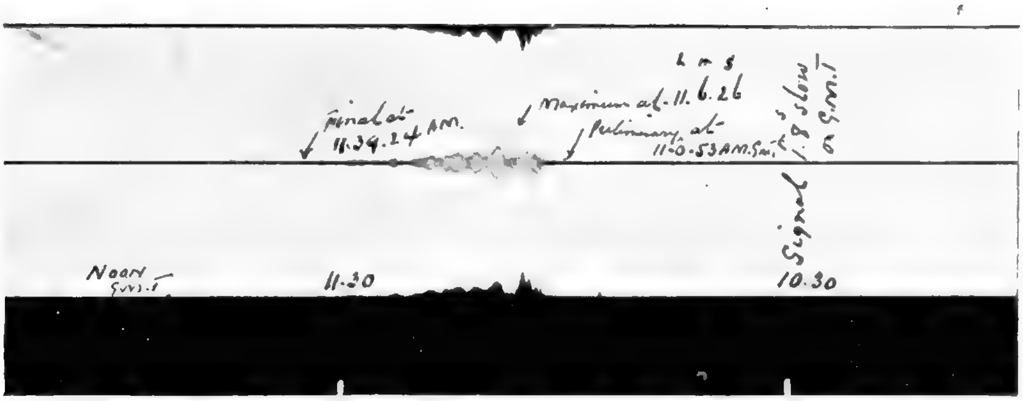
Numerals refer to Earthquake Register.



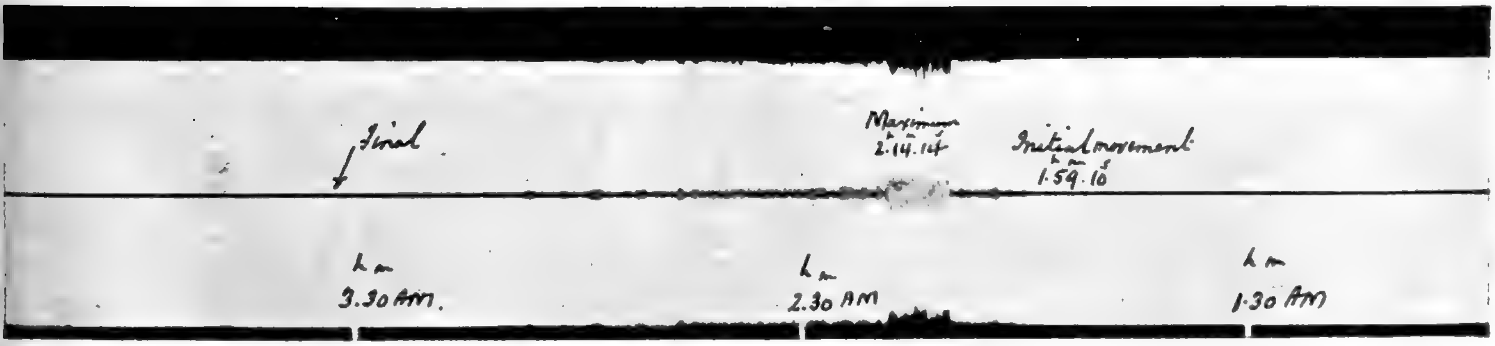
No. 16. *April* 20, 1902.



No. 17. *April* 21, 1902.



No. 32. *May* 26, 1902.



No. 49. *September* 22, 1902.

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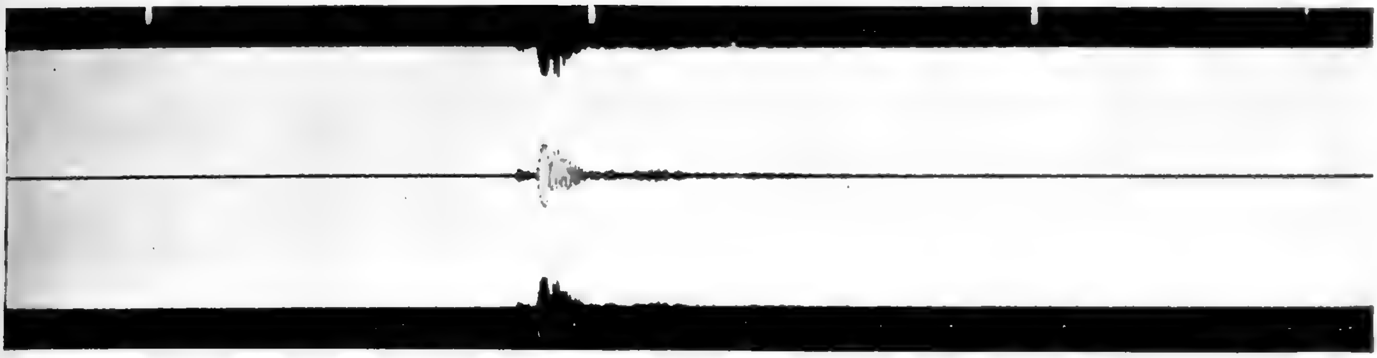
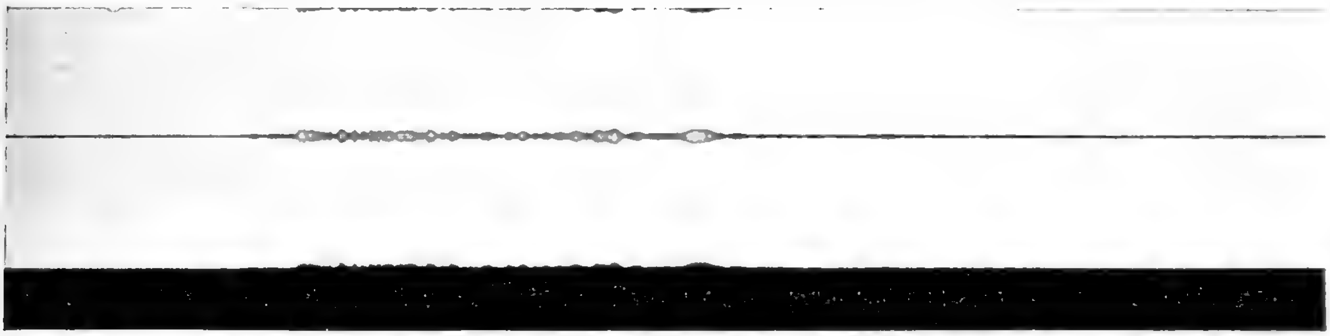
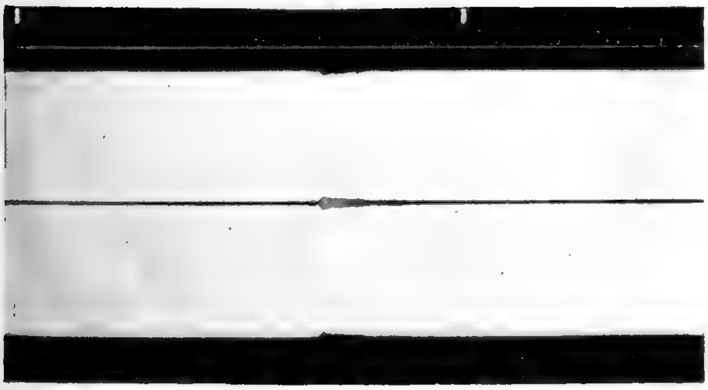


No. 77. *April* 10, 1903.



No. 82. *April* 29, 1903.

No. 90. *June* 8, 1903.



No. 117. *September* 23, 1903.

No. 118. *September* 23, 1903.

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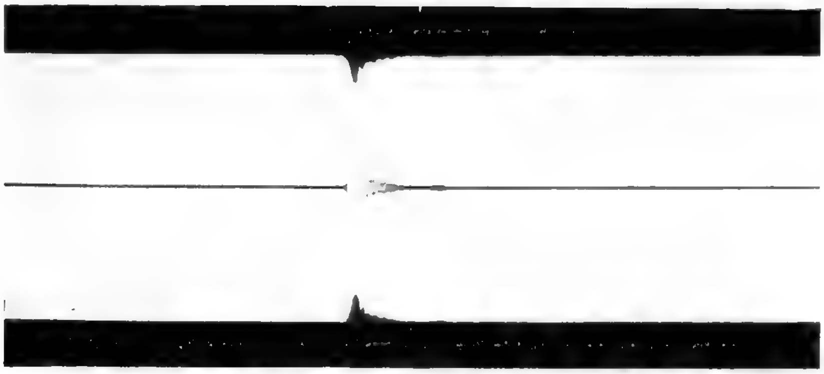
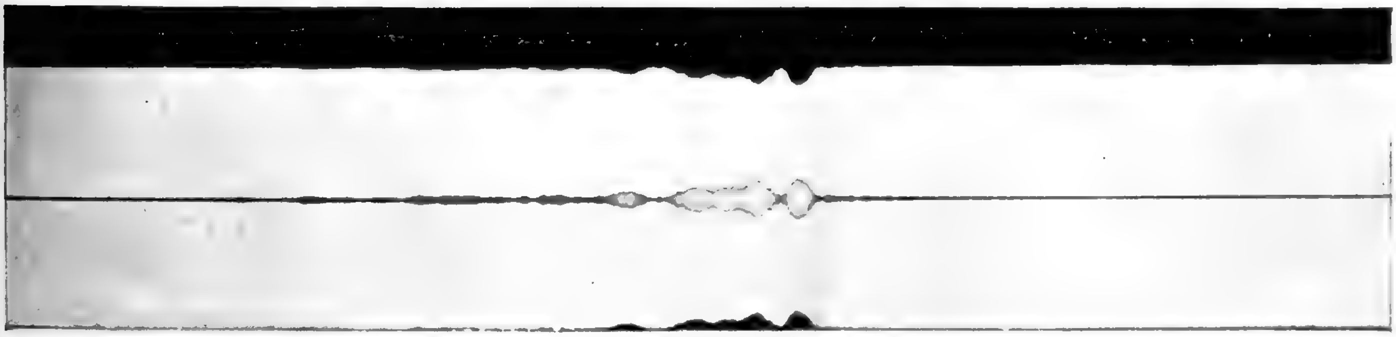


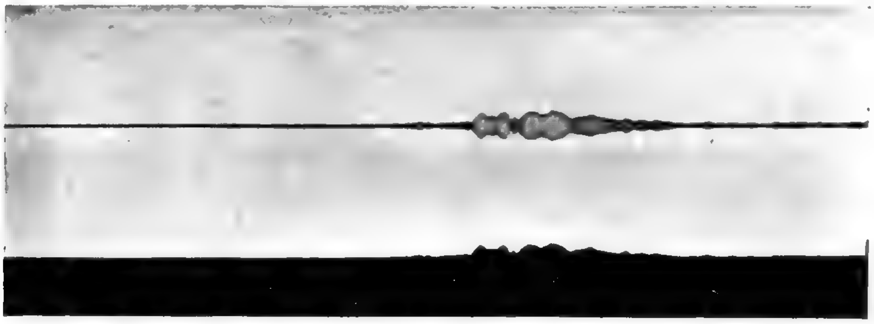
No. 119. *September* 26, 1903.

No. 121. *October* 8, 1903.

No. 125. *October* 21, 1903.



No. 127. *October* 29, 1903.



No. 128. *October* 30, 1903.

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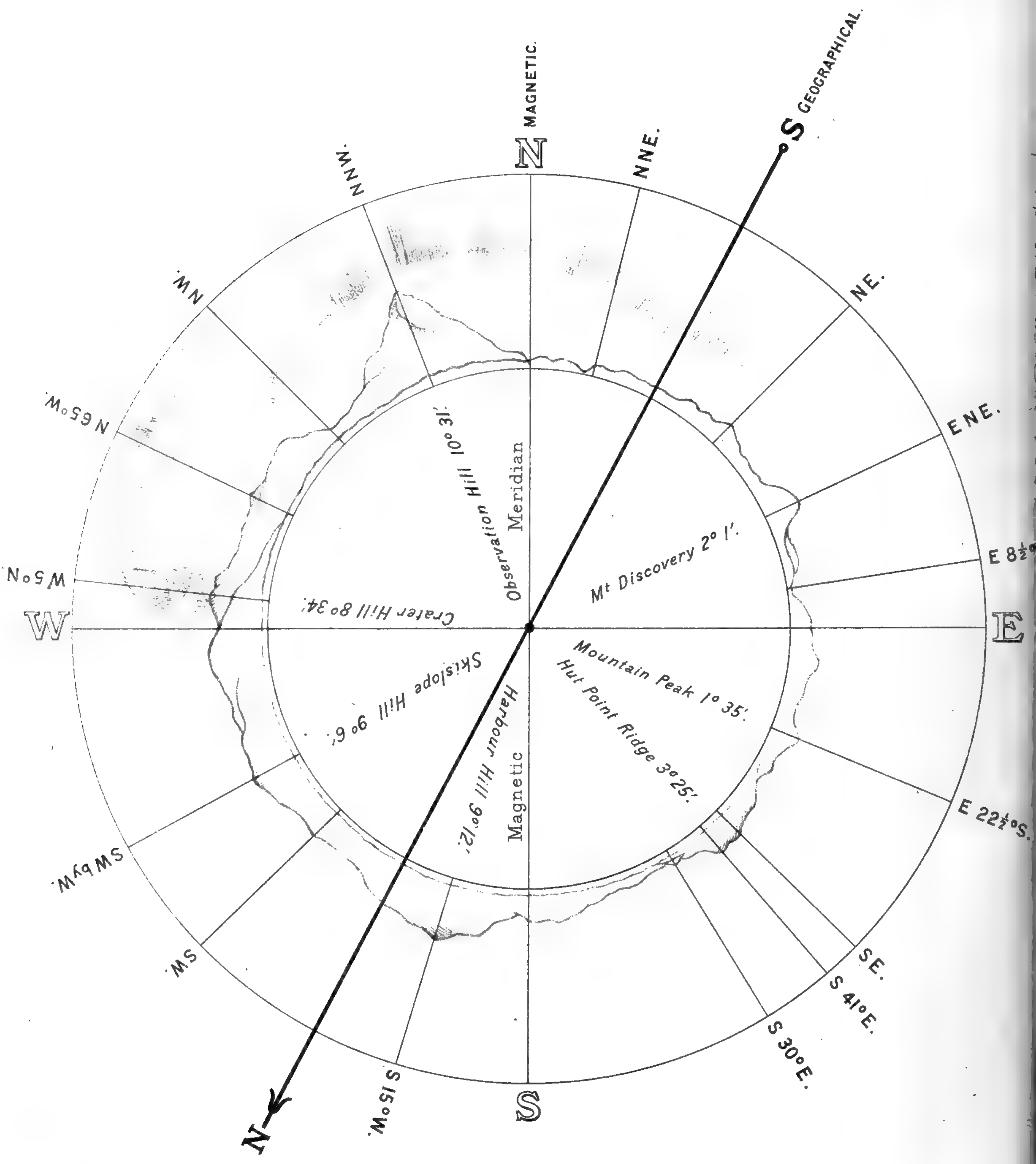
IV. ANTARCTIC OBSERVATIONS OF AURORA

1902-1903.

OBSERVATIONS OF AURORA.

Introduction, by L. C. Bernacchi.

Journal of Observations.



Note. Centre of Circle is position of the observer and the ship in Winter Quarters.

West, Newman lith.

"Aurora Chart." April 8-9, 1903.

INTRODUCTION

BY

L. C. BERNACCHI.

A RECORD of the auroræ visible during the two winters 1902 and 1903 was kept. The observations were generally made by the officer who was on meteorological duty for the night—a duty in which all the members of the "Discovery's" wardroom participated.

Ordinarily, the observations consisted of noting the time, position of the aurora, its altitude and amplitude, intensity, form, movement and duration. These observations were entered in a special journal kept for the purpose, and a rough "chart" of the surrounding hills was supplied each night for drawing in the position with regard to the magnetic meridian (see Plate 7). Whenever the display was fairly extensive, the physicist was called and special observations were taken, such as measurements of its intensity, width of bands, altitudes, and times of special movements.

On the whole the displays, although very frequent, were extremely poor, and were generally in the following forms:—

1. Faint lights, with no defined forms.
2. Luminous patches, which frequently presented the appearance of clouds.
3. Incomplete arcs, or segments of arcs, of which the brilliancy was not uniform nor the border regular. From these arcs rays would frequently shoot up intermittently.
4. Rays, or vertical shafts, separated from each other at a greater or less distance, frequently described as streamers.
5. In one or two exceptional cases irregular bands, formed of rays or vertical shafts, pressed close together and forming "draped auroræ."

The faint lights and luminous patches were of the most varied dimensions, sometimes very small, and at other times occupying almost the whole of the eastern (geographical) sky; their brilliancy was rarely much more intense than that of stars of the 4th magnitude, or even the Milky Way. They formed, as it were, a white veil over the sky, through which stars of small magnitude were plainly visible. A clearly defined arc, formed of a homogeneous luminous mass touching the horizon at both extremities, was rarely seen.

From the middle of the moon's first quarter to the middle of its last quarter the auroræ were generally quite invisible. Spectroscopic observations of the auroræ were not successful, due, apparently, to the weak intensity of the light. On some occasions the characteristic yellow line near D was seen by means of a direct-vision spectroscope, but, although plates were exposed on many nights in the prismatic camera, the times of exposure varying from a few minutes to twenty-four hours or more, not the slightest trace of the spectrum could be discovered on developing the plates. The spectrum plates (Cadet) appeared to be in fairly good condition, good photographs of the spectrum of krypton gas and of the sun and atmosphere having been obtained on them.

The observations of atmospheric electricity taken during the displays reveal no special effect referable to the aurora.

An examination of the journal shows that the largest number of auroræ occur during the mid-winter months, June and July, and that there is some indication of May being relatively a quiet aurora month in both years, but this may be purely an accident. The small number observed in March and September is, of course, due to the large amount of daylight. A daily variation of the aurora at Winter Harbour is probably shown, the maximum occurring at about 2h. a.m., which is also near the time of the mean maximum altitude of the display. The time of maximum intensity appears to depend upon the latitude, it being later as we go towards the pole. Thus, at Cape Adare (Lat. 71° S.) it is about 9h. p.m., and on the "Belgica" Expedition (Lat. 71° S.) also about 9h. p.m. The aurora with us usually appeared first at about 4h. p.m., low down on the horizon, and gradually moved up towards the zenith, reaching a maximum altitude at about 4h. a.m. (See the frequency diagram, p. 126.)

There are many points of interest, such as a diurnal period, a monthly period due to the moon's phases —the magnetic direction of aurora at different hours of the day—simultaneous appearance of auroræ with those at northern stations and with sudden outbreaks of solar spots, the relation with terrestrial magnetism and meteorological phenomena, &c.

With regard to the direction of aurora at Winter Harbour, it is interesting to note that displays were almost exclusively confined to the geographical eastern sky, which was also the direction from which the prevailing winds blew. Auroræ were seldom seen in the geographical west. Arcs and segments of arcs at right angles to the magnetic meridian (N.) were frequently recorded.

In the following observations all the times given are local mean time.

All auroral directions are astronomical, unless clearly stated otherwise or where the word "magnetic" indicates that the direction is magnetic.

All wind directions are astronomical.

Where altitudes of beams, shafts, rays, &c., are given, the altitude of the lowest part closest to the horizon is meant, unless expressed otherwise.

Temperatures are in Fahrenheit degrees.

The very excellent drawings reproduced in Plates 8 to 14 were made on the spot by Dr. EDWARD A. WILSON.

JOURNAL OF OBSERVATIONS.

WINTER QUARTERS { Latitude 77° 51′ S. / Longitude 166° 45′ E. }

MAGNETIC DECLINATION 152° E.

1902.

April 1.—At 1h. a.m. observed faint curtain of aurora in N. true; altitude about 2° to 4°; weak intensity and slow movement.

At 1h. 15m. a.m. aurora glow in N. true. Beams of aurora visible at intervals in N. until about 3h. 30m. a.m.

At about 3h. 2m. a.m. faint beam in N.N.E., occasionally stretching up towards zenith. Temperature of the air, − 8° F. No wind, clear sky, bright moonlight. Little Ci.-s. cloud.

April 2.—Time 0h. 10m. a.m. Beam of aurora seen in S.S.W., about 30° above the horizon, very faint and slow in movement. Bright moonlight.

2h. a.m. Faint beam in N., about 5° above horizon, slow movement. Temperature, − 12° F. Ci.-s. cloud, 3. Bright moonlight.

April 3.—Time 4h. a.m. Beam of aurora in S.W., very faint, slow movement. Altitude from 20° to 70°. Temperature of air, − 10° F.

April 6.—Aurora (very faint) observed at about 2h. 20m. a.m.

At from 2h. 12m. a.m. to 2h. 22m. a.m. faint aurora arc stretching from S. to N.E. true, apex nearly E. true, altitude 15°; occasional beams moving vertically, comparatively slow movement. Intensity very low, but little stronger than the "Milky Way"; certainly too weak for spectroscopic observations. Temperature of air, − 10° F. Clear sky, no clouds. Very faint mist over sky, giving stars a "watery" appearance.

Aurora had entirely disappeared at 3h. a.m.

April 7.—At 9h. 10m. p.m., faint aurora glow in E., altitude 20°, only visible for few minutes, it being soon obscured by clouds. Temperature, − 11° F. Blowing a gale from S.E.

April 9.—At about 2h. 25m. a.m., M.T. (3h. 20m. p.m., G.M.T., on 8th), observed aurora in N. and N. by E. true, in the form of three streamers radiating from N. (Plate 8). Very little movement discernible in curtains, the vertical beams remaining stationary for a considerable length of time, viz., 2 minutes, and only varying in intensity. The intensity was equal to a star of between the 2nd and 3rd magnitude. Temperature, − 3° F. Wind S.E., 4. No clouds.

At about 2h. 44m. a.m. the two smaller streamers had almost faded away, but the principal streamer had become more intense and stretched across zenith forming a very grand glowing arc, containing faint tints of red, but with scarcely any appreciable movement in it. No vertical beams at all.

Phenomenon had entirely disappeared at 2h. 55m. a.m.

April 10.—From midnight April 9 to 0h. 20m. a.m. aurora arc visible, extending from S. true to E.N.E. Apex of arc nearly due S.E., magnetic meridian, altitude 10°. Intensity star of between 3rd and 2nd magnitude. Slow movement; constituted of vertical beams which remained stationary for some time. Temperature of air, − 1° F. Clear sky. Only dark band of cloud in S. beneath arc. No wind.

1902.

April 11.—Very faint aurora beams visible in S. and S.E. at between 2h. a.m. and 4h. a.m. Altitude 20° Temperature, + 6° F. Clear sky.

April 13.—At about midnight, M.T., aurora glow in E., about 5° above horizon. No beams visible; intensity very weak and varying. Wind S.E., 4–5. Cloud 3, Ci.-s.

April 15.—At noon, M.T., faint curtain of aurora stretching from magnetic E. to W., 10° above horizon at extremity, and 50° at W. Centre of curtain within a few degrees of zenith. Movement rather rapid. Intensity weak. Temperature, – 12° F. Wind S.E. true. Clear, but slight mist partly obscuring stars.

From above date until May 5 no sign of aurora was seen. During the latter part of April, the bright moonlight possibly made it impossible to see, and during the first 5 days of May a heavy storm blew from S. and S.W., and the drifting snow which accompanied it totally obscured the sky. Ice in McMurdo Sound was driven out, and the open water advanced to within a few hundred yards of the "Discovery."

May 6.—An aurora was observed at 4h. a.m., M.T. The display extended from S. magnetic, round through W. to N. magnetic. The most brilliant portion was in S. 15° W. magnetic and 20° in altitude. Faint red was here visible at the base of the beams. A denser part of this totally eclipsed stars of the 4th magnitude. The following are the altitudes: S.W. (magnetic) 40°, W. (magnetic) 30°, N.W. magnetic 60°, N. magnetic 20°, E.N.E. magnetic 10°. Temperature at the time was + 17° F. No clouds. Wind S.E., 2.

May 7.—At 8h. 7m. p.m. faint aurora glow from N.W. by N. to W. 70° N. (magnetic). Streamers hidden behind the hills, one in W. 10° N. magnetic visible 2° above summit of ridge. Temperature, – 6° F. No clouds. Wind N.E., 4.

Almost entirely disappeared at 8h. 45m.

May 9.—1. At 6h. a.m. faint streamers in W. and S.W. by W. magnetic, and faint-glowing aurora cloud in S.S.W. magnetic. Temperature, – 16° F. Wind E. by N., 2. Clouds 4, Ci.-s. in W.

May 9.—2. At 9h. 7m. p.m., aurora arc at right angles to magnetic meridian position, as indicated on chart. Altitude of centre, 4°; amplitude, 60°. Altitudes 9° and 14° to 15°. Aurora glow in N.W. by W., from which beams from time to time emanated, light white with a tint of yellow.

From 9h. 17m. p.m. to 9h. 22m. a very well-defined arc, perpendicular to meridian. Altitude 9°. Extremities as before, base sharp and dark beneath. Streamers above arc 10° to 15°, extending from N.W. to E.N.E. magnetic. Intensity variable, very slow movement, more of a glowing type. Too weak for spectroscopic observations.

At 9h. 32m. p.m. arc was from 12° to 14° in altitude, extending from N. 20° W. to N.E. by N. (magnetic). Intensity varying greatly. At one time the distance between arc and streamers and beams was only about 1°, and a dark space lay between.

At 9h. 42m. p.m. aurora arc had entirely disappeared, and only glow behind hill in N. 20° W. (magnetic) remained, and from which flashes of light would occasionally move up to about 15°. When arc faded away its altitude was 14°. At times during the display a doubtful appearance of the characteristic aurora line near D could be seen. Temperature, – 28° F. No wind, no clouds.

May 10.—At 8h. p.m., M.T., aurora glow appeared in N.W. magnetic, from which streamers would occasionally emanate. Amplitude of glow, W. 7° N. to N.W. by N. (magnetic). Altitude of streamers not more than 5°.

At 8h. 47m. p.m., bright patch in form of rough arc in N.W. magnetic.

Display had almost entirely disappeared at 9h. p.m., only an afterglow remained. Temperature, – 6° F. No wind, no clouds.

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May 11.—2h. a.m. Very faint aurora, forming an incomplete arc. Total altitude, 15°. No streamers.

6h. a.m. An incomplete arc, height about 8°, moderately bright and composed of short, closely set streamers, in patches, very fluctuating. In 15 minutes no trace visible.

May 13.—6h. a.m. After a very clear and still night in which no aurora appeared there were two very faint beams rising some 10° from the western horizon (magnetic).

May 14.—6h. a.m. Air very still, faint streamers from S. to N.W. magnetic, altitude up to 40°, also small circle of aurora light near zenith. No colours.

May 31.—Two patches of aurora glow just over hill in S.W. magnetic, very faint. Time 6h. a.m. Temperature, +13°·8 F. Wind E.S.E., 2–3.

June 1.—At 8h. a.m., faint aurora beams in W.N.W. magnetic. Altitude of beams or streamers between 10° and 20°. Temperature, −2°·9 F. Clouds St. and Ci.-s. Wind N.E., movement rapid, visible for very short time.

June 2.—At 6h. a.m., two faint streamers visible for short time in S.W. magnetic, altitude 15° to 40°, rising from behind hill. Temperature, −3° F. No clouds. Wind E. by S., 2.

June 5.—2h. 15m. a.m. Very faint, but rather extensive, aurora. A glow above the hills from E. to S. (true) in a low arc on the horizon. Temperature, −16°·5. Wind E. by N., 4. There were also a few faint beams in the S., altitude between 20° and 30°. Also an indistinct curtain, or ribbon of rays, very faint, and stretching across the heavens towards the S.E., and within a few degrees of the zenith.

4h. a.m. A faint arc, 20° in height, from N.N.E. to W (magnetic). −15° F.

Midnight. Faint aurora in N.N.E. to W.N.W. (magnetic). Altitude 20°.

June 6.—At 8h. a.m. Aurora curtain from N.E. (magnetic) to S. 5° (magnetic) through W. (magnetic). The curtain rose rapidly from 10° to 40° in altitude. There was very little perceptible movement among the rays, but great and sudden variations in the intensity of the light. Phenomenon lasted about 20 minutes and then entirely disappeared. Temperature of the air, −17° F. No clouds. Wind E. by N., 3.

At 8h. p.m., faint aurora glow in N.W. (magnetic). −9° F. Clear sky. Wind N.W. The glow moved round very gradually to W.S.W. (magnetic), taking nearly two hours to reach that point; no streamers visible, altitude no more than 5°. The temperature fell to −28° F. in early part of afternoon, but rose again very rapidly with wind.

June 7.—At 0h. 45m. a.m. observed fairly strong aurora in form of rough, broken-up arc, stretching from N.E. (magnetic) to S. 20° W. (magnetic), and passing through zenith. Altitude 40° in N.E., and down to summit of hills and behind them in S. 20° W. The phenomenon can scarcely be said to have taken the form of an arc, the light was too broken up and was more of the nature of luminous clouds, difficult at times to distinguish from the Milky Way, and varying greatly in intensity. The average width of these "clouds" was from 1° to 3°. No streamers whatever were visible, and very little movement was perceptible. The only movement appeared to be from S.W. to N.E. (magnetic). The glow at times became fairly intense, but never even faintly red. Stars of 3rd magnitude were frequently entirely eclipsed. The interval in time between maximum glow and fading away of any particular patch was a matter of a few seconds, viz., from 20 sec. to 50 sec. No clouds.

4h. 2m. and 4h. 7m. a.m. were the times of the brightest displays of a colourless aurora, stretching from S.W.S. to N.E. (magnetic), with a brighter patch in the S.W.S. (magnetic) and a fainter one in the N.E. (magnetic). The intervening part showed only a glow which occasionally faded away. The only streamers seen were in the S.W. by S. (magnetic), and these were

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brightest when a patch of light from below appeared. Length of streamers 2°, altitude of display 20°. Temperature, – 19° F. No clouds, light airs from N.E. true.

At 4h. 35m. a.m., dull glow in S.W. by S. (magnetic), fading away towards N.W. (magnetic).

6h. a.m. Patch with faint streamers between N.E. and N.N.E. magnetic.

8h. a.m. Parts of three arcs, apparently concentric. The outermost, starting on the horizon at E.N.E. (magnetic), rose gradually to 30° at N.N.E. (magnetic). Within this rose a smaller portion at N.E. (magnetic), extending to N.N.E. (magnetic), where, like the last, it was discontinued. At N.N.E. (magnetic) rose the third, which just cleared Observation Hill, and then, rising to 20° or 30° over the hills at W. 5° N. (magnetic), dropped to the horizon again S. or a trifle E. of S. (magnetic). The arches were formed entirely of sheafs of vertical rays. The rays were very brilliant at times in the N.N.E. and N.W. (magnetic) of the arc. The rays were throughout 10° or 20° in length, except a few persistently longer and narrower and bright rays in S. (magnetic).

Duration some 15 minutes at least. Movement was not flickering, but from N.E. to N. (magnetic) and W. (magnetic) by gradual transportation of the whole arc, or rather fading at N.E. (magnetic) and simultaneously appearing in N. and W. (magnetic). No wind, but strong wind sprung up soon afterwards.

10h. p.m. Faint aurora clouds near zenith.

June 8.—At 4h. a.m., faint auroral streamers from S. 5° W. to W.N.W. (magnetic). Altitude of display from 15° to 45°. Length of streamers 2° to 20°. Patch of auroral luminosity in S.W. by W. (magnetic). The display was evidently shining through a thin mist.

June 10.—An extensive, though faint, aurora glow, extending from E. to S.E., observed at 0h. 5m. a.m. Altitude 12°. No streamers. Temperature, – 22° F. Wind, 1–2.

No sign of aurora at 2h. 0m. a.m.

At 4h. 0m. a.m. very extensive faint aurora glow over hills N.E. to S.E., with one streamer due N., bright in comparison, especially just above the hills, reaching an altitude of 20°.

At 6h. a.m. the conditions were exactly the same, except that the single streamer was at N. by E. (all bearings true). Temperature at 4 a.m., – 24°·5 F.; at 6h. 0m. a.m., – 23° F. Light wind, clear sky.

At 7h. 45m. to 8 a.m., vertical beams arranged more or less closely together to form an arc, which extended from near N.E. (magnetic) to S. magnetic, across N. and W. Altitude at each extremity the visible horizon; at its highest over N.W. magnetic, about 20°, or a little more, to 30° at the summit of the streamers. Some of the W.N.W. streamers were 30° in length, but were very faint. Some of the N.E. streamers were very bright and glowing, the glow lasting for a few seconds.

The S.W. and S. streamers were all faint, long, and very narrow, sometimes from 20° to 30° in length from the horizon. All the S. streamers appeared to be inclined to the right of the vertical, all the N.E. to the left. The end of the arc at the N.E. was indefinitely reduplicated and the ends of each piece turned upward rather from the horizon. The dark section of sky below the arc was well marked. – 21°·3 F. High E. airs (true). No clouds. Apparent movement S. to E. true. No corona.

June 11.—6h. a.m. Faint arc of streamers, highest above Observation Hill, discontinued eastwards just past that point. Greatest altitude 15°, E. extremity near Mount Discovery. Streamers appeared to be issuing from a dark cloud-like space below them and extended for 3° or 4° towards zenith. The streamers had a wavy, or flickering motion, but were always faint, the most pronounced being to the W. of Observation Hill (bearings true).

8h. a.m. Auroral arc S. to E. true, formed of faint streamers. Altitude 20°. Temperature, – 21° F. No wind, clear sky.

11h. a.m. Faint aurora streamers, 20° in length, stretching across zenith from N. by W. S. by E. magnetic. – 28° F. Wind E.S.E. No clouds, clear sky.

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June 13.—About 11h. 45m. Aurora glow suddenly appeared in S. 25° W. (magnetic) and stretched up in a narrow winding ribbon to about 20° above the hills. The light was fairly intense, but died out almost entirely in 15 minutes. Examined the light with spectroscope, but could not distinguish even the characteristic line near D. Temperature, − 26° F. Wind E. by N., 2. No clouds.

2h. a.m. General diffused light from N.N.E. to S.W. (true), bright but rapidly fluctuating streamers in N.N.E. from ridge top to zenith, others shorter and fainter in E. and S.E. Very little that was defined in the S. and W.

4h. a.m. Two companion streamers in N. (true), about 45° in altitude. A faint arc of streamers in N.E to (true) S.W., strongest to the N., but faint and fluctuating in intensity. A pale diffused light in the S.

6h. a.m. Only a very faint streamer in N.E. true, and more diffused streamers over Observation Hill.

8h. a.m. About a third of a semicircular arc of vertical rays rising from the horizon at N.E. (magnetic) and attaining an altitude of from 30° to 40° in N. (magnetic), or a little W. of N. (magnetic). Intensity faint, length of beams up to 10°. Movement practically nil. At the same time an irregularly vertical streamer of light was to be seen in E.N.E. magnetic, fading out at about 50° or 60° from the horizon where it originated. − 31° F. Wind E., 4. The display was higher than the faint arcs usually seen at 8 a.m.

June 14.—2h. a.m. Faint auroral glow, about 11° in altitude, S.W. by W. (magnetic).

4h. a.m. Faint auroral arc, with curtains extending from S.W. by W. (magnetic) to N.N.W. (magnetic) and rising to an altitude of 45°. One bright streamer shot up to an altitude of 75° from S.W. by W. (magnetic).

4h. 30m. a.m. One definite streamer shooting up from S. 20° W. (magnetic) to altitude of 75°. This gradually faded away and was not to be seen at 4h. 40m.

5h. a.m. Long single streamer again visible in S. 20° W. magnetic, rising to 75°.

6h. a.m. Disconnected patches of curtain, extending from N.N.W. (magnetic) to E.N.E. (magnetic) at an altitude of 30°. Between these patches long beams arose to an altitude of 70°. Phenomenon faint.

8h. a.m. A disconnected aurora arc from N.E. by N. to S.W. (magnetic), and from 20° to 30° in altitude at centre, N. extremity 10° to 15° in altitude, and S. extremity about 5°. Length of individual streamers not more than 8°, on an average about 3°. Fluctuations in the intensity of the light, but very little apparent movement. There was, however, a very gradual movement up towards the zenith and advanced to within about 3° of it at noon.

At 10 minutes after noon the phenomenon had entirely disappeared. Brightest patches were very carefully examined with spectroscope (direct vision), but no lines could be distinguished, the light evidently being too weak. Colour of phenomenon, nebulous whiteness, at times faintly green. Temperature at 8h. a.m., − 32° F.; at about 10h. a.m. or 10h. 30m. a.m., − 43° F.; at noon, − 32° F. Barometer low, but steady. Light N.E. airs, clear sky.

June 15.—6h. a.m. Very faint rays in N.N.E. magnetic, altitude above horizon 10° to 12°, rays 1° to 2° in length. Temperature, − 24°·8 F. Wind N., 2. No clouds.

8h. a.m. Arc of vertical streamers, starting from horizon at N.E. magnetic, rising to 20° and 30°, its highest at N.N.W. magnetic, and falling to S.W. and S. magnetic. Streamers bright, massed together and luminous, with a greenish tinge at N.N.E. magnetic, and at this end rather short, say 10°, whereas towards S.W. and S. magnetic they were very faint, narrow, and long, say 30° in length. − 36°·8 F. Calm, clear sky. Intensity faint, except for a few seconds in N.N.E. magnetic, where it was greenish and close, otherwise all white or faint straw colour. Movement imperceptible. Convergence of streamers on each side of centre of arc towards W. and N. 20° W. magnetic.

From June 15 to June 30 bright moonlight or overcast skies prevented any aurora being seen.

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June 30.—At 9h. 27m. p.m., faint aurora arc from Observation Hill to Crater Hill, altitude 15° to 18°. It had completely disappeared at 9h. 32m. p.m.

At 10h. p.m. glow over Crater Hill.

July 1.—2h. a.m. More or less permanent glow E.N.E. to E.S.E. (true), waxing and waning rapidly in intensity. Streamers occasionally E.S.E. to S.S.E. Maximum intensity in various directions at various times and in any one direction only lasting for the briefest space (4 or 5 seconds). Temperature, – 16° F. Quite calm, clear sky. Intensity at greatest = 3rd magnitude stars. Curious shadow effect under streamers, extending N. by E. to S.S.E. (true). Distinct double curtain in E.S.E., altitude 40°. Upper curtain fainter than lower and occasional streamers above it, extending to altitude 40°. Streamers to the E. faint, altitude 20° to 30°. Maximum intensity equal to star of 2nd magnitude. – 13° F. Wind N. by E, 1. Clear sky.

6h. a.m. Faint glow N. to N.E., faint streamer rising 20° in that direction. – 22° F. Calm and bright.

8h. a.m. Arc formed of vertical rays, extending from N.E. magnetic through N. to N.W. (magnetic) and ending in a faint glow along the hill tops at W. (magnetic). Maximum height of arc 20°. Length of beams 10° to 15°. Intensity faint. No pronounced beams. – 22° F. Calm and no wind. Fifteen minutes previous to this there were no beams between W. and N.N.W. (magnetic), but a faint arc of luminosity and three detached masses of auroral cloud and a few faint beams in N. (magnetic).

July 2.—2h. a.m. A faint sign of auroral curtain E.N.E. to E. by S. (true), altitude 45°, lasting for a few seconds.

July 4.—2h. a.m. Some slight patches above Harbour Hill and here and there towards zenith. Light streamers also over hills to the N. of Harbour Hill.

4h. a.m. Two bands of streamers of fair brightness, of greenish-yellow light, having a sharply defined lower edge, extended in the form of fractions of arcs from just above Crater Hill towards the S., and rising in that direction as well as from a little to N. of Harbour Hill and extending in same direction. From these bands streamers radiated towards, and almost extended to zenith, but continually varying. These portions of arcs then changed their form and assumed a more zigzag, or serpentine form, and continually changed their shape, glowing and waning in the same varied manner.

At 4h. 10m. a.m. a bright strand of streamers shot up over the hills further to the N., extending to within 40° of zenith. This also glowed and waned rapidly and was of a greenish-yellow line.

At 4h. 20m. a.m. some streamers were also seen in the S., very faint, while a confused film of streamers and patches of auroral light continued to play in the E. and N.E.

At 4h. 25m. a.m., part of double arc stretching from S.W. (magnetic) to about W. (magnetic). Very faint; not much brighter than the "Milky Way." Space between the two arcs 3°; larger space at W. extremity, where arcs were about 20° above horizon. In S.W. (magnetic) arcs rose up from above hills. One or two isolated streamers to S. of S.W. (magnetic). Phenomenon very transient. No movement, excepting that of light glowing up suddenly and then dying out again in a few seconds. Carefully examined light with Metz direct-vision spectroscope, but could see no sign of lines.

At 4h. 35m. a.m., low arc of light suddenly formed from S.W. to N. 25° W. (magnetic) and became comparatively intense, as bright as any yet observed. Altitude in N. (magnetic) 15° and rising from behind hill in S.W. (magnetic). No sign of streamers. Colour yellowish green. Examination with the spectroscope revealed the characteristic yellow line in the greenish-yellow part of the spectrum quite plainly, but very faint, and not sufficiently well defined to measure its position. Temperature, – 9° F. Light air from E. by N. true, clear sky.

The bright glow had quite disappeared at 4h. 37m. a.m., and at 4h. 39m. a.m. a similar arc in position, amplitude and altitude had formed.

6h. a.m. Arched band of streamers radiating towards zenith, extending irregularly and interruptedly from over Mount Discovery, Observation Hill (3° above it), Crater Hill, and over Harbour Hill to N.N.E. magnetic. The streamers were most brilliant and strongest in the S. magnetic. A little W. of Observation Hill, where they seemed to eclipse stars of 4th magnitude, these streamers appeared, with slight variations, to be fairly constant.

8h. a.m. The right half of an arc formed of vertical beams. Started from the horizon at E.N.E. and N.E. (magnetic) and rising to 15° or 20° over Observation Hill at N.N.W. magnetic, was lost at about 20° over N.W. magnetic, where there were the only beams of any length (viz., about 10°). Intensity faint. Light N.E. airs. – 6° F. No clouds, very clear.

7h. 20m. a.m. Nothing of the arc described above was visible, but there were two patches of faint vertical streamers over N.W. (magnetic), which started at an altitude of 40° and rose to 50° and 60°. Beyond these there was no glow or arc. Meteorological conditions same as at 8h. a.m.

Time, noon. Very faint auroral beam across zenith from E. to W. (magnetic), faint on account of twilight. – 9° F. Wind E., 2. No clouds.

July 5.—(Plates 9 and 10.) At 0h. 30m. a.m., broad and rather brilliant double arc, extending from S.S.E. to S. (true), altitude 10° to 70°, with a distending curtain above, altitude 45°, varying quickly in brilliancy. Auroral glare in the E. and S.E. true.

From 0h. 52m. a.m. to 1h. 7m. a.m., observed aurora as follows:—Dull, luminous arc from N.N.E. to W. (magnetic), altitude (apex over Observation Hill) 18°, almost stationary and little variation in the intensity of the light. A great mass of irregular aurora clouds, comparatively bright, stretching up from S.W. by S. (magnetic), across zenith, forming light luminous patches here and there in its course. All stars plainly visible through the clouds. With Metz direct-vision spectroscope the line in yellow-green part of spectrum visible, but very faintly, and impossible to measure its position. Large prismatic camera set up, plate exposed, and instrument directed to brightest patches. [On subsequent development, nothing appeared on the plate, although it was exposed for at least 8 hours. Many plates have already been exposed, but without the slightest result. The spectrum plates used (Cadet's) are apparently in good condition, and good photographs have been procured of all the lines of krypton gas and the pure spectrum from end to end of a bright-burning oil lamp.] Temperature, – 10° F. Light N.E. airs, no clouds.

At 1h. 7m. a.m. nearly whole of eastern sky (W. magnetic) was lit up with faint aurora clouds which crossed zenith and stopped 5° W. of zenith.

Fairly brilliant display from 1h. 7m. a.m. to 1h. 57m. a.m. (true), principally in S. (magnetic) in form of two radiating streamers.

At 1h. 47m. a.m. to 1h. 52m. a.m. very beautiful folding curtain rising from hill in S. (magnetic) to an altitude of 30° in S. 15° E. (magnetic). With spectroscope characteristic line near D visible, but too faint to measure. The aurora clouds seemed to drift before the wind and ultimately reached to within 45° of W. horizon (true).

From 1h. 15m. to 2h. 0m. a.m. the auroral display in N. (true) was very fine and at times of a greenish tint, with portions of arcs radiating from N. to W.N.W. (true), maximum altitude 45°, and to N.E., maximum altitude 45°, and one from N.E. to S.E. (true), about 30°. The arc from N. to W.N.W. quickly changed from a glow to patches of streamers, which again changed to a curtain, and then to a series of curtains travelling up towards the zenith and W. As these faded, a spiral curtain brightened up from the same N. point, reaching about 30° in altitude, with very bright base, the curtain being of a green-yellowish tint, with very faint pink hue at the base. This spiral gradually transformed into a series of streamers, and subsequently diffused into a glow. At the same time there was an arc of streamers in the S.E. true, and a

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glow in the E. (true), and very faint streamers from nearly all parts of the heavens, excepting the W. true.

4h. a.m. Very faint streamers in N., N.E., S., and N.W. true, reaching up to about 50° altitude, and disappearing about altitude 20°.

July 6.—2h. a.m. Faint aurora for a few moments. A semi-arc of streamers S.E. to E. (true), crest of arc S. true, where the longest and brightest streamer was 20° to 40° in altitude.

4h. a.m. Faint streamers in the E. and S. true, strongest in S., 20° to 40° in altitude.

6h. a.m. Luminous aurora clouds in S. (true) in a somewhat serpentine form, rather bright just for a few moments, a few very faint streamers in the E. true.

8h. a.m. Single aurora beam in N.W. (magnetic), altitude 20°.

Midnight. Faint arc, extending from Observation Hill to Bluff, altitude at brightest part 10°.

July 7.—2h. a.m. A few faint beams shooting up from S.W. by W. (magnetic) to the zenith; intermittent and lasting a few seconds only in each case.

5h. a.m. Faint auroral curtains, extending from Observation Hill to S. true, altitude generally 30°.

Similar phenomenon at 6h. a.m.

8h. a.m. A faint semi-arc of more or less diffused vertical beams, rising from N.N.W. magnetic to a height of 30° over W.N.W. (magnetic), where it was lost. Outside this was a fainter half-arc, rising from N.E. (magnetic) and ending at an altitude of about 20° over N.N.W. magnetic. Intensity faint. Wind nil. Temperature, – 24° F. No clouds.

6h. p.m. Bright auroral glow from E. to S.E. true, at times forming bright arc, but generally diffused glow, altitude 7°. – 14°·5. E, 1–2.

8h. p.m. Faint arc of streamers from E.N.E. to S.E. true, altitude 10°. Light E. airs. – 11° F.

Midnight. An arc of luminosity, no beams apparent, stretching from a height of 10° at E.N.E. magnetic to 20° at N.N.W. magnetic. Vertical breadth of arc from 6° to 8°. Intensity very faint. – 19° F. Calm, no clouds. No marked darkness beneath and in the arc.

July 8.—Time 6h. a.m. Extensive aurora of vertical streamers, arranged chiefly in pairs, some very broad and very long, length from 40° to 60°, and extending up to the zenith at N.W. (magnetic), otherwise arranged in an arc, quickly shifting upward and being replaced by another from below, so that in the N.E. (magnetic) there were sometimes the extremities of as many as four arcs in view at once. General intensity faint. Brightest streamers in E.N.E. (magnetic) very low down and short, to W. magnetic high and long, S.W. magnetic long, but base touching hills. There were no true curtains, and instead of a dark appearance beneath the arc there was more inclination to a faint luminosity, which may have been thin mist. Calm. Temperature, – 12°·5 F. No clouds.

July 10.—8h. a.m. Irregular arcs formed of vertical streamers, from horizon in N.E. magnetic to W., where altitude was from 10° to 20°. In N.W. by N. magnetic one of these arcs was moving fairly rapidly to the right. The upper part of the curtain was from 30° to 40° above the horizon when it had swung round to face the observer. Intensity variable, bright at times, movement of curtain visible. Temperature, – 8° F. Calm, clear sky, no clouds.

At 4h. 27m. p.m. fairly bright aurora glow, just showing upon hills from W. 5° N. to N.W. magnetic. Only lasted a few minutes. No clouds. Wind E., 2. – 4° F.

July 12.—At 6h. a.m. faint curtain from N.N.E. (magnetic) through 10° of amplitude, altitude 10° to 15°, light fading in upper part, two or three vertical shafts about N. Others N. 40° W. to N. 70° W. (magnetic), altitude 30° to 45°, light fading in altitude. No part of phenomenon exceeding 4th magnitude star in intensity. Wind E.N.E., 4–5.

At about 8h. 20m. a.m. observed disconnected curtain of aurora from N.N.E. to N.W.

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(magnetic). Apex nearly over Observation Hill, and altitude 15°; movement slow and gradual towards zenith. Length of streamers 2° to 4°. A few isolated streamers near zenith, and in S. magnetic, about 8° above horizon. Intensity faint. Temperature, – 11°·2 F. Wind E. by S., 3. No clouds.

The faint display continued until about 9h. 30m. a.m.

July 13.—4h. a.m. Fairly bright curtains N.N.E. to E.N.E. at an altitude of 12° to 50°. Four vertical shafts N. by W. to N.N.E., rising in three cases to an altitude of 60°, and in one case with a small gap at 75°, continuing on and forming a very bright area directly in the zenith. The brightest portion was about equal to stars of 4th magnitude—whole display undergoing rapid changes. Wind S.E. by E., 2–3. Temperature, – 14°·8 F. All bearings astronomical.

August 5.—Midnight. Very faint streamers in S.S.W. true.

August 7.—2h. a.m. Narrow arc of streamers issuing from dark background from E.N.E. to S.W. (true) greatest altitude just over and as high as Observation Hill.

4h. a.m. Odd streamers in band-like arrangement in N.E., over Harbour Hill, and slightly extending to S. Temperature, – 32° F. Wind E.N.E., 3–4. Clouds nil.

August 10.—2h. a.m. A very faint luminous glow along the S. horizon, disappearing before it reached 10° in height. No rays or streamers connected with it. In the N.E. there was at the same time a very faint luminous cloud, about 30° up from the horizon, which gradually changed into a long faint streamer and extended vertically upwards to within 20° or 30° of the zenith. Intensity very faint. Movement not discernible. Temperature, – 23°·3. Light N.E. airs. Ice crystals falling.

4h. a.m. Faint vertical streamers, forming a rough arc in the E. (magnetic), starting about 15° to 20° from horizon and rising to 20°. Also a patch of luminosity W. by S. (magnetic). No ice crystals falling. – 28°·6. Calm, bright, hardly any mist.

August 11.—2h. a.m. Comparatively brilliant display, four curtains, the largest and brightest in the N., converged in the zenith and continuing in winds and folds down to about 30°. All four curtains appeared to curl in the same way. The spaces between them were practically occupied by portions of vertical rays, all apparently converging to the zenith. There was no perceptible auroral arc.

4h. a.m. In the zenith a short and very luminous streak, direction N. and S. true, vertical streamers all round from zenith to horizon, some of them of unusual length, all converging at the zenith, one short bright curtain curving from zenith to the N., altitude of lower end 60°. The streamers were brighter to N. and N.W. true than elsewhere.

6h. a.m. Very faint aurora display in form of corona. Streamers diverging in all directions from zenith, and in N. and N.E. true, almost reaching the top of the hills. Faint luminous cloud in centre near zenith, but too dim to perceive any movement in it.

August 22.—At 10h. p.m., M.T., faint auroral cloud from N.E. to S.W. true, very diffused, breadth 2° to 4°. Altitude S. of zenith 70°. Rather misty sky. Temperature, – 9°·2 F. Wind ENE, 2.

August 23.—Midnight. Very faint auroral cloud in S.W. and N.E. In former direction 40° altitude and latter 55°. Faint glow over hills in N.E. and E. true.

August 25.—Midnight. Two well-defined streamers in N.N.E. and E.N.E. converging to the zenith. Comparatively brilliant above the hills and getting fainter higher up. The display gradually became fainter and ceased altogether soon after 1 a.m. Bearing true. Temperature, – 8°·5 F. Wind N.N.W., 2–3. Sky misty.

At about 10 minutes past midnight a huge arc of aurora light rose from N. by E. true and

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glow in the E. (true), and very faint streamers from nearly all parts of the heavens, excepting the W. true.

4h. a.m. Very faint streamers in N., N.E., S., and N.W. true, reaching up to about 50° altitude, and disappearing about altitude 20°.

July 6.—2h. a.m. Faint aurora for a few moments. A semi-arc of streamers S.E. to E. (true), crest of arc S. true, where the longest and brightest streamer was 20° to 40° in altitude.

4h. a.m. Faint streamers in the E. and S. true, strongest in S., 20° to 40° in altitude.

6h. a.m. Luminous aurora clouds in S. (true) in a somewhat serpentine form, rather bright just for a few moments, a few very faint streamers in the E. true.

8h. a.m. Single aurora beam in N.W. (magnetic), altitude 20°.

Midnight. Faint arc, extending from Observation Hill to Bluff, altitude at brightest part 10°.

July 7.—2h. a.m. A few faint beams shooting up from S.W. by W. (magnetic) to the zenith; intermittent and lasting a few seconds only in each case.

5h. a.m. Faint auroral curtains, extending from Observation Hill to S. true, altitude generally 30°.

Similar phenomenon at 6h. a.m.

8h. a.m. A faint semi-arc of more or less diffused vertical beams, rising from N.N.W. magnetic to a height of 30° over W.N.W. (magnetic), where it was lost. Outside this was a fainter half-arc, rising from N.E. (magnetic) and ending at an altitude of about 20° over N.N.W. magnetic. Intensity faint. Wind nil. Temperature, – 24° F. No clouds.

6h. p.m. Bright auroral glow from E. to S.E. true, at times forming bright arc, but generally diffused glow, altitude 7°. – 14°·5. E, 1–2.

8h. p.m. Faint arc of streamers from E.N.E. to S.E. true, altitude 10°. Light E. airs. – 11° F.

Midnight. An arc of luminosity, no beams apparent, stretching from a height of 10° at E.N.E. magnetic to 20° at N.N.W. magnetic. Vertical breadth of arc from 6° to 8°. Intensity very faint. – 19° F. Calm, no clouds. No marked darkness beneath and in the arc.

July 8.—Time 6h. a.m. Extensive aurora of vertical streamers, arranged chiefly in pairs, some very broad and very long, length from 40° to 60°, and extending up to the zenith at N.W. (magnetic), otherwise arranged in an arc, quickly shifting upward and being replaced by another from below, so that in the N.E. (magnetic) there were sometimes the extremities of as many as four arcs in view at once. General intensity faint. Brightest streamers in E.N.E. (magnetic) very low down and short, to W. magnetic high and long, S.W. magnetic long, but base touching hills. There were no true curtains, and instead of a dark appearance beneath the arc there was more inclination to a faint luminosity, which may have been thin mist. Calm. Temperature, – 12°·5 F. No clouds.

July 10.—8h. a.m. Irregular arcs formed of vertical streamers, from horizon in N.E. magnetic to W., where altitude was from 10° to 20°. In N.W. by N. magnetic one of these arcs was moving fairly rapidly to the right. The upper part of the curtain was from 30° to 40° above the horizon when it had swung round to face the observer. Intensity variable, bright at times, movement of curtain visible. Temperature, – 8° F. Calm, clear sky, no clouds.

At 4h. 27m. p.m. fairly bright aurora glow, just showing upon hills from W. 5° N. to N.W. magnetic. Only lasted a few minutes. No clouds. Wind E., 2. – 4° F.

July 12.—At 6h. a.m. faint curtain from N.N.E. (magnetic) through 10° of amplitude, altitude 10° to 15°, light fading in upper part, two or three vertical shafts about N. Others N. 40° W. to N. 70° W. (magnetic), altitude 30° to 45°, light fading in altitude. No part of phenomenon exceeding 4th magnitude star in intensity. Wind E.N.E., 4–5.

At about 8h. 20m. a.m. observed disconnected curtain of aurora from N.N.E. to N.W.

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(magnetic). Apex nearly over Observation Hill, and altitude 15°; movement slow and gradual towards zenith. Length of streamers 2° to 4°. A few isolated streamers near zenith, and in S. magnetic, about 8° above horizon. Intensity faint. Temperature, $-11°\cdot2$ F. Wind E. by S., 3. No clouds.

The faint display continued until about 9h. 30m. a.m.

July 13.—4h. a.m. Fairly bright curtains N.N.E. to E.N.E. at an altitude of 12° to 50°. Four vertical shafts N. by W. to N.N.E., rising in three cases to an altitude of 60°, and in one case with a small gap at 75°, continuing on and forming a very bright area directly in the zenith. The brightest portion was about equal to stars of 4th magnitude—whole display undergoing rapid changes. Wind S.E. by E., 2–3. Temperature, $-14°\cdot8$ F. All bearings astronomical.

August 5.—Midnight. Very faint streamers in S.S.W. true.

August 7.—2h. a.m. Narrow arc of streamers issuing from dark background from E.N.E. to S.W. (true) greatest altitude just over and as high as Observation Hill.

4h. a.m. Odd streamers in band-like arrangement in N.E., over Harbour Hill, and slightly extending to S. Temperature, $-32°$ F. Wind E.N.E., 3–4. Clouds nil.

August 10.—2h. a.m. A very faint luminous glow along the S. horizon, disappearing before it reached 10° in height. No rays or streamers connected with it. In the N.E. there was at the same time a very faint luminous cloud, about 30° up from the horizon, which gradually changed into a long faint streamer and extended vertically upwards to within 20° or 30° of the zenith. Intensity very faint. Movement not discernible. Temperature, $-23°\cdot3$. Light N.E. airs. Ice crystals falling.

4h. a.m. Faint vertical streamers, forming a rough arc in the E. (magnetic), starting about 15° to 20° from horizon and rising to 20°. Also a patch of luminosity W. by S. (magnetic). No ice crystals falling. $-28°\cdot6$. Calm, bright, hardly any mist.

August 11.—2h. a.m. Comparatively brilliant display, four curtains, the largest and brightest in the N., converged in the zenith and continuing in winds and folds down to about 30°. All four curtains appeared to curl in the same way. The spaces between them were practically occupied by portions of vertical rays, all apparently converging to the zenith. There was no perceptible auroral arc.

4h. a.m. In the zenith a short and very luminous streak, direction N. and S. true, vertical streamers all round from zenith to horizon, some of them of unusual length, all converging at the zenith, one short bright curtain curving from zenith to the N., altitude of lower end 60°. The streamers were brighter to N. and N.W. true than elsewhere.

6h. a.m. Very faint aurora display in form of corona. Streamers diverging in all directions from zenith, and in N. and N.E. true, almost reaching the top of the hills. Faint luminous cloud in centre near zenith, but too dim to perceive any movement in it.

August 22.—At 10h. p.m., M.T., faint auroral cloud from N.E. to S.W. true, very diffused, breadth 2° to 4°. Altitude S. of zenith 70°. Rather misty sky. Temperature, $-9°\cdot2$ F. Wind ENE, 2.

August 23.—Midnight. Very faint auroral cloud in S.W. and N.E. In former direction 40° altitude and latter 55°. Faint glow over hills in N.E. and E. true.

August 25.—Midnight. Two well-defined streamers in N.N.E. and E.N.E. converging to the zenith. Comparatively brilliant above the hills and getting fainter higher up. The display gradually became fainter and ceased altogether soon after 1 a.m. Bearing true. Temperature, $-8°\cdot5$ F. Wind N.N.W., 2–3. Sky misty.

At about 10 minutes past midnight a huge arc of aurora light rose from N. by E. true and

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stretched across zenith (apex 5° S.E. of zenith) down to W.S.W. The light was very diffused and cloud-like. No vertical rays visible. Breadth of arc in N. by E. 5° and from 2° to 4°. Some isolated luminous patches remained fairly dense and persistent.

August 27.—A few minutes before midnight dense patches of aurora in zenith and little to E. of zenith. Only visible for a few minutes.

Had entirely disappeared at midnight. Sky partly misty.

August 28–29.—(Plate 11.) Midnight. Faint arc in N.E., extending from 12° to zenith, fading in places and becoming patchy. Streamers from zenith, but very faint. Also small patches in and near zenith. Temperature, – 9°. b. Wind N.E., 3.

2h. a.m. Double arc in E.S.E. to S. Lower one luminous and very steady, altitude of centre 12°. Upper one, consisting of rays, about 45° in length, moving quickly from W. to E. and also varying its distance from the lower arc. Neither very bright. Wind N., 1. b. – 5° F.

4h. a.m. Very bright streamers in N. and N.E., extending to zenith. Faint streamers in S.W. from zenith to 45°. Bright glare from E. to S., altitude 10°. Arc from N.E. to S.E., altitude 70°, of rapidly moving streamers, with curtains forming and fading quickly. Brilliant patches in and about zenith. Solitary faint streamer from zenith to points between E. and S.W. – 18°·8 F. b. Calm, ice crystals falling.

September 9.—Midnight. Very faint auroral light in N.W. Temperature zero. N.N.E., 2 Ci.-s cloud, 2.

September 18.—Very faint aurora in zenith at 10h. 30m. p.m. Temperature, – 23° F. E., 1. No clouds.

September 19.—Midnight. Faint aurora, extending from N.E. to S.W. Temperature, – 20°. Calm. b.

September 19.—Midnight. Faint aurora, with vertical rays visible in N.E. Temperature, – 15°·2 F. E., 4–5. St. 4. (Too much daylight, aurora now invisible.)

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March 29.—11h. p.m. to midnight. Very faint auroral curtain, from about 10° W. of zenith down to within 10° of W. horizon. Light at times scarcely visible, and at its maximum intensity but little brighter than the "Milky Way." Temperature, + 7° F. Calm, no clouds.

(This is the first indication of an aurora visible to the eye since September of last year.)

March 30.—Midnight. Very faint auroral light near zenith. Temperature, – 1° F. Wind E., 3–4. b.

At 2h. and 4h. a.m., faint aurora near zenith. – 1° F. Wind E., 4–5. b.

April 3.—2h. a.m. Broad and somewhat faint auroral band, some 30° above S.W. horizon, extending towards, but not reaching zenith. Varying intensity, more defined edge N.W. side.

April 4.—Midnight (3rd). Faint auroral arc to S., about 40° altitude. Another arc, about 15° altitude brighter than stars of 3rd magnitude. Direction of movement, from E. to W. rather rapid. Two long streamers from S.W. to S. to zenith. The whole display very faint. Cloudless sky. Temperature, – 10° F. N.E., 2–3.

0h. 30m. a.m.—Faint arc of streamers to S., altitude about 5°. All streamers short and arc disconnected at times. Movement very rapid from E. to W. Phenomenon very faint. Disconnected streamers near zenith from E., S.W., and W.

1h. 0m. a.m. Five distinct arcs, the lower one about 12° in altitude, and the upper one at the zenith. Movement E. to W. rapid. Intensity of light at times dimming stars of 2nd magnitude. The arc at the zenith very small but bright, with rapid movement to N.W., the other arcs increasing in amplitude. The lowest one extending from E., S.E., to S. Also two streamers from N.E. 60° to zenith, and another short one from N.W. and near zenith. Wind gusty from N.E., 1–3.

1h. 30m. a.m. Very similar display to that at 1h. 0m. a.m. Streamers in N.E. longer more disconnected and brighter. Patches of light in S. and S.W.

2h. a.m. Very faint disconnected streamers visible all round from N.W. through E. to S.S.W., the northern ones being the longest and brightest. Faint arc in S.E., about 12° altitude. Patches about zenith. Movement still fast from E. to W., except in those to N., where the movement is much slower. Wind N.E., 2–3. $-10^{\circ}\cdot 5$ F.

2h. 45m. a.m. Very faint disconnected streamers in S. and S.W. from zenith. Brighter streamers from zenith to 20° altitude in N.E., and moving slowly westward. Cloudless sky. Wind N.E., 1–2. A few solitary patches of light near zenith.

April 5.—Short, faint, vertical streamers from S.S.E. to S. by W., altitude of upper end about 40° Cloudless sky.

2h. a.m. One continuous streamer, from 30° altitude in S.S.W., through zenith. A faint luminous patch in S.W., altitude about 50°. Temperature, – 10° F. Wind E, 2–4.

April 7.—(Plate 12.) 2h. a.m. Very faint streamers in N.E. and S. Light from 30° to 70°.

Midnight to 0h. 5m. a.m. on 8th. Two very bright rays in the N.W. magnetic, but they lasted only a minute or so. There was a low arc of fainter rays, stretching from N. 20° W. to N.E. magnetic. The bright rays started about 10° above the horizon and ended at about 20° altitude. The fainter rays reached no higher than 10° or 15°, starting from what looked like a dark band of cloud in the N. magnetic. Wind N.E. true, 1–2. Clouds none. b. Temperature, – 21° F.

April 8.—2h. a.m. (see Plate 7). A confusion of vertical rays, arcs, scrolls, bands and banners covering the sky from W. magnetic to E. magnetic, through N. magnetic up to zenith, where a corona was twice formed. Movement, when apparent, from left to right, occasionally marked, but generally indistinct. Rays, &c., changing rapidly in intensity, position, and amplitude. At one time the zenith was crossed by a waving band from N. to S. Wind N.E., 1. Temperature, – 19° F. Clouds nil.

A few minutes after 2h. a.m., nearly the whole of the E. sky was lighted up by faint auroral displays—luminous patches, rays, bands and disconnected arcs. The lateral movement of the rays was not very rapid, but, at times, perfectly distinct from N.E. to S.W. true, or, more generally speaking, from E. to W. There was, however, a very perceptible and gradual movement of the whole actively luminous display towards the zenith until at about 2h. 20m. a.m., a very characteristic corona was there formed and lasted for several minutes, but at no time was there any red or pink shown, the colour being a pale straw with tinges of green. Stars of the 4th magnitude were visible through the brightest patches, but dimmed. It was impossible to note any special rays or arcs, as they were so very confused and evanescent. The display commenced in the S. true, gradually faded there, and appeared in the N.E. true.

Amount of electricity in the air about normal. Barometer rising rapidly.

4h. a.m. Bright greenish rays in the S. to S.E. magnetic, extending to 20° or 30° in altitude. Faint rays all round to the N. and N.E. magnetic, becoming invisible in the faint light of the rising sun.

5h. a.m. Bright yellowish rays, forming an arc from N. to N.E. magnetic, 20° above horizon, moving rapidly to various directions. The rays were quite distinct, notwithstanding a good deal of light from the sun below the horizon.

10h. p.m. Faint yellowish rays of aurora, extending from N.W. by N. magnetic round to

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N.E. by N. magnetic, at an altitude varying from 8° in N.W. by N. magnetic to 12° in N.N.W. magnetic and to 4° in N.E. by N. magnetic. – 28°·2 F. Calm, cloudless sky.

10h. p.m. Faint yellowish streak, extending from an altitude of 10½° to 25° in N.W. by N. magnetic. Most brilliant rays in N.N.W. magnetic, as bright as a star of 3rd magnitude.

Midnight. Bright rays of light in W. magnetic, extending from 8° to 18° in altitude, and from W. ½ N. to N.W. by N. magnetic, in the form of an arc, getting fainter towards the N.W. by N. (magnetic) end, which was at an altitude of about 25°.

April 9.—0h. 15m. a.m. The above had all disappeared, except for a broad streak in W. ½ N. magnetic, from an altitude of 9° to 15°, where it was very faint. Temperature, – 27° F. Wind N. by E., 1. Cloudless sky. A very faint arch, extending from N.W. by N., altitude 8°, to N.N.E. magnetic, altitude 20°, just discernible. A faint patch bearing N.E. by E. magnetic, at an altitude of 5°.

2h. a.m. Faint streamers to an altitude of 12°. Very faint arc, extending from N. 20° W. (magnetic) to N.W. by N. magnetic, at an altitude of about 15°. Cloudless sky. – 26°·5 F. Calm.

6h. a.m. Broad faint streamers bearing S. (magnetic), altitude 6° to 9°. – 22° F. Light Ci.-s. cloud bearing N. by E. true. Wind N.N.E., 1.

April 11.—2h. a.m. A steady streamer maintained, stretching from Harbour Hill to almost overhead. This streamer has a concave side to the W., and lies due N. and S. The western edge is most defined and the sky appears darker immediately adjacent to this edge than in any other part of the sky.

No sign of aurora from April 11 to 18, due, perhaps, to bright moonlight making these faint displays invisible.

April 19.—10h. p.m. Auroral arc, extending from W. 5° N. magnetic to N.E. magnetic; apex 13° above horizon, and a little to N. magnetic of Observation Hill. Motion slow, streamers short, viz., from 1° to 2°, and brightest to N.E. magnetic. Intensity of brightest patch = star of 3rd magnitude. Wind E.S.E. true, 2–3. Temperature: – 15°·3 F. No clouds. Fairly bright moonlight. Arc had entirely disappeared at 10h. 10m. p.m.

11h. 20m. p.m. A similar, but fainter, arc formed. Amplitude same, but altitude of apex had increased to about 30°. Nothing visible at 11h. 30m. p.m.

Midnight. Very faint auroral clouds around zenith. Moonlight very bright. Barometer falling somewhat fast and temperature rising.

April 20.—1h. 30m. a.m. Two faint streamers in N., each about 10° in length and about 4° apart, starting from 5° above horizon.

2h. a.m. Faint auroral patches near zenith.

10h. p.m. Extremely faint auroral arc, extending from N.E. by E. magnetic to N.W. by W. magnetic. Apex N. by W. magnetic, altitude 11°.

Midnight. Faint streamer about N.E., rising to 70° from horizon.

April 21.—Midnight. A very perfect arc, extending from horizon at S.W. true to N.E. true. Greatest altitude about 30°. Formed entirely of vertical rays. Fairly brilliant in the N.E. Temperature – 40° F. b. Calm.

April 22.—2 a.m. A band, with a twist at the zenith, made a complete arc from the S. horizon to the N. horizon (true). Temperature, – 37° F. b. Calm. Intensity moderate.

April 23.—2h. a.m. Faint bands of aurora, extending from zenith down to top of land, bearing N. 20° W. magnetic. Temperature, – 15° F. Wind E. by N. true, 2–3. bc. Cu. 1, N.W. magnetic.

4h. a.m. Bright and broad streaks of auroral light, altitude 10°, bearing N. 80° W. magnetic and N. 75° W. magnetic. Faint band bearing W.S.W. magnetic, extending from altitude 8° to 15°. Temperature of air, – 13°·4 F. Wind E. by N. true. Cloud, Cu. 2, N.W. by W. magnetic.

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April 24.—2h. a.m. Auroral streamers, of very slight intensity, to the E.N.E. and S.E. true. Altitude up to 30°. Temperature, – 19°·4 F. Wind E. by N., 3–4. No clouds.

April 25.—Midnight. Auroral streamers, visible for a few seconds at intervals of 30 seconds, S. to about E.S.E. Sky cloudless. Longest streamer S., altitude 45° to 50°; shortest from horizon to 10°. Temperature, – 25°·2 F. Calm.

April 26.—2h. a.m. Streamers N. to S.E. true, but very weak, although bright at times, especially one to the N., which was broader than usual, but low. Calm. Temperature, – 28°·2 F. No clouds. Extreme altitude 55° to 60°.

4h. a.m. Vertical rays, bearing from S.S.E. true to N.W., of varying intensity. One overhead stretching across the sky S. to N. Calm. Temperature, – 39° F. No clouds.

April 27.—4h. a.m. Faint vertical rays showing from N. round to E.S.E.

6h. p.m. Faint streamers from zenith to S. and S.E. true.

8h. p.m. Very faint auroral arc of streamers, extending from S.E. to S.W. true. Altitude of apex 7°. Temperature, – 37° F. Calm. b.

Midnight. Faint aurora streamers from E.N.E. to S.W. Altitude from 20° to 35°. No clouds. Temperature, – 27° F. No wind.

April 29.—4h. a.m. Streamers E.N.E. and S. by E. Arc E. to S.S.E., faintly visible at 3h. 45m. a.m., increased greatly in brilliancy in two succeeding minutes. Altitude 20°. At maximum brilliancy a lower arc, altitude 15° to 17°, appeared. Both arcs rapidly vanished and were indistinguishable at 4h. a.m. As arcs grew, streamers paled, and, at disappearance of former, latter again shot up, reaching an altitude of 40° in direction noted above. The greatest brilliancy was in centre of arc and = star of 2nd magnitude. Calm, bright. Temperature, – 10° F.

6h. a.m. Streamers flashing at intervals of 2 to 3 minutes in N.N.E., and an occasional faint gleam in S. by E. direction. Brilliancy eclipsed by growing twilight. Calm. b. Temperature, – 14° F.

April 30.—2h. a.m. Faint streamers, N.E. and E. true, reaching to 60°.

4h. a.m. Faint streamers in same position. Temperature, – 8° F. N.E., 2–3. b.

9h. 35m. p.m. Two faint streamers in W. true, near zenith.

May 1.—2h. a.m. Fleeting streamers to S. and S.E. true.

4h. a.m. Fleeting streamers over Observation Hill and the land eastward.

May 4.—2h. a.m. Very faint auroral arc over Observation Hill. Apex N.N.W. (magnetic). Altitude 12°. One extremity W. 5° N. magnetic, other invisible. Clear sky, no wind. Temperature. – 3°·5 F.

May 6.—6h. a.m. Faint diffused auroral cloud in the zenith, which soon disappeared. b. Clear starlight, Temperature, – 3°·5 F. Calm, light S.E. airs.

May 7.—8h. a.m. Auroral light. Temperature, – 7°·5 F. Calm, light snowflakes falling. Clear sky in zenith. Apparent movement of aurora to S.

May 16.—6h. a.m. Faint auroral streamers in N.E. and S. true, altitude 60°, and cluster of streamers in zenith. Temperature, – 50° F. Calm and bright.

May 20.—8h. a.m. Very faint auroral streamers from S.E. to W., altitude 25° to 45°.

May 21.—8h. a.m. Faint aurora in the S.E.

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May 25.—4h. a.m. and 6h. a.m. Faint aurora showing from N. to E.S.E. true.

May 26.—2h. a.m. Faint auroral streamers from S.E. to N.

4h. a.m. Faint auroral streamers over Observation Hill.

6h. a.m. Faint auroral streamers S. and E. Temperature, − 11° F. N.E., 4–5. bq.

May 27.—2h. a.m. Faint auroral streamers due E. true, altitude 25°. bm. Temperature, − 8° F. S. by E., 2–3.

May 28.—4h. a.m. Faint auroral streamers in N.E., through E. to S. and S.W., altitude 10° to 45°.

6h. a.m. "Corona" near zenith, streamers radiating to horizon and top of hills, except in W., where they only descended to within 60° of horizon. Sinuous, convoluted mass moved rapidly from "corona" towards N.E. Streamers moved laterally (with hands of watch). Faint prismatic colouring in "corona." The whole display seemed to move over towards the N.E. Directions true. Phenomenon had entirely disappeared at 6h. 15m. a.m.

7h. 30m. a.m. Some streamers appeared over Observation Hill, altitude about 60°, but were most evanescent, only remaining a few minutes.

10h. 45m. p.m. Aurora semi-arc emanating from below hill in N.W. by W. (magnetic) and terminating abruptly over Observation Hill (N.N.W. magnetic), where altitude was 20°. Light very faint and diffused.

Midnight. Two irregular bands of aurora, of greenish to pale rose hue in S., stretching from S. to S.E. at 7° to 10° above the horizon. From these bands streamers radiated upwards for a short distance. Varied continuously in form, colour, and intensity.

May 29.—2h. a.m. Detached, isolated patches in N.E. true, a little above the hills; from these, streamers radiated towards zenith. Also an auroral glow to S. true.

4h. a.m. Filmy auroral band from S., across zenith to N., broadening as it spread to the N., and broke into patches of streamers in the S.

6h. a.m. Patches of aurora between Crater and Harbour Hills. The light in above, except when otherwise mentioned, was a pale straw.

3h. p.m. Continued display of aurora in the S. and S.E., low on horizon, from 0° to 3° in altitude. Low arcs rising close upon one another, sometimes as many as parts of 4 or 5, the southern extremities only being complete. High rays occasionally shot towards the zenith. The darkness below the arcs was marked. Movement chiefly from E. to S. in the rays, but from 3h. to 4h. 30m. p.m. the whole display had shifted from S. to E.

6h. p.m. Faint streamers over Observation Hill, extending round to S. and S.W. Temperature, − 32°·5 F. b. Calm.

Midnight. Continuous arc from N.E. to S.W. through E. (true), altitude 20° to 12°. This faded, and broken bands of streamers "ran" along where the arc had been, movement E. to W. all very faint. A few detached streamers in S.S.E., altitude about 10°, and in S. about 30°. − 28°·5 F. Calm. b.

May 30.—2h. a.m. Very brilliant display in N., and extending through E. to S.W. (true). On seeing it at first the brightest part was in the N. (true), nearly dimming stars of the 1st magnitude, and was in the form of a spiral, gradually changing into a curtain, and, when about 50° in altitude, trending away in a luminous arc to E. and S.W., and about 2° in width. The movement was rapid from the foot of the curtain along to the S.W. end of arc. Above and below this arc were numerous fainter arcs, some composed of short streamers, and others only a luminous diffused glow. After the movement was completed, throughout the entire arc, from N. to S.W., the display faded, and then slowly brightened again from the W. end and travelled back to the N. The whole was of a pale green tint. Luminous patches in and about the zenith. Wind N.W., 1. A band of stratus cloud was visible in the S. (altitude 10°) with aurora streamers behind it.

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Aurora display at 2h. 10m. a.m. Exceptionally bright, and one of the most interesting yet observed. At about 2h. 15m. a.m. a huge arc extended from S.W. magnetic to nearly N. magnetic. Apex about 25° in altitude, width 2°, inner part near horizon brightest and sharply defined. Intensity of light at times nearly equal to that of a star of 1st magnitude. Colour light yellow and straw and sometimes tinges of green, but never any indication of red or pink. Movement very gradual from horizon towards zenith, and at times rapid lateral movement in light from E. to W. (true). Arcs and intensity of light most evanescent, only lasting a few minutes, but rapidly appearing again in other directions.

At 2h. 20m. two arcs formed over Observation Hill, altitude 20° to 30°, width 1° to 2°, and remained fairly bright for a few minutes, but quickly faded away again. Brightest patches of aurora were in S. and S.W. magnetic. Very few streamers and vertical shafts. Light was of a diffused nebulous nature. The apex of the whole phenomenon, which consisted of arcs and fragments of arcs, was in N.W. magnetic. Altitude from 15° to 30°. Display had nearly disappeared at 2h. 40m. a.m. Absolutely no sign of auroral light in sky at 3h. a.m. Placed prismatic camera on ship's rail and exposed plate to part of sky where light was brightest. Left exposed for nearly 8 hours.

May 31.—(Plate 13.) 4h. p.m. Two large arcs rising in the S. formed of diffused and extensive vertical rays of light. The arcs rose at an angle of about 45° to 60° to the horizon, but gradually became more vertical and folded upon themselves at intervals, and then the eastern ends began to form a corona around the zenith, the easternmost of the arcs folding round the zenith to the right, the southernmost folding round to meet it to the left. Movement sideways slow, vertically rapid. Intensity bright as it rose to the zenith.

June 1.—2h. a.m. Very faint auroral glow and curtain 3° S. of Observation Hill (true), and altitude 15°.

4h. a.m. Very faint auroral streamer from zenith to N. by W. horizon (true). Temperature, – 19° F. Wind E., 5. Clear sky.

June 2.—Overcast during most of night.

6h. a.m. Fine aurora S.E. to N.W. (true), most brilliant N.W. Rapidly fluctuating curtains and isolated streamers. Some isolated patches passing to near zenith. Temperature, – 23° F. Wind E. by N., 5–6. b.

Midnight. Low aurora in the N., vertical streamers just appearing above the hills, very vivid greenish light, little motion. – 24° F. Light E. airs. b.

June 3.—2h. a.m. Extensive aurora, at times brilliant and with much diffused light all over the heavens. There was a succession of curtains rising from the E., touching the horizon at N. and S., and crossing the zenith towards the W. in the form of very large arcs. These curtains seemed broadside on while low down, and gradually narrowed as they rose toward the zenith, appearing to be seen edgewise when overhead. There were sometimes four or five curtains rising one above the other. None passed more than 10° or 20° to the W. of the zenith, becoming there diffused and waxing and waning in intensity, apparently with the force of the wind, which was somewhat squally, force 1–3 E. Temperature, – 21° F. b.

2h. 15m. a.m. to 2h. 30m. a.m. extensive arc. At first apex 5° or 6° E. of zenith, which gradually moved up into zenith. Breadth 2° to 3°. N. and S. extremities of arc to within 30° of horizon on each side. Intensity of light at times fairly strong, 10·5 on wedge photometer, which value just eclipses α Centauris. Light diffused and no vertical shafts. Phenomenon had entirely faded at 2h. 30m. a.m. Exposed spectrum plate for some hours.

4h. a.m. A faint curtain of vertical streamers, about 8° altitude, in the E. true, and a nebulous streamer somewhat higher toward the N. Wind N.E., 2. – 22° F. b.

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6h. a.m. Beams of aurora appearing above the hills to an altitude of 8° to the E. (true). Intensity faint. Light N. airs. b. – 19° F. Some still fainter beams at about 10° to 20° altitude in the S. true.

8h. a.m. Faint aurora in E. and N., bright arc from N.W. to S.E. true.

10h. a.m. Faint, but extensive, aurora in E. and S. true, altitude from 10° to 60°.

Noon. At about noon a low aurora arc on S.E. horizon. Apex about 3° in altitude, and almost exactly in magnetic meridian. Rapid motion in light from left to right, or W. to E. magnetic. (Seen from the Sound some distance from ship.)

(Plate 14.) Auroral arcs and streamers were visible all afternoon, waxing and waning in S.E. and at times bright. Altitude 5° to 50°.

8h. p.m. Faint aurora, visible in patches, E., S., and S.E.; brighter patch and streamer in W.

10h. p.m. Faint bands in N.W. magnetic. Light W. airs. b. – 23° F.

Midnight. Faint bands in same position.

June 4 —2h. a.m. Very faint aurora light, just above hills, bearing E. true. Altitude 10°.

4h. a.m. Faint aurora light in S.E. true.

6h. a.m. Faint streamers of aurora light from N.N.W. (true) to S. (true) at altitude 15° to 20°, varying in intensity, but never bright. Intensity of light equal to star of 4th magnitude.

8h. a.m. Streamers from N. to S.W., brightest to the E.

10h. a.m. Faint irregular streamers in S., altitude 50° to 80°. Arc from S.E. to S.W., altitude 30°.

June 5.—4h. a.m. The upper edge of an auroral curtain showing above the upper edge of a bank of stratus cloud. Altitude 20° and stretching from N. to S.E. true. The curtain was by no means sharply defined on its upper edge, but appeared to be of remarkably even breadth (2° to 3°), and, though very moderately brilliant, of equal intensity at equal altitudes throughout. Two streamers running up to the zenith from N. and N.W. true. Wind S.E., 4–9. Temperature, – 23° F. Weather bq ✢.

6h. a.m. Very faint aurora in N.N.W.

June 6.—6h. a.m. Aurora in N., E., and S., very faint, strongest in E., altitude 40°. Calm. Temperature, – 29° F. b.

June 14.—2h. a.m. One bright auroral streamer passing through zenith, direction N. by E. to S.W. true.

June 16.—6h. a.m. Two streamers seen for few minutes in gap (Observation Hill).

8h. p.m. Faint auroral arc of streamers from S.E. to S.W. through S., altitude about 40°.

June 17.—2h. a.m. Extensive auroral arc from N. to S. horizon across zenith; plainly visible in brilliant moonlight. Lasted about 3 minutes.

Midnight. Faint aurora light E.S.E., altitude 6° to 10°.

June 18.—2h. a.m. Faint arc from E., altitude 5°, to S. by W., 6°. Apex E.S.E., altitude 11°.

4h. a.m. Faint patches of aurora between N.E. and E. by S., and altitude 8° to 20°.

10h. a.m. Bright streamers in S.E. to N.E. and N. true. Part of corona in zenith. Two arcs of streamers N. to S.E., altitude 40° and 60°. Very bright streamer in N.

At about 1h. 30m. p.m. saw faint and low aurora arc in magnetic N., and almost at right angles to magnetic meridian. A large faint arc was observed soon after 10h. a.m. rising from Observation Hill and sweeping across the sky in a N.N.W. direction true, crossing to within 5° of zenith to the E.

During most of afternoon there was a bright and extensive aurora low down on horizon, extending from behind Mount Terror to N. end of White Island. At times streamers rose to 5° altitude, and were bright. Lateral movement rapid.

10h. 25m. p.m. Aurora curtain from N.E. by E. (magnetic), 30° above horizon, to N.W. magnetic, 20° above horizon. Altitude of centre 30°. No rays, but all a cloud-like mass of irregular form with inside edge sharply defined. Brightest patch in magnetic meridian. Width of curtain in some places 5°. Rapid movement towards zenith, but slow lateral movement.

Display had faded before 10h. 35m. p.m., leaving only a faint glow in the N.W.

10h. 44m. p.m. Large faint arc from E. magnetic to N.W. magnetic. Streamers in E. and dense patch of light in N.W. magnetic. Altitude of apex 45°.

10h. 55m. p.m. Patches of light near zenith (N. magnetic). Strange milky appearance of space of sky through which aurora has passed.

Midnight. A comparatively bright, extensive, rapid-moving auroral display. The most noticeable feature was that the lower edge of the arc was the better defined, though neither edges were sharp; the extremities were rather broader than the centre. A fine arc, about one-fifth part of a circle, its breadth not more than 1°; altitude at its centre 8°, where it was also most brilliant, but of extremely variable and rapidly changing intensity, limits E.S.E. to S.E. by E. (true). From the E.S.E. point to 70° altitude there were a considerable number of detached "lights" spreading in azimuth at 30° altitude, and appearing to be parts of an extensive, but incomplete curtain. A few streamers were visible, starting brightly, but fading completely away before reaching an altitude of 20°—two of these at S. and S.S.W. points (true), and three between E.N.E. and E. by S. points. The whole display extended from E.N.E. to S.S.W. (true). Temperature, $-36°\cdot2$ F. Weather b. Calm.

June 19.—2h. a.m. Auroral display of same extent as at midnight, with the exception that there was no arc visible. Intensity very rapidly changing from fairly brilliant to most faint. Temperature, $-41°$ F. b. Calm.

4h. a.m. Three faint streamers N.N.W. to N. by E. true, fading away completely before 20° altitude.

6h. a.m. Very faint aurora S.E. and S.S.E., 12° altitude. Temperature, $-28°$ F. Weather b. Wind light, variable air.

8h. a.m. Faint aurora S.E. to E.S.E.

4h. p.m. Seen from Sound. Aurora extending from E. to S., at an altitude of 10° to 20°, formed of diffused streamers, some visible from ship, showing above Observation Hill. Minimum temperature in Strait, $-51°\cdot5$ F. Temperature at time, $-32°\cdot5$ F. b. Erebus smoke going E.

8h. p.m. Bright arc of streamers from N.E. to S.E. (true), altitude 9° to 15°.

10h. p.m. Disconnected auroral curtain in S. and S.E., altitude 30° to 40°.

Midnight. Auroral glow on the N. side of Crater Hill. Faint glow in S.

June 20.—2h. a.m. Auroral arc from Crater Hill to Observation Hill.

4h. a.m. Aurora light in E. true. No definite arc or curtain.

6h. a.m. Faint aurora streamer from Crater Hill to Observation Hill.

6h. p.m. Auroral display in E. horizon.

Note below is of aurora witnessed in Sound, behind Observation Hill:—

[Between noon and 6h. p.m. incessant display from E. to S. by E. (true).

1h. p.m. A bright wavy line, general direction horizontal, altitude 20°, continuous and without streamers. During the afternoon streamers rose from it, their lower end forming brilliant luminous patches in the line, which began to take the form of an arc; then streamers

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were visible to an altitude of 40° and converged to a point slightly S. of the zenith. Lower edge of arc very even and well defined.

5h. to 6h. p.m. Arc still in same place, but most of the streamers rising from its northern end, and some of them remarkably sharp and brilliant at 5h. 30m. p.m. A second arc appeared below it without streamers. A loop appeared at N. end of upper arc. The streamers faded one after the other from S. to N. When the most northern one had disappeared, new ones formed at the S. end. While the display was at its brightest, it cast well-defined shadows of objects on the floe. Occasionally, in the brightest patches, a pale-green colour was discernible.]

10h. 30m. p.m. Bright auroral arc, extending from E.N.E. to W.S.W., right through zenith, broad in zenith.

June 21.—6h. a.m. Auroral arc very bright, at intervals of thirty seconds to a minute. Highest point 30°. Moving from S. to N.N.W. Temperature, – 28° F. Calm. b.

[4h. 0m. to 4h. 30m. p.m. Went out into Sound and witnessed fine auroral display low down on N. (magnetic) horizon.

At first a long streak of diffused aurora extended from near Mount Terror (or W.N.W. magnetic) to about N.W. magnetic, about 2° in altitude. Soon after an arc was formed from N.W. to N. (magnetic), altitude of apex 3°, then the glow near Mount Terror faded, leaving a milky appearance of the sky, and another arc formed, the apex of which was almost at right angles to the magnetic meridian, altitude 3°. A few isolated beams and patches of light on each side. A very fine curtain of draped aurora was formed a little to the right of the arc at about 4h. 30m. p.m., that part of the curtain nearest the horizon being bright and dense, and contained just a trace of pink. Vertical shafts at extreme right of curtain, but other parts diffused light. Lateral movement rapid, but practically no vertical movement. Display lasted nearly all day, but very low down on horizon, and quite invisible from the ship.]

Midnight. Streamers from N. to S., brightest to N.

June 22.—2h. p.m. Bright aurora to S.E. true, streamers to 20°, and bright glow below hills. A curtain rose to 40° altitude.

1h. 30m. p.m. Bright glow in N.W. magnetic, just showing above gap. Evidently a bright display in same quarter as yesterday, and low down. Inspected the glow with direct-vision spectroscope, and the characteristic yellow aurora line near D was quite distinctly visible for more than 15 minutes, but could see no other lines. Directed prismatic camera towards glow, with Cadet spectrum plate exposed. Magnets appear disturbed. Perhaps the low arc and display in magnetic N., which is repeated for many successive days, bears some relation to the large deflexions in H magnet so frequent and similar—on many of the magnetograms—between 1h. p.m. and 6h. p.m., M.T.

4h. to 6h. p.m. Faint display to N. and E. true.

Midnight. Arc from E.S.E. to S.W. by W., altitude 70°, the widest part not more than 2°. Very bright in the centre, lower edge sharp at W. side (altitude 30° W. side). Completely faded away at 10 past 12. Faint streamers from Observation Hill to Crater Hill. Temperature, – 38° F.; min. – 44° F. Calm.

June 23.—6h. a.m. Faint aurora from E.S.E. to E.

4h. p.m. [In Sound, streamers and arc low down on horizon from N.E. to E.S.E. true.]

10h. p.m. Aurora patch in S. and E. true.

Midnight to 0h. 20m. a.m. Bright aurora patch in zenith, with long streamer extending from it northwards (true). Movement of this streamer N. was very rapid. Light diffused. Two faint curtains a little to S. of Observation Hill and altitude between 10° and 20°.

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June 25.—4h. p.m. Faint aurora in S. and S.S.E.

Midnight. Patches of streamers to E., altitude 10°.

June 26.—2h. a.m. Band of aurora, extending from S., passing a little E. of zenith to N. Patches in E.

4h. a.m. Streamers from N.E. to S.

6h. a.m. Irregular streamers from N.E. to S. and in S.W.

June 30.—8h. p.m. Bright streamers from N.E. to S.E., altitude 10°.

July 1.—8h. p.m. Bright aurora glow in E. and S.E. behind hills.

8h. 26m. p.m. Short curtain, extending from W. 20° N. to W. magnetic. Bright as star of 2nd magnitude. Movement left to right, rather rapid. Breadth of curtain 5° to 6°, altitude 15°. Sky covered with thin mist. This disappeared in a few minutes, leaving only a diffused light, which remained some time after. Exposed spectrum plates.

10h. p.m. Very faint streamers between W.N.W. and N.N.E. (magnetic), altitude 8° to 15°. Temperature, − 20° F. Misty all round to an altitude of 80°. Calm.

Midnight. Bright arc between W.N.W. 8° to N.W. 15° (magnetic). bc, 2. Clouds W. to N.W. true.

July 2.—1h. a.m. Four faint bands between N. 20° W. and N.N.E. (magnetic), altitudes 8°, 10°, 12°, and 15°. Bright confused patch S.W., altitude 12° to 20°.

2h. a.m. Faint auroral bands of light between S.W. by W. and N. 20° W. magnetic, and faint streamers S.W. magnetic, 10° to 15° in altitude.

6h. a.m. Bright patch between S.W. and N.N.E., altitude 10° to 20°.

The above auroræ, July 1 and 2 (10h. p.m. to 6h. a.m.), varied considerably in intensity and form. The intensity never exceeded a star of the 2nd magnitude, but was generally much fainter.

8h. a.m. Bright auroral arcs and streamers S. to N.W. true, and two beams over White Island (S. by E.) resembling clouds, the whole being very unsteady. Visible for 30 seconds E. to N.W. arcs, altitudes 20° to 30°, the brightest vertical ray reaching to about 40°. Weather bright. Wind E.S.E., 1–2. Temperature, − 18° F.

July 3.—6h. a.m. Rapidly changing, but generally faint aurora, extending N.E. to S.S.E. Streamers from N.E. to E.S.E., extending to an altitude of 20°. An incomplete curtain E.S.E. to S.S.E. between the altitudes of 7° and 18°. Temperature, − 23°·5 F. Weather b. Wind E. by N., 6–7.

10h. a.m. Faint arc from N.N.E to S.S.E., altitude 10°. Streamer in N.

4h. p.m. Bright arc from S. to N.E. by E. Part of arc, low down on horizon, seen from Cape Armitage, altitude 5°, E. to S.S.E.

6h. p.m. Faint auroral arc in E.S.E.

July 4.—2h. a.m. Faint streamers in N., altitude 40°, three in number and quite detached.

4h. a.m. Very faint patch in N., altitude 20°. Very faint band in E., altitude 10°, parallel to hills. Above this, at an altitude of 15°, very faint streamers occasionally manifested themselves.

6h. a.m. Very faint streamers in S., altitude 10°.

Midnight. Faint arc S.E. to E.

July 5.—8h. a.m. Faint arc from N.E. to S.E., altitude 10°.

10h. a.m. Faint arc from N. to S.E.

July 6.—Arc from S.S.E. through zenith to N.N.E. (No time stated.)

July 12.—4h. p.m. Extensive faint aurora in N. extending to 20° and 30°.

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July 15.—4h. a.m. Faint aurora in E., altitude 15°.

Auroral streamers were seen low down on horizon from E. by S. to S.E., at about 4h. 5m. p.m., and lasted some time. Fairly bright. None of the streamers attained a greater height than 4°.

July 16.—4h. p.m. Faint arc from E. by S. to N.W. by W., altitude 20°.

Midnight. Extensive, though very faint, auroral glow N. to S.E., reaching to 40° in altitude, fading away completely and reappearing again at intervals of about 30 seconds. Temperature, − 32° F. Weather b. Calm.

July 18.—4h. p.m. Diffused aurora light in S.E. and streamers to altitude 8°.

July 19.—4h. a.m. Faint arc N. to E., altitude 15° and 7°. Wind N.E., 1–2. No clouds.

6h. a.m. Arcs, N. to S.E., seen at intervals of 20 to 40 seconds. Temperature, + 3° F. b. Calm.

An especially brilliant aurora suddenly appeared a few minutes after 4h. p.m., in the shape of a curtain, or segment of an arc, extending from W. 20° N. to N.E. magnetic. There was more movement, both vertical and horizontal, than has yet been observed. The vertical movement of the whole display *en masse* was fairly rapid from S. (or N. magnetic) towards the zenith, and the horizontal motion of the huge shafts of light at one time too rapid for the eye to follow. The intensity of the light rapidly changed, frequently showing a green hue, and occasionally a faint pink. Directed spectroscope towards the light, but it was too evanescent and shifting to see anything. Altitude at first was about 10° at the extremities E. and W., and 20° in centre, but this gradually rose to 50° and 60° in the centre. The brightest display was at about 4h. 10m. to 4h. 15m. p.m.; had almost entirely disappeared at 4h. 25m., and at 4h. 35m. there were very faint, slightly luminous patches here and there. During this special display a bright auroral glow showed up above the hills almost at right angles to the curtain. The display originated quite suddenly in the direction of Mount Discovery (E.N.E. magnetic) and flashed across the sky towards Observation Hill in a few seconds. Temperature of air, − 3°·2 F. Wind E.N.E., 2–4. Clouds nil. The temperature during the last two days has been abnormally high, the maximum yesterday being + 12° F. This seems to indicate a warm current from some direction, perhaps from the Ross Sea. Brisk N. and N.W. winds prevailed yesterday. A deep red glow from the sun below the horizon appeared this morning and remained in the northern sky until about 2h. 30m. p.m. This glow extended to quite 20° in altitude. This characteristic glow appears for two or three days some weeks before the return of the sun and some weeks after it leaves.

The display, which from the ship showed just above the hills, was seen by an observer in the Sound and took the form of two segments of arcs, extending from N.E. to S.S.W., with streamers radiating from the upper edges towards the zenith.

July 20.—8h. p.m. Faint auroral glow behind hills to N.E.

Midt. Band of auroral light crossing zenith E. and W., 10° to 15° in length. Faint luminosity low in sky, S. to S.S.E. Temperature, − 17° F. b. Wind E. by N., 1.

July 21.—4h. p.m. Auroral display in E.

July 22.—2h. a.m. Extensive, complicated, and rapidly changing display from S. by W. to S.E. true, rising to zenith, and occasionally beyond. At first appearing as a number of parallel segments of arcs, from horizon to 70° in altitude, though as many as seven could be distinguished, some were irregular and dimly outlined; numbers 2 and 3 from zenith were especially bright, uniform, and exact in parallelism. Later this phase changed to one in which the same portion of the sky was covered with numerous irregular patches of light. At 2h. 15m. a.m. the arcs above and below re-formed. There seemed a movement in parts of the display to the N.N.E., but some patches, carefully watched, remained quite stationary. One arc distinctly passed from S. to N. of zenith, and, when S., its upper edge had the usual vertically fibrous fringe. Immediately overhead there was a mere band of light, but to the N. the vertical fibres again sprang up. The greatest brilliancy was about equal to a star of the 2nd magnitude. Temperature, − 30° F. b. Calm.

July 23.—2h. a.m. Faint auroral streamers converging N. to E., altitude 50°. Temperature, + 2° F. Wind E., 1–2.

July 24.—2h. a.m. Diffused aurora in S.E. and S. and slight trace in S.E. at 4h. a.m.

Midnight. Very faint narrow auroral band, extending from N.E. to S.W. through zenith. No movement visible. Calm. b. Temperature, − 8° F.

July 25.—4h. a.m. Very faint and disconnected arc of rays, extending from N. through E. to S.W., altitude between 30° and 40°. No movement visible. Wind N., 1. Temperature, + 9°·2 F.

6h. a.m. Very faint and disconnected arc of rays, extending from N. to S.E., altitude 20° to 30°. This shortly changed into a narrow arc of diffused light, with extremely faint rays at the N. end.

From 4h. to 6m. a.m. there was a continuous aurora of the above nature, sometimes extending to the S., but always faint and of the same altitude.

8h. a.m. Very faint auroral streamers S.E. and E.

Midnight. Faint auroral streamer in S.E.

July 26.—2h. a.m. Faint auroral streamer in S.E.

4h. a.m. Low arc S. to S.E., altitude of apex 20°. Occasional bright rays, showing above land, from S.E. to N.E., extending to an altitude of 50°. Auroral curtain in N., altitude 30° to 70°.

6h. a.m. Low arc S. to S.S.E., streamers, or rays, through E. to N.

8h. p.m. Diffused extensive aurora from E. to S.W., very faint.

10h. p.m. Aurora light just showing up above hills from N.N.W. (magnetic) to S. 15° W. magnetic.

Midnight. Aurora just above hills, from S. to S.W. magnetic, altitude about 5°.

July 27.—2h. a.m. Isolated patches of diffused aurora, from N. to S.E., true, altitude 10° to 30°.

4h. a.m. Streamers, or rays, from N. to S.E., true; various heights, mean 40°.

The aurora was more or less visible all night, and confined principally to N.E. true, average altitude 20°. Died entirely away at about 5h. a.m., when a very thin mist of Ci.-s. cloud covered the sky, partially obscuring the light of the stars. Temperature, − 24° F. to − 31° F. Calm. b.

At about 9h. 45m. p.m. an unusual form of aurora appeared. A band of light extended from due S. to due N., passing round through E. Breadth of band 5° and averaged 12° in altitude. Intensity fairly strong in N., where a greenish tint predominated, and occasionally a reddish hue manifested itself. The display reached its maximum brilliancy at about 9h. 50m. p.m., and had almost entirely disappeared at 10h. 10m. p.m. A few arrow-like beams were visible here and there just above the band.

Midnight. A few faint streamers in E.S.E. true, and then a segment of a low arc appeared in gap. It became bright and faded away in the space of about three minutes.

July 28.—2h. a.m. Faint aurora diffused over the E., forming a narrow curtain and a few streamers scattered irregularly.

3h. a.m. Fine display of aurora, involving the whole heavens from N.W. by E. to S. true. Nothing ever visible in S.W. Three fine compact curtains in the E., one above the other, height

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of uppermost approximately 60°. Three more curtains, more diffused, but bright and much folded, extended from N.W. to zenith, where there were two large bright luminous clouds. The rest of the area was filled with more or less isolated streamers, small or fragmentary curtains or clouds. All was constantly changing both in shape, position, and brightness. The three N.W. curtains broadened and faded, then becoming more brilliant and folded; the easternmost disappeared, the central remained more or less, and the westernmost travelled over to the westward and disappeared at an altitude of 60°, or thereabouts. Beyond this nothing was ever seen. The eastern curtains disappeared (these had the form of arcs) and were replaced by scattered fragments of curtains and a large faintly luminous cloud (sufficient to throw up a large part of the outline of Mount Erebus). At one time a single curtain appeared to have four folds, each fold being very bright and lasted a few minutes. To the S.E. was an occasional curtain and numerous isolated streamers, one of these 40° in altitude, very bright.

4h. a.m. Only the remains of the above display visible in the form of two curtains; several faintly luminous clouds and streamers, principally to the N. and N.W. true.

6h. a.m. Faint streamers to N.E. true, fainter to the S.E., and an auroral cloud over White Island. Temperature, – 18° to 30° F. Calm. b.

8h. a.m. Double auroral arc, very bright, but not lasting longer than one minute. Streamers to an altitude of 30°. Direction E. to S.S.E. true. Temperature, – 19° F. Wind E., 2–3. No clouds.

4h. p.m. Diffused aurora low down to S.S.E.

8h. p.m. Aurora glow, with a few faint streamers in S.E., altitude 10°.

8h. 45m. p.m. Faint auroral bands in gap, and one over Observation Hill. Directed prismatic camera towards light.

10h. p.m. Aurora in well-defined arcs, S., about 5° in altitude.

July 29.—2h. a.m. Broken arcs of medium intensity were to be seen in almost every part of the sky up to the zenith in the E. and S. true. Movement not very apparent, but the intensity was very variable. b. Calm. Temperature, – 42°·3 F.

4h. a.m. Broken portions of arcs to be seen low on the S. horizon, filling the sky to a greater elevation towards the E. and N., where two wide curtains rose vertically from the horizon nearly to the zenith, pale green in colour and of considerable intensity. Movement not very apparent. Calm. – 39°·5 F. b.

6h. a.m. Two faint arcs, one above the other, in the S. and S.E. and E. up to 10° altitude, formed of a multitude of distinct rays, with very little blending. Calm. – 38° F. b.

4h. p.m. Bright confused auroral arc, from S.E. to E.S.E., at 5° altitude.

8h. p.m. Bright band of rays, N. to E.S.E. true, altitude 10°. Patches of rays in N.

11h. p.m. Arc of light, E. to S.S.E. true, apex 8°, width 1° to 2°. Fainter segment above, 12°.

Midnight. Band of bright light between W. by N. and N.N.E. magnetic, apex N. by W. magnetic, altitude 9°. bm low down in W. Calm. – 31°·2 F.

Fairly bright display seen one mile S.E. of Cape Armitage, between 7h. and 9h. p.m., extending from behind Mount Terror to S.E. true, and starting with a red-rolled mass, about 5° above the horizon. This was very bright and lasted about three minutes, then changed to arcs of rays, some being double and rising to 20°. This was the brightest phase, then formed a long arc, or curtain, with rays to S.E. and N.E., altitude 30°. The whole split up into isolated rays. A greenish tint was observed during the phenomenon. – 33° F. Calm and bright.

July 30.—4h. a.m. Short arcs, 2° broad, between W. and N. by E. magnetic, altitudes 8°, 15°, 20°, and 28°. Very variable in intensity and position.

6h. a.m. Faint bands of rays, between S.W. and N. by E. magnetic, between 8° and 60° in altitude. Very variable in intensity and position. b. E.S.E., 1. Temperature, – 32°·2 F.

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August 11.—At 7h. 30m. p.m. diffused aurora cloud in N. by E. true, altitude 10°, also a streamer stretching from altitude 15° E. true, passing within 7° S.W. of zenith and continuing for some distance towards W.S.W. Ci.-s. cloud over sky, so aurora must be fairly strong to show through. Colour pale straw, with suspicion of pink. Blowing hard, but little drift.

August 12.—7h. 14m. p.m. Diffused band from S.S.W. to W. true, altitude 10°. Width of band 5°.

8h. p.m. Two arcs extending from W. to E. in N. and S. (true), altitude of arc in N. about 20°, altitude in S. about 50°. Moderately bright. The arc in S. quickly faded out, but one in N. faded and brightened intermittently. Patch of streamers to W. in form of a curtain, but very ragged and faint. Glow to N.E.

Midnight. Two faint vertical curtains of auroral light, bearing N. by W. and N. by E. true, to an altitude of 20°. Wind E.N.E., 2–4. bq. Temperature −12° F.

August 13.—2h. a.m. Faint auroral arc between E. by S. and S.E. true, altitude 8° to 10°, apex E.S.E. true, 12°. Wind N.E. by N., 2–4. bq. Temperature, −10°·5 F.

4h. a.m. Two faint streamers N. and N.E. true, altitude 10° to 20°. Wind N. by E., 2–3. bq. −6°·2 F.

10h. p.m. Fairly brilliant display, consisting of a complete arc, extending from N. to S. and two streamers. The highest point of the arc was due E. true, with an altitude of 15°. At its E.S.E. point it was distorted by a relatively more brilliant and wider zone of light with a streamer rising out of it to 30° altitude. An independent ray also rose to 30° altitude to the S.E., but did not quite reach to the arc. The breadth of the arc was between 2° and 3°, the lower edge more defined than the upper, but neither particularly definite. Very rapid movement and very rapidly changing in form. By 10h. 10m. p.m. the arc had completely disappeared and was replaced by streamers of irregular altitude and interrupted in their lengths. The streamers rose at various points where the arc had been, the extremes being at E.N.E. and S. by E. points, with two more in between. The altitude of the highest was 40°. This latter display was also very rapidly changing. Wind S.E., 2–3. −13°·2 F. Weather b.

10h. 20m. p.m. Diffused streamer from due N. true, spreading out fan-like to about 30° altitude, but one thin band from one side of the fan extending across the sky to the W.

No aurora visible at 10h. 45m. p.m.

At 11h. 10m. p.m. fine arc in S., extending from N.W. magnetic to N.E. magnetic, altitude of apex 25°, and exactly in magnetic meridian. The N.E. extremity much the brightest and formed of vertical rays, while N.W. and centre was rather faint and about 4° in width. The whole display moved rapidly towards zenith and at the N.E. formed draped aurora of a greenish tint, which appeared to brighten up with heavy gusts of wind. Blowing hard from S.E., and air full of minute air crystals. A few isolated rays in N. true, altitude 40°. Shortly after a bright draped curtain appeared a little to E. true of zenith, altitude 80°, and arc became very faint.

At 11h. 20m. p.m. only a few faint cloud-like patches here and there were visible.

Midnight. Very faint aurora, incomplete arc E. to W. Greatest altitude S. true, 8°, varying in intensity rapidly. b. −12°·0 F. Wind E. by S., 3–4.

August 14.—2h. a.m. Very faint, but extensive, aurora. Patches scattered about asymmetrically from N. to S.S.W.

4h. a.m. Extremely faint aurora N., N.N.E., and E., barely visible at times. b. Temperature, −15°·9 F. Wind S.E., 0–2.

6h. a.m. Two very faint auroral streamers to the E., rising to 15°, rapidly changing. b. −13° F. N.E. by E., 2–3.

August 15.—Faint aurora seen from Sound at about 5h. p.m., S.E. by E. true, the centre of display. Rays to an altitude of about 20°.

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August 16.—2h. a.m. Faint auroral arcs and rays, E. to S. true, altitude 10° to 30°. Calm. b. Temperature, – 12° F.

4h. a.m. Auroral display, bright at times, N. to S.E. true. Wind E. by S., 2–3. b. – 9° F.

Midnight. Vertical beams of aurora showing over Observation Hill, just discernible. Wind E, 4–5. b. – 9° F.

4h. p.m. Faint aurora.

August 17.—An unusual position for aurora observed soon after 11h. p.m. Arc extending from S. magnetic to E. 25° S. magnetic, apex S.E. by S. magnetic, altitude 17°. It is very unusual to see an auroral arc in the N.W. true.

Midnight. Very faint streamers over Crater Hill. Bright arc from Crater Hill to Observation Hill, maximum altitude 25°. Faint display S.W. to S. true and changing rapidly. Extensive patches from S. to N.W. true, and which rapidly disappeared. Altitude of highest 50°. b. Wind N.E., 4–5. Temperature, – 15°·2 F.; min. – 25°·2 F.

2h. a.m. Bright streamer of irregular altitude, from S.S.E. to N.N.W. true, the highest being 25°. b. – 16° F.; min. – 19°·8 F. Wind N.E., 3–4.

August 19.—2h. a.m. Bright band of irregular thickness, from 20° altitude at N.E. true, direct to zenith and 5° beyond. Arc to S., 30° altitude, stretching S.E. to S.S.W. true. Not so brilliant as zenith band.

At 2h. 5m. the whole phenomenon had faded greatly and did not again become bright, although watched until 2h. 15m. a.m. E.N.E., 5–6. b. Temperature, – 11° F.

4h. a.m. Streamers and patches of light N. to E. and extending to zenith. A few stray and less brilliant streamers to southward. Calm. b. – 9° F.

August 23.—11h. 20m. p.m. Bright aurora, extending from N. by W. to S.E. true, glow over the hills, but no beams.

August 25.—At 5h. 50m. p.m. diffused band of aurora from N. to E. true, across tops of hills and in gap, forming a double arc. Width of band and arc 3° to 5°, diffused green and faint pink in lower parts. Light seemed to be moving from N. to S. Average altitude 10°; highest N., where it was nearly 15°, and lowest E., where it was only 8°.

At 6h. p.m. light had almost entirely disappeared.

August 26.—2h. a.m. Long, low arcs, well-defined and complete, formed of closely packed rays of small altitude. The largest arc rose to 10°, and stretched from N.E. to S.E. true, joining here a smaller, which rose to only 3° or 4°, and extended from S.E. to S., or a trifle W. of S., true. Movement slight. Portions of broken arc and a few beams appeared at greater altitudes, but the brighter parts were all low. Intensity fairly marked in E. Greenish light. Calm. b. Temperature, – 32° F.

4h. a.m. Much aurora in the N., E., and S. true, up to the zenith. An extensive folded curtain of long beams rose from the N. to the zenith. Diffused greenish light mingled with broken arc in the "gap" and over the hills to the N.E. Long beams shot upwards from what were apparently broken arcs, or curtains, in various parts of the sky, from the horizon upwards, S., E., and N. Intensity of individual patches, bright and greenish, for a short while here and there. Movement inconspicuous. No brilliancy in the zenith and no appearance of corona. Light W. airs. – 26° F. b.

From 7h. p.m. to 7h. 50m. p.m. brilliant aurora was observed. Started with rays showing up above the hills from N. magnetic all the way round to S. magnetic. Some of these rays were exceptionally long, extending, in some cases, to an arc of 50° (vertically). The display seemed to have no special form. All manner of sinuous, evanescent streamers, arcs, &c., were observed. At about 7h. 35m. p.m. one streamer, or ray, about 1° in width, extended vertically above Observation Hill to about 83° in altitude. This is the longest ray we have observed. At

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7h. 40m. p.m. a winding streamer, or curtain, appeared in the "gap" and extended to about 45° in altitude. This was the most brilliant part of the display and was about equal to a star of the 2nd magnitude. At 7h. 50m. p.m. the display had almost dispersed, but remained faint and very diffused, like a kind of light luminous mist for some time after. Colour, straw, green, and faint tint of pink in brightest and lowest parts. Breadth of streamers about 2° to 3°, light diffused, sharper edge near earth, and, although flashing out and then fading away continually, appeared to have but little lateral or vertical movement. The display was specially notable for its extent, viz., from N. to S., and complexity of its forms, but at no time very brilliant. Average altitude 15° to 20°. Dry bulb = +1°·0 F. and wet = zero. Rising rapidly. At 6h. p.m. temperature was −25° F. Wind light E. airs. b. Exposed two spectrum plates to light, but without result.

9h. 45m. p.m. Well-formed arc, extending from N.N.W. to W. 5° N. magnetic, altitude of apex 11°, faint, breadth 3°.

August 27.—Midnight. Two incomplete arcs of moderate intensity, extending S.E. to S.S.W. true; edges ill-defined, but no outlying luminous patches at all. The upper arc about 20° in altitude, the lower about 12°. One above the other. Weather, b. Calm. Temperature, −18° F.

August 28.—2h. a.m. Extensive but rather faint and disconnected aurora extending from N.N.E. to S.S.E. true. Rapidly changing. Brightest at the commencement of an incomplete curtain rising from the N.E. to 70° altitude. b. Calm. Temperature, −24°·7 F.

4h. a.m. Extensive, though barely visible, aurora from N.N.E. to S. true, reaching 40° in altitude. b. E. airs. −20°·6 F.

Midnight. Slight auroral streamer in E. −20° F.

August 29.—2h. p.m. Pale auroral curtain in N., and broken arc over Crater and Observation Hills.

September 14.—A rather fine display manifested itself soon after 10h. p.m., commencing in a large arc of faint rays, extending from E. to W., apex 45°.

At 10h. 20m. p.m. the arc had risen to 75° (apex) and extended from directly over Mount Discovery (E.N.E. magnetic) to W. 5° N. magnetic. Width of arc 2°, broadest in N. true; light rather faint and diffused.

At 10h. 30m. to 10h. 35m. p.m. aurora was rather fine, extensive, and fairly brilliant, extending from Mount Discovery, across and through zenith, to nearly due N.

The aurora was most beautifully draped along its whole extent, and would flash out brilliantly for a few seconds. Breadth of display 5°, N. edge sharply defined.

At 10h. 40m. p.m. display had almost faded away.

September 15.—10h. 35m. p.m. isolated faint ray over Crater Hill, altitude 20°.

At 10h. 55m. p.m. display was almost exactly similar to that last night. A huge streamer, about 4° in width, and draperies extended from about 15° above Mount Discovery, up and through zenith, towards N. true.

Soon after 10h. 58m. p.m. the display formed a loop around zenith. Still draped and faint, but very sharply defined aurora, like rays to the left. The dark spaces between each ray were about equal to the breadth of the ray. Light diffused = star of 3rd magnitude.

Whole display very evanescent, and had almost entirely disappeared at 11h. p.m. Temperature, −34° F. Wind N.E., 3–4. bc. Ci.-s. 2.

[The aurora displays seem to increase in mean altitude from month to month. They are now much more confined to the zenith and are generally more or less draped. Notes should be carefully examined for any indication of such monthly period in altitude.—L. C. B.]

The following few observations made *at sea* may here be added:—

March 8, 1904.—Latitude at noon, 60° 42′ S.; longitude at noon, 161° 11′ E. At about 8h. 30m. p.m. faint aurora cloud appeared in E.

At 9h. 40m. p.m. became fairly brilliant and formed a huge arc, stretching from E. horizon to W. horizon and to S. of zenith. Altitude of apex 70°, breadth of arc 3°. Light pale straw and white, with tinge of green, but no red. Very diffused. No sharp vertical rays. Movement slight.

At 9h. 45m. p.m. had nearly all dispersed. Temperature, + 36° F. Wind W. by N. Barometer 28·70 inches. Cloud nil.

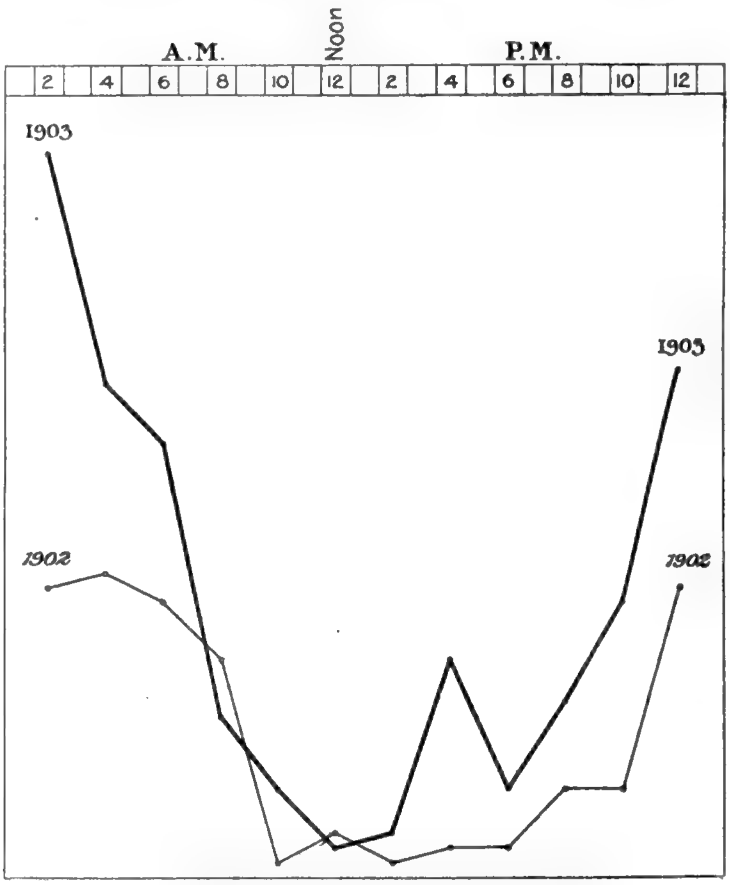
At 10h. p.m. arc again visible, extremities bearing nearly same, but altitude of apex increased to 80° or 85° broader in W. than formerly. Same diffused appearance.

March 13.—Latitude at noon, 53° 32′ S.; longitude at noon, 165° 17′ E. Slight auroral displays have been seen nearly every evening, but extremely faint.

Heavy squalls of wind and hail last night, when force of wind rose to 10, Beaufort's scale, and some of the hailstones measured 1·6 centims. through their major axis and 1·3 centims. through their minor. Also occasional flashes of lightning in various directions, but principally N.E. During middle watch there was an extraordinary display of St. Elmo's fire on mast-heads and yard-arms, at times so brilliant as to show outline of crow's nest and yards against the dark sky. The phenomenon was most brilliant at midnight and between 1h. a.m. and 2h. a.m.

TABLE showing Number of Days in each Month when Auroræ were Recorded.

Year.	March.	April.	May.	June.	July.	August.	September.	Total.
1902	0	10	8	11	10	9	4	52
1903	2	18	14	18	22	14	2	90
Days . . .	2	28	22	29	32	23	6	142



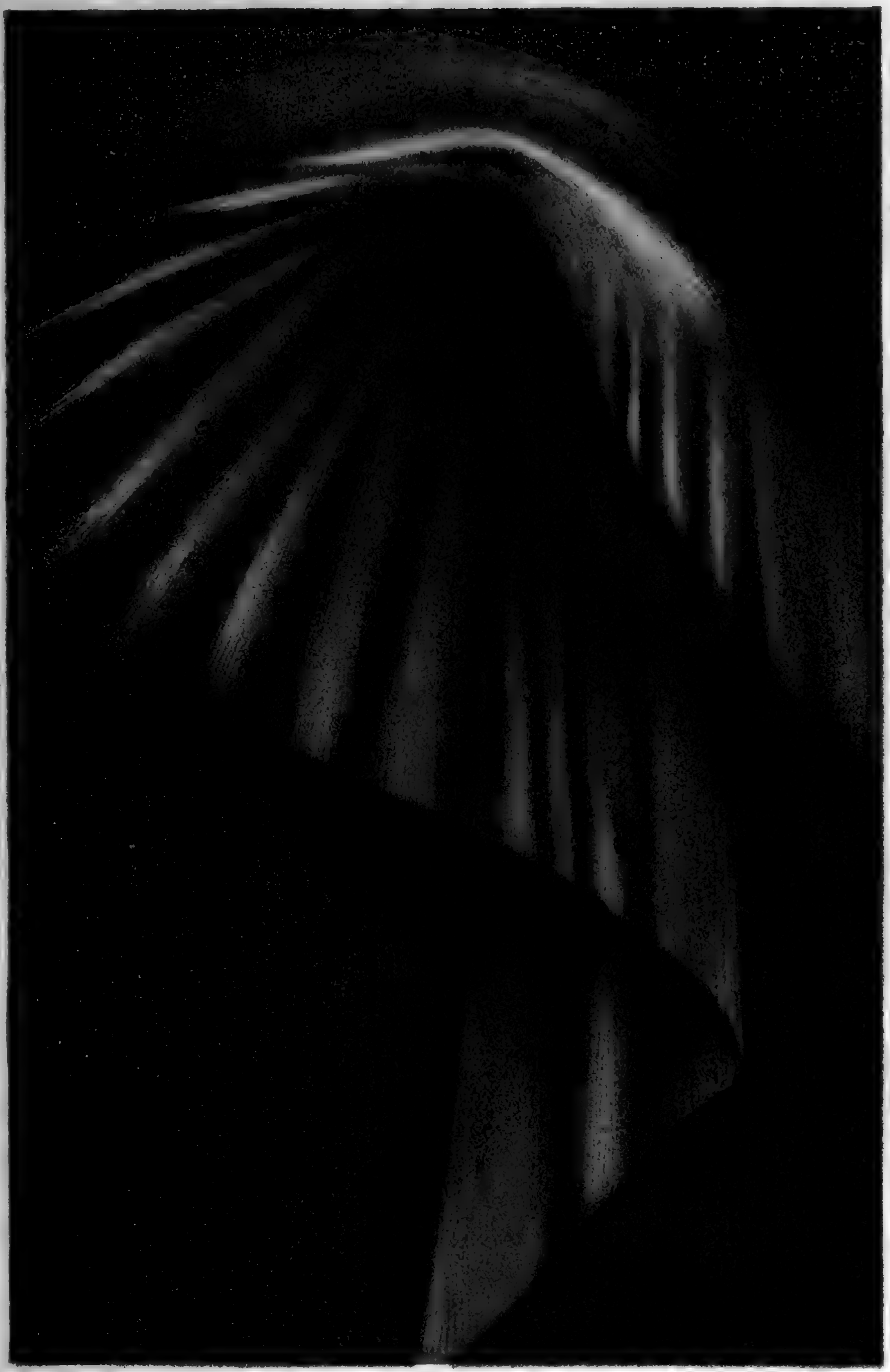
Curves showing diurnal frequency of auroræ.

West, Newman lith.

Auroral Streamers, April 9th, 1902. 2h 25m AM, M.T.

West, Newman lith.

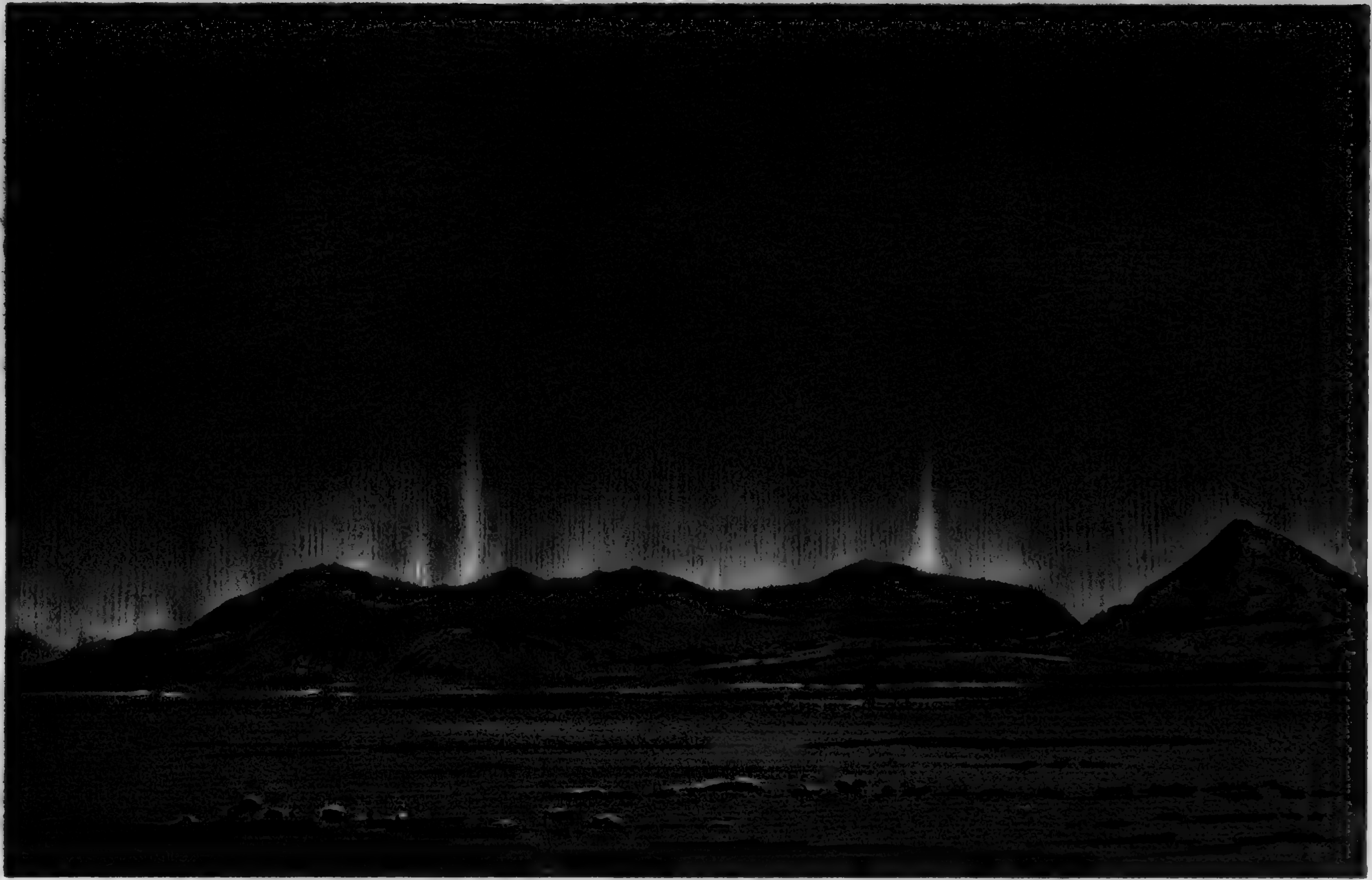
Corona, April 8th 1903. 2h A M.



West, Newman lith.

Corona, May 31st 1903. 4h P.M.

PLATE 14.



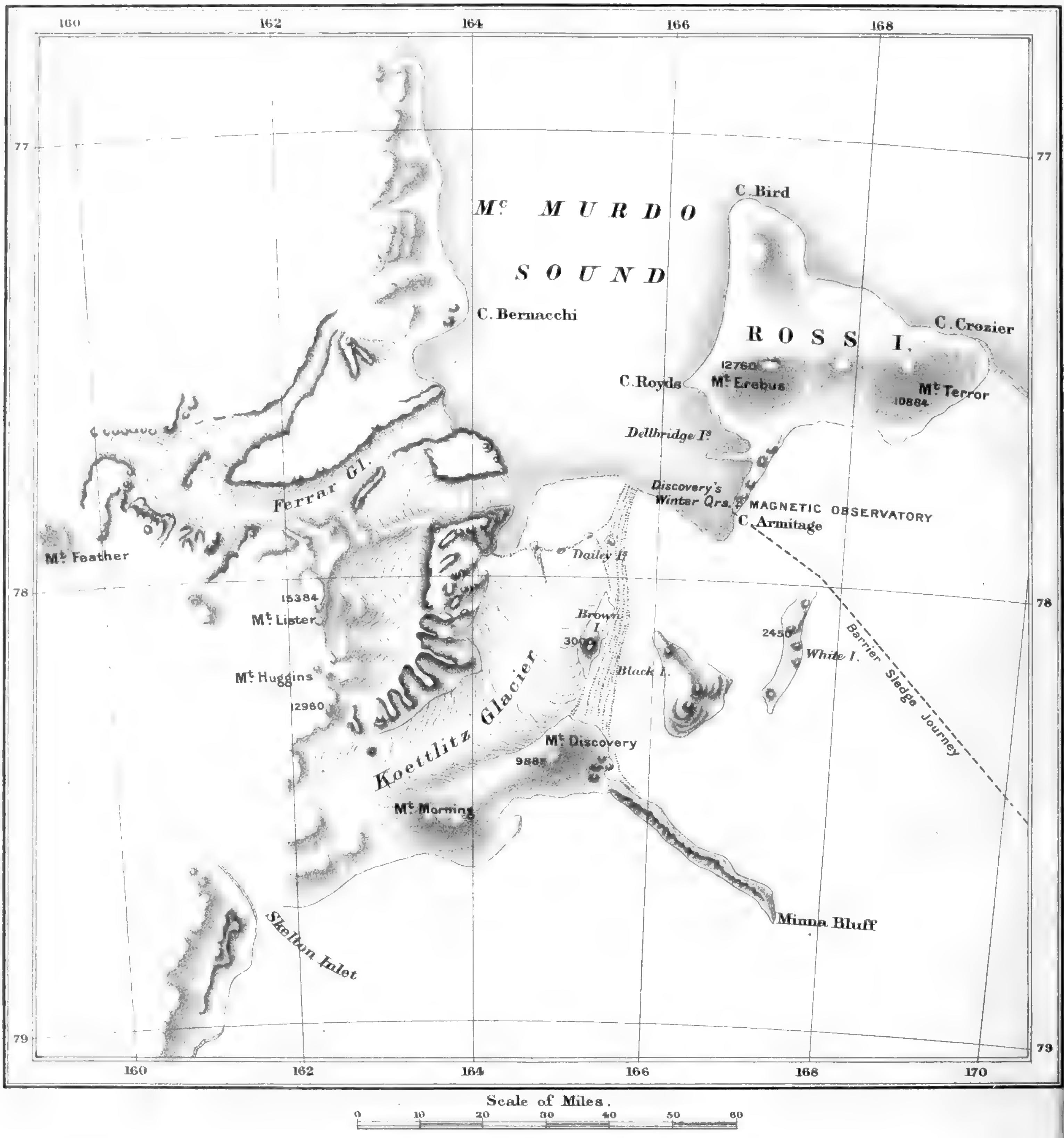
West, Newman lith.

Low Auroral Arc showing above Hills, June 3rd 1903, noon.

V. ANTARCTIC MAGNETIC OBSERVATIONS

1902-1904.

ANTARCTIC MAGNETIC OBSERVATIONS, 1902-1904.



The parts coloured brown indicate rock-outcrops through the ice-sheet. (For the nature of the rocks see the large map accompanying the volume on Geology)

Heights are given in feet.

I. INTRODUCTORY STATEMENT.

BY

L. C. BERNACCHI, F.R.G.S.

Winter Quarters.—The Winter Quarters of the ship "Discovery," of the National Antarctic Expedition, were situated in latitude 77° 50′ 50″ south, longitude 166° 44′ 45″ east of Greenwich, and to the south of a narrow peninsula extending in a south-west direction from the base of an island formed by Mounts Erebus and Terror. The "Discovery" remained frozen-up in her Winter Quarters from February, 1902, until February, 1904. With the exception of the first and last months the magnetic observations extended over the whole period.

Instruments.—Besides the Fox and Lloyd-Creak instruments for the determination of Inclination and Total Force at sea, the "Discovery" was supplied with Unifilar Magnetometers and Dover Circles for the determination of absolute Declination, Horizontal Force, and Inclination on shore, and with a set of Eschenhagen variometers, or self-recording instruments, for obtaining a continuous photographic record of the changes in Declination, Horizontal Force, and Vertical Force.

The Magnetic Observatory at Christchurch, New Zealand, was made the primary base station of the Expedition in the Southern Hemisphere; there the constants for the instruments were determined before sailing in 1901, and again on returning in 1904. Our thanks are due to the New Zealand Government for their courtesy in placing the Observatory at our disposal, and to Dr. Coleridge Farr, D.Sc., and Mr. H. F. Skey, B.Sc., of the Observatory, for their valuable assistance.

As the magnetic programme of the Expedition was an important one, preparations were at once made to commence observational work and to complete the construction of the Magnetic Houses for March 1.

Observatory Site.—The spot selected for the Observatory, although the best available, was hardly an ideal one for magnetic observations. From a magnetic point of view, an observatory of this kind should be placed in a position as little as possible disturbed by the presence of magnetic rocks; but it would be difficult, if not impossible, in the whole length of Victoria Land to find such an undisturbed locality, unless it were on the surface and near the seaward edge of one of the extensive ice-floes, far from the actual coast line, such as the Great Ice Barrier.

The site selected for the houses was a low and fairly level piece of rocky ground close to the extremity of the peninsula, and at a distance of about 300 yards from the ship. (See Plates 15, 16.)

The peninsula (*vide* Map) is about 10 miles long by a mile broad, and has an average height of 600 to 700 feet, although the extremity where the Observatories were placed was only 30 feet above mean sea level. The rocks of which it is composed are practically of three varieties.

Geological Formation.—(1) A yellow breccia which occurs in three well-marked heights, the nearest of which was 3 miles distant from the Observatory and 1400 feet high. This rock did not appear to be developed to any great extent, but occurred as a volcanic pipe surrounded by the basalt which forms the major part of the peninsula.

(2) The trachyte found on Observation Hill, a hill three quarters of a mile distant from the Observatory, and 750 feet in height. This hill was conical in shape, the upper half being composed of a trachyte of a specific gravity 2·244, and the lower half of a lava containing lapilli of a very varying composition, and with a specific gravity in one case of 2·87.

(3) A black basalt which is by far the most important rock both as regards its development and

physical properties. It forms the ridge called Harbour Heights, and reaches from Hut Point (the extremity of the peninsula) to the base of a conspicuous rock some 6 miles along the peninsula named Castle Rock. It forms three quarters of the rock of the peninsula, and rises to an average height of 700 feet between the two points mentioned above, and lies nearly perpendicular to the magnetic meridian. It has a specific gravity of 2·929, and under the microscope shows frequent plates of magnetite. Hut Point is entirely formed of it, and it was over this rock that the magnetic observations were made.

Mount Erebus, 25 miles distant, rises as a full-bodied cone, with its base 12 miles distant. The specific gravity of the external rock may be taken as 2·9. The mountain lies north by east of the Observatory, and is nearly 13,000 feet high.

Mount Terror, lying nearly 40 miles north-east of the ship, is nearly 11,000 feet high, and is composed of basic rocks of specific gravity 2·97. The two are joined by a ridge probably 8000 feet high, and of a similar rock to that which forms the masses of Erebus and Terror.

There is no important land development to the southward, there being only the two islands under 3000 feet high and composed chiefly of basalt of specific gravity 2·9. These are respectively 20 and 25 miles distant from the Observatory.

Mount Discovery lies south-west at a distance of 50 miles. It is also conical, with a height of nearly 10,000 feet, and the diameter of the base some 10 miles. It appears to be chiefly composed of the same basic rock so common in this locality.

Turning to the west there is a totally different development of rocks. A great mountain chain, running nearly due north and south, lies at a distance of 70 miles from the ship, and rises to heights of 12,000 and 15,000 feet, and is on an average about 11,000 feet high.

This chain is composed of granites, diabases, and quartzites. The granites form the core of the chain and rise to a height of 4500 feet above sea level. They vary in composition and have a specific gravity between 2·6 and 2·7. Above this occurs a diabase up to a height of 8000 feet. This rock lies practically horizontally on the plutonic rocks (though interrupted by faults) and has a specific gravity of roughly 2·8, while above it, and also horizontal, a sandstone occurs which has a specific gravity not greater than 2·67.

It must be borne in mind that the above directions of the various land masses are *true*, and that, as the Declination amounted to about 152° east, the magnetic directions are entirely different, the north-seeking end of the magnet pointing within 30° of the geographical south.

I am indebted to Mr. H. T. FERRAR, M.A., for the whole of the above geological information.

Observation Houses.—The Observation Houses were constructed of large asbestos slates, screwed on to the outside and inside of a wooden framework. The larger of the two, used for the Variation House, was 11·6 feet by 11·6 feet and 6·8 feet high. The Absolute House was slightly smaller. Although, perhaps, small log houses would have been more suitable, they certainly would not have been so light, compact, and easily portable. The asbestos houses were fairly satisfactory, but had some grave disadvantages.

By the end of February, 1902, the erection of the Variation House (A) was completed, and the variometers set up and working. The Absolute House (B) was completed later, and placed 25 yards to the north of (A). For the absolute instruments a brick pillar was built up through the floor of B, 3 feet 6 inches above it, and 2 feet by 1 foot 6 inches square. The door of the house faced nearly due west (true), and narrow openings with sliding doors were made across the roof and down the north and south walls in, as near as possible, the geographical meridian, for the purpose of using a transit instrument or theodolite.

Azimuth Mark.—An azimuth peg was erected a little to the south of west, 30 yards from the observational pillar. The peg was an iron one, driven into the frozen ground to a considerable depth, and only 1 foot showing above the surface. At the top was a circular hole, across which a wire was stretched, and a light was placed behind when bearings were taken from the Absolute House in the dark winter months. This mark remained throughout the two years, and was at no time disturbed. The azimuth of this fixed mark for Declination observations was determined by a number of sun azimuths in the spring and summer of 1902–1903 and 1903–1904.

The Absolute Observations.—As soon as possible the absolute values of Declination, Horizontal Force, and Inclination were determined, the instruments employed throughout the two years being the same, viz., Unifilar Magnetometer No. 25 by Elliott Bros., and Inclinometer No. 27 by J. Dover. All the magnets were adjusted in their stirrups for the latitude, and for the Horizontal Force observation Magnet 25A was generally employed. The results of the observations show how constant the moment of this magnet remained. The silk suspension threads were the same throughout, and were never once broken or changed.

The method of observation was the same as that employed at Kew and other observatories, the only difference being that, instead of distances 30 centims. and 40 centims., in the deflection experiment 42 centims. and 56 centims. were used, owing to the small size of the force.

Magnetically disturbed days, especially in the summer, were very frequent. It was only on a few days in each month that good absolute observations were possible. It was not always easy to select quiet days. Frequently attempts at absolute observations had to be abandoned on account of too great disturbance, and, in the winter, sometimes on account of a blizzard, which made intercourse between the ship and the shore, and observing in the small exposed absolute house, almost impossible.

Observations for Local Attraction.—In order to determine the influence of the rocks at the Observatory on the absolute values, a large tent was erected on the unbroken sea-ice in McMurdo Sound in November of 1903, 1·7 miles from the nearest shore line and over a spot where the depth of water was 200 fathoms (1200 feet). Soundings showed the water to deepen quickly from 2 fathoms at Hut Point to 180 fathoms a mile further out in the Sound to the west, while 10 miles away to the west-north-west the sounding was 100 fathoms. The deepest sounding was 400 fathoms, at a point 2 miles south-east of Observation Hill, and other soundings showed that the water was much deeper to the south and to the south-east than to the north and north-west of Winter Quarters.

The Sound, therefore, may be taken to be 40 miles wide, with an average depth of 200 fathoms. The ship when anchored in Winter Harbour had 9 to 11 fathoms of water, while on the north side of Hut Point the water quickly deepened to 50 fathoms close in to the land. Hut Point itself is continued half a mile to the south-west below water, in a shoal which gives soundings of from 2 to 25 and 40 fathoms.

Three sets of observations were taken, viz., on November 4, 6, and 8. The results differ considerably from those taken on shore, and indicate a larger dip and a smaller value for the Horizontal Force, whilst the Declination seems less easterly. These observations were the standard sets taken as being most undisturbed, and used as the base to which all the observations on board the "Discovery" were reduced.

The establishment of the Absolute House out on the sea-ice, although perhaps possible during the second year, would have been attended by considerable difficulty and some risk, especially as it would have been fully exposed to the heavy winter storms, and the surface of the ice, being hard and smooth, offered very little holding ground. During the first year practically nothing was known of the ice conditions in the Sound; indeed, up to quite late in the year the ice within a few hundred yards of the ship was continually breaking up and drifting away.

Observations Across Barrier.—The tent on the ice was also made the base station for the observations taken on the Ice Barrier sledge journey of November 10 to December 10, 1903, with Inclinometer No. 27 by J. Dover, having two reversible Inclination needles and two Total-Force needles. The farthest point reached was about 155 geographical miles south-east of Mount Erebus. The geographical positions of the "camps" were determined, whenever possible, by means of sextant observations of the sun in an artificial mercury horizon.

With the exception of those taken on November 28, all the magnetic observations were taken in the evenings between 7 p.m. and 9 p.m., after the day's march. On two occasions only was it possible to observe in the open air. In most cases the strong cold wind with drifting snow prevented open-air observations, and they were then taken in the small, low sleeping tent, while the other two occupants waited outside. These observations ought to give some indication of the rate of change over an apparently undisturbed area in these latitudes.

Other Absolute Observations.—The only other observations on land that require special mention are a set of Dips and Total Force taken at Cape Adare in January, 1902. The observations were taken over exactly the same spot as those of 1899, and the values obtained show little sign of secular change.

During February of 1904 the "Discovery" endeavoured to penetrate into Wood Bay for the purpose of getting magnetic observations on shore, or on fast-ice removed from the shore at the bottom of the bay and as close to the magnetic pole as possible; but the attempt had to be abandoned on account of the bay being packed with heavy close ice.

During the year 1900 a set of magnetic observations were taken on shore in Wood Bay by the Southern Cross Expedition, and gave an inclination of 88° 2′ south, but as the volcanic character of the rocks there is much similar to that at Winter Quarters, it is possible that this value is too small, and that Wood Bay is closer to the magnetic pole than this would indicate.

A sledge journey from Wood Bay in the direction of the magnetic pole may be attended by considerable difficulties, on account of the lofty mountain ranges that may have to be crossed; but at Lady Newnes Bay, about a degree further north, the mountains are comparatively low, and entirely snow-clad. A journey to the magnetic pole from here might be successful, especially during the summer months of December, January, and February, when the temperatures are such as permit the handling of magnetic instruments without undue inconvenience.

L. C. Bernacchi.

II. REDUCTION OF THE ABSOLUTE AND RELATIVE MAGNETIC OBSERVATIONS.

BY

COMMANDER L. W. P. CHETWYND, R.N.

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THE observations considered in this paper comprise:—

Observations made at Winter Quarters, by Mr. L. C. BERNACCHI.
Observations made during south-eastern sledge journey, by Mr. L. C. BERNACCHI.
Observations made at Cape Adare, Cape Crozier, and Falkland Islands, by Mr. L. C. BERNACCHI.
Observations made during western sledge journey, by Lieutenant A. B. ARMITAGE, R.N.R.
Observations for Inclination, made on board the "Discovery" at sea, by Lieutenant ARMITAGE and Mr. BERNACCHI.
Observations for Declination, made on board the "Discovery" at sea, by Lieutenant ARMITAGE.
Observations for Declination, made on shore, by Captain R. F. SCOTT, R.N., and other officers of the Expedition.

Mr. L. C. BERNACCHI and Lieutenant A. B. ARMITAGE, R.N.R., by whom the observations were principally made, had had previous experience in magnetic observation.

The instruments with which the Expedition was furnished were lent by the Admiralty and comprised the following:—

Two Unifilar Magnetometers, Nos. 25 and 36, by ELLIOTT BROS.
Two Inclination Circles, Nos. 26 and 27, by DOVER.
Two Lloyd-Creak Circles, Nos. 143 and 149, by DOVER.
Two Fox Circles, Nos. 28 and 29, by DOVER.
One Set of Eschenhagen Magnetographs.

The "Discovery" was also fitted with the requisite compasses for navigational and observational work on board, and compasses for sledge work.

Observations made at Kew, before the Expedition sailed and also on its return, showed that the instruments were in good accord with the Observatory standards and had maintained their condition satisfactorily. Observations made at Christ Church Observatory also confirmed this.

All the available information has been through my hands, and the reduction of the observations has been made by me and checked. The geographical positions were supplied by Lieutenant G. MULOCK, R.N., one of the officers of the Expedition.

The absolute observations were mainly made in a hut (hereinafter referred to as the Absolute Hut) set up near the vessel's Winter Quarters, its position being in latitude 77° 50′ 50″ S., longitude 166° 44′ 45″ E.

In November, 1903, a temporary station was erected on the ice in McMurdo Sound, at a distance of 1·7 geographical miles from the nearest visible land, and about the same distance from the "Discovery."

The depth of water under the ice at this station was 200 fathoms, its position being in latitude 77° 51′ 1″ S., longitude 166° 36′ 42″ E.

A comparison of the results of observations made at the Ice Station with those made in the Absolute Hut shows that at the latter position the magnetic conditions were largely affected by local attraction.

The Horizontal Force was approximately 50 per cent. greater at the hut than at the Ice Station, the Inclination 2° less. The Declination at the hut was about 5° greater (more easterly) than at the Ice Station.

COMPARISON of Results at Absolute Hut with those at the Ice Station.

	Inclination, S.	Horizontal Force.
AT THE ICE STATION.	° ′	
Mean of results of observations made November 4, 6, and 8, 1903 . .	86 23·3	0·0433
AT THE ABSOLUTE HUT.		
Mean of the values measured from absolute observation diagrams for November 4, 6, and 8, 1903	84 34	0·0686
DECLINATION.	° ′ ″	
At the Ice Station, January 30, 1904	147 45 52 E.	
At the Absolute Hut, January 17, 1904	153 9 50 E.	

All relative observations were referred to values obtained by observation at the Ice Station.

Absolute observations for Horizontal Force, Inclination, and Declination were made in the Absolute Hut by Mr. BERNACCHI, at intervals averaging a month to six weeks, between the dates April 17, 1902, and January 17, 1904. The results of these observations have in each case been plotted, and curves drawn, from which the approximate change during the year can be inferred, but these results are affected by uncertainties as to the diurnal variation.

In view of the fact that continuous photographic records of the changes in Horizontal and Vertical Force and in the Declination were obtained by means of the Eschenhagen magnetographs, and are being measured and considered by the staff of the Observatory Department of the National Physical Laboratory, no attempt has been made to derive values of the diurnal variations from the absolute observations themselves.

The results of the absolute observations afford the means of standardising the values indicated by the photographic curves.

SECTION II.

Absolute Horizontal Force Results.

The instrument used throughout was Unifilar No. 25.

Magnet No. 25D was used for the observations of dates April 17, May 12, May 26, and June 30, 1902.

In all subsequent observations Magnet 25A was used.

To obtain the value of the correction for P (see Admiralty 'Manual of Scientific Inquiry'), the mean of the values derived from the whole series of observations with each magnet was taken.

For Magnet 25D the result gave P = 0; for Magnet 25A the result was P = +0·25.

The logarithms of the correction factors due to this latter value for the distances used in the deflection observations, viz., magnet at 42 centims. and 56 centims., are respectively

$$\bar{1}\cdot99994 \quad \text{and} \quad \bar{1}\cdot99996,$$

and these values have been used in the reduction of the observations.

Table I.—Horizontal Force Results. (See figs. 1 and 2, p. 137.)

Date.	Magnet.	Mean time of observation.	X, absolute Horizontal Force, c.g.s.	*m*, moment of collimator magnet at temperature 0° C.
1902		h. m.		
April 17	25D	4 22 p.m.	0·06603	905·4
May 12	,,	6 1 ,,	0·06463	902·3
,, 26	,,	5 32 ,,	0·06542	894·2
June 30	,,	4 33 ,,	0·06665	894·7
July 23	25A	3 37 ,,	0·06650	942·0
September 5	,,	4 34 ,,	0·06716	942·4
October 21	,,	4 53 ,,	0·06757	943·0
November 12	,,	5 0 ,,	0·06653	942·7
,, 12	,,	7 52 ,,	0·06635	941·6
December 27	,,	5 7 ,,	0·06446	940·1
1903				
January 7	,,	4 19 ,,	0·06383	942·9
,, 30	,,	5 1 ,,	0·06308	942·9
March 10	,,	5 31 ,,	0·06348	946·1
May 19	,,	4 44 ,,	0·06665	943·6
June 28	,,	5 8 ,,	0·06757	943·7
August 31	,,	5 5 ,,	0·06886	943·7
November 2	,,	4 44 ,,	0·06924	943·8
1904				
January 17	,,	4 9 ,,	0·06370	942·0

SECTION III.

Absolute Inclination Results.

The standard adopted for observations of Inclination is the value as obtained with Circle No. 27, corrected for instrumental difference as determined at Christchurch Observatory. Comparative observations were made with the instrument at Kew before the Expedition sailed, and again on its return, and the results show that the instrument had maintained its condition satisfactorily. The conditions in the Antarctic, however, differ considerably from those at Kew, and it is believed that observations made at Christchurch afford more reliable data for instrumental differences than those at Kew.

Observations at Christchurch Observatory in December, 1901, and in April, 1904, showed the following differences from the Observatory standard:—

CORRECTIONS to be Applied to Observations with Circle No. 27 to Reduce them to Christchurch Observatory Standard.

Date.	Needle No. 1.	Needle No. 2.
1901	′	′
December	−0·93	−1·36
1904		
April	−0·44	−2·55
Mean	−0·68	−1·95

In other words, the south Inclination shown by Circle No. 27 was in excess of Christchurch Observatory standard by 0′·68 for Needle No. 1 and 1′·95 for Needle No. 2. These values for instrumental differences are confirmed by the results of the observations at the Absolute Hut, Winter Quarters.

In ten cases out of thirteen the result of observation with Needle No. 2 is in excess of that with Needle No. 1. The mean value of the differences between the needles in all thirteen cases gives the result that observations with Needle No. 2 are in excess of those with Needle No. 1 by 1′·2, which is in fair accord with the difference as determined from the comparative observations, viz., 1′·3.

The observations at the Ice Station and during the sledge journeys are not so consistent, but in view of the better conditions for observing, which in all probability prevailed at the Absolute Hut, it seems reasonable to attach greater importance to results obtained at this station than to those at out-stations under varying conditions.

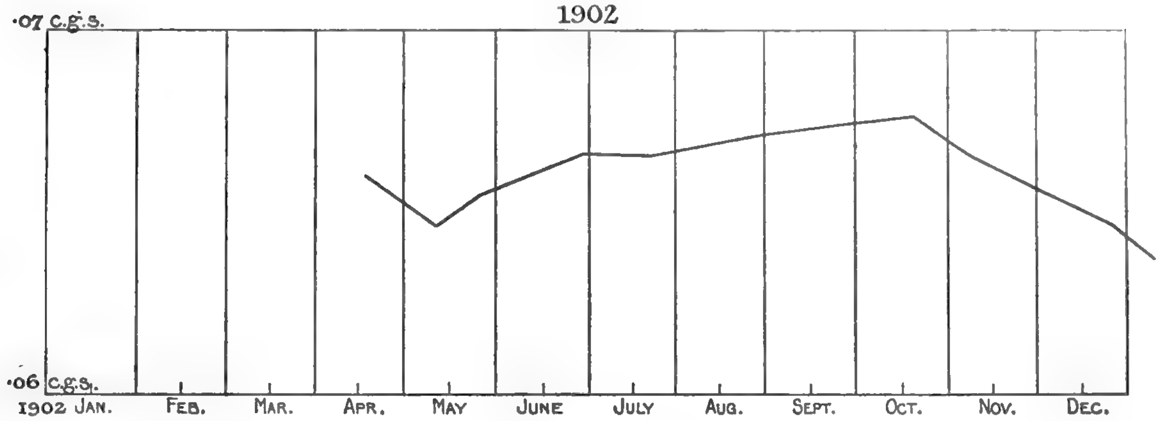
TABLE II.—Absolute Inclination Results. (See fig. 3, opposite.)

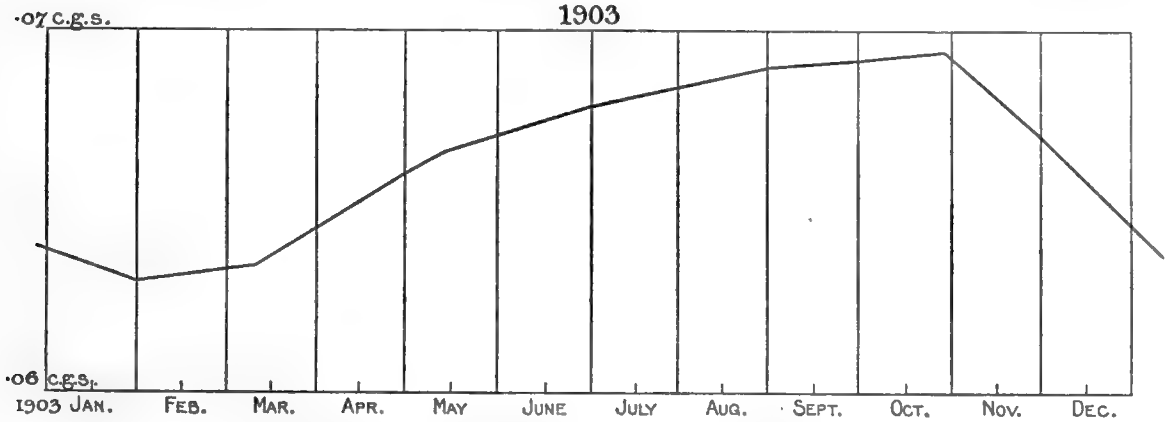
Date.	Needle No. 1.		Needle No. 2.		Mean.		Remarks.
	Time.	Inclination, S.	Time.	Inclination, S.	Time.	Inclination, S.	
1902	h. m.	° ′	h. m.	° ′	h. m.	° ′	
April 17	—	—	3 35 p.m.	84 39·2	—	—	Needle No. 3:— 3h. 22m. p.m., 84°45′·5.
May 12	3 35 p.m.	84 49·6	3 53 ,,	84 49·4	3 44 p.m.	84 49·5	
June 30	0 49 ,,	84 45·6	1 0 ,,	84 43·1	0 54 ,,	84 44·3	
July 23	*3 7 ,,	84 41·7	*2 53 ,,	84 38·8	3 0 ,,	84 40·2	Times are only recorded for commencing No. 2 and ending No. 1.
September 5	0 32 ,,	84 40·1	0 49 ,,	84 40·6	0 40 ,,	84 40·3	
October 21	1 36 ,,	84 39·7	1 50 ,,	84 41·4	1 43 ,,	84 40·5	
November 28	9 42 ,,	84 46·1	—	—	—	—	Needle No. 5:— 9h. 45m. p.m., 84°47′ 6.
December 27	—	—	0 50 p.m.	84 52·6	—	—	Needle No. 3:— 1h. 3m. p.m., 84°51′·7.
1903							
February 10	1 17 p.m.	85 0·2	1 2 p.m.	84 58·1	1 9 p.m.	84 59·1	
March 10	0 30 ,,	84 56·2	0 43 ,,	84 57·1	0 36 ,,	84 56·6	
May 19	0 56 ,,	84 43·4	1 8 ,,	84 44·0	1 2 ,,	84 43·7	
June 28	1 27 ,,	84 37·8	1 38 ,,	84 39·4	1 32 ,,	84 38·6	
August 31	1 9 ,,	84 34·5	1 24 ,,	84 34·7	1 16 ,,	84 34·6	
September 30	0 31 ,,	84 30·4	0 46 ,,	84 31·4	0 38 ,,	84 30·9	
November 2	0 28 ,,	84 32·2	0 49 ,,	84 32·4	0 38 ,,	84 32·3	
1904							
January 17	0 6 p.m.	84 51·3	0 14 ,,	84 51·8	0 10 p.m.	84 51·5	

* In the case of the observations of July 23, 1902, the mean time of observation for each needle has been obtained by applying the mean of the differences in time between other observations to the mean time of these two observations.

No comparisons are available to reduce for instrumental differences the results obtained with Needles Nos. 3 and 5.

Figs. 1 and 2. Absolute Horizontal Force Diagrams.

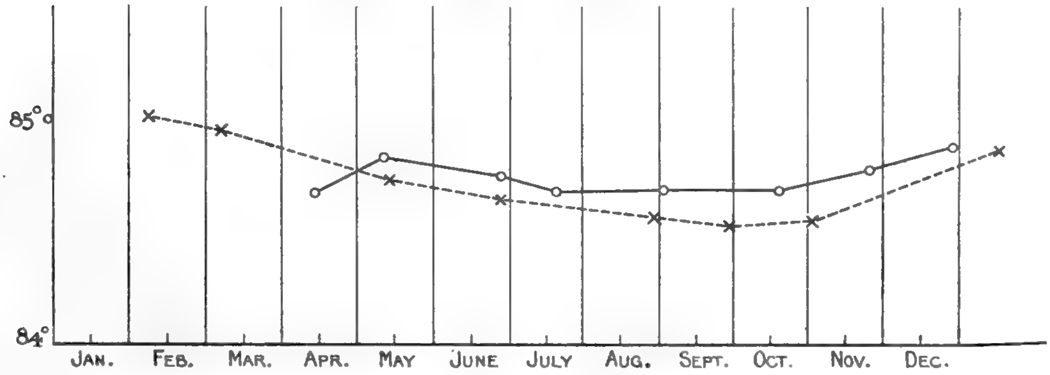




Mean, April—December, 1902	0·0662
„ „ „ 1903	0·0675
Difference, 1902–1903	0·0013 increase.
Mean for the year 1903	0·0665

These values are obtained from measurements of the ordinates of figs. 1 and 2, at the middle of each month.

Fig. 3. Absolute Inclination Diagram.



Values for Year 1902 indicated thus: ————————

„ „ „ 1903 „ „ : - - - - - - - - - - -

Mean, May—December, 1902	84° 43′·5
„ „ „ 1903	84 36·8
Difference, 1902–1903	6·7 decrease.
Mean for the year 1903	84 42·7

These values are obtained from measurements of the ordinates of fig. 3 at the middle of each month.

SECTION IV.

Absolute Declination Results.

The observation for Declination consists of two operations :—

1. The determination of the direction of the magnetic axis of the suspended magnet relative to the zero axis of the instrument.
2. The determination of the azimuth of a fixed mark, to which the direction of the zero axis of the instrument is referred.

Shortly, Part 2 is known as the determination of the azimuth of the mark.

Observations to determine the azimuth of the mark were made on ten occasions, during the years 1902 and 1903.

The results of the observations, in some cases, show considerable inconsistency, and in order to form an opinion as to the best value, the change in the sun's bearing, corresponding to the interval of time between the two successive transits of each observation, was calculated independently from the observations themselves.

The observed change of bearing, as derived from the difference of the readings of the unifilar circle, represents :—

The true change of bearing ± twice the amount of instrumental error due to the axis of the mirror bearings not being at right angles to the line of the telescope (or to the plane of the mirror not being parallel to the axis of its bearings).

Thus, by comparing the calculated and observed change of bearing, we have the means of determining the error due to the above causes.

In the following table are given the calculated change of bearing, the change of bearing observed, and the amount of instrumental error derived from each observation.

Table III.

Date.	Time interval.	Calculated change of bearing.	Observed change of bearing.	Instrumental error.
1902	min. secs.	° ′ ″	° ′ ″	′ ″
December 3	3 3·5	0 44 30	0 44 50	− 0 10
„ 9	2 53	0 41 39	0 41 40	− 0 0·5
„ 18	2 40·5	0 39 11	0 39 20	− 0 4·5
„ 26	3 33·2	0 51 43	0 51 10	+ 0 16·5
1903				
January 7	3 35·7	0 52 59	0 53 10	− 0 5·5
„ 18	3 5	0 45 33	0 45 20	+ 0 6·5
„ 27	2 46	0 40 34	0 40 40	− 0 3
October 20	3 45·7	0 55 11	1 43 50	−24 19·5
„ 21	4 24·5	1 5 33	0 17 0	−24 16·5
1904				
January 11	4 4·4	1 0 13	1 50 40	−25 13·5

In the observation of date October 21, 1903, Mr. Bernacchi apparently observed with the mirror in the reversed position first; there is no objection to this, but it accounts for the observed change of bearing being only 17′.

It is evident from the instrumental errors deduced above that the instrument was in fair adjustment up to and including the observation of date January 27, 1903; equally is it evident that subsequent to that date the instrument was considerably out of adjustment so far as the mirror is concerned.

The error of observation due to this cause is eliminated by taking the mean of the readings observed with the mirror erect and reversed, but the evidence of the mirror being out of adjustment, together with the inconsistency of the results of the observations taken on two consecutive days, October 20 and 21, 1903, seems to suggest the probability that the instrument was out of adjustment in other respects.

The results of the three observations recorded subsequently to January 27, 1903, are inconsistent with each other and individually with previous observations, and cannot therefore be considered as affording values as reliable as the previous observations, of which there appears no reason to doubt the reliability.

The results of all the observations are given in the following Table IV :—

TABLE IV.

Date.	Azimuth of the mark.
1902	° ″
December 3	121 16 52
„ 9	121 48 7
„ 18	122 46 23
„ 26	121 22 12
1903	
January 7	121 18 02
„ 18	121 16 41
„ 27	121 17 25
October 20	121 10 30
„ 21	121 36 10
1904	
January 11	120 52 06

In the recorded times of transit of the sun's limbs, there is an inconsistency in the observations of dates January 27 and October 20, 1903, amounting in the former case to 7 seconds and in the latter to 5 seconds. These may possibly have been caused by a change of atmospheric conditions causing refraction, or by an error in noting the times. In either case the result of the observation is not affected to any appreciable extent.

No explanation can be found for the apparent inconsistency of the results of the observations dated December 9 and 18, 1902, but they appear to be quite outstanding, and it is considered advisable to discard them.

Omitting the results which appear to be doubtful, viz., those of dates December 9 and 18, 1902, October 20 and 21, 1903, and January 11, 1904, there remain the following :—

Date.	Azimuth of the mark.
1902	° ′ ″
December 3	121 16 52
„ 26	121 22 12
1903	
January 7	121 18 02
„ 18	121 16 41
„ 27	121 17 25
Mean	121 18 14

This mean value has been used in reducing the observations for absolute Declination.

The omission of the doubtful observations confines the accepted results to a short period of two months, December, 1902, and January, 1903, and it has therefore been necessary to assume that the azimuth of the mark did not alter during the two years in which the absolute observations were made.

In this connection it is of interest to note that the mean of the results of the observations of dates October 20 and 21, 1903, gives the value 121° 23′ 20″, which differs by only 5′ 6″ from the accepted value.

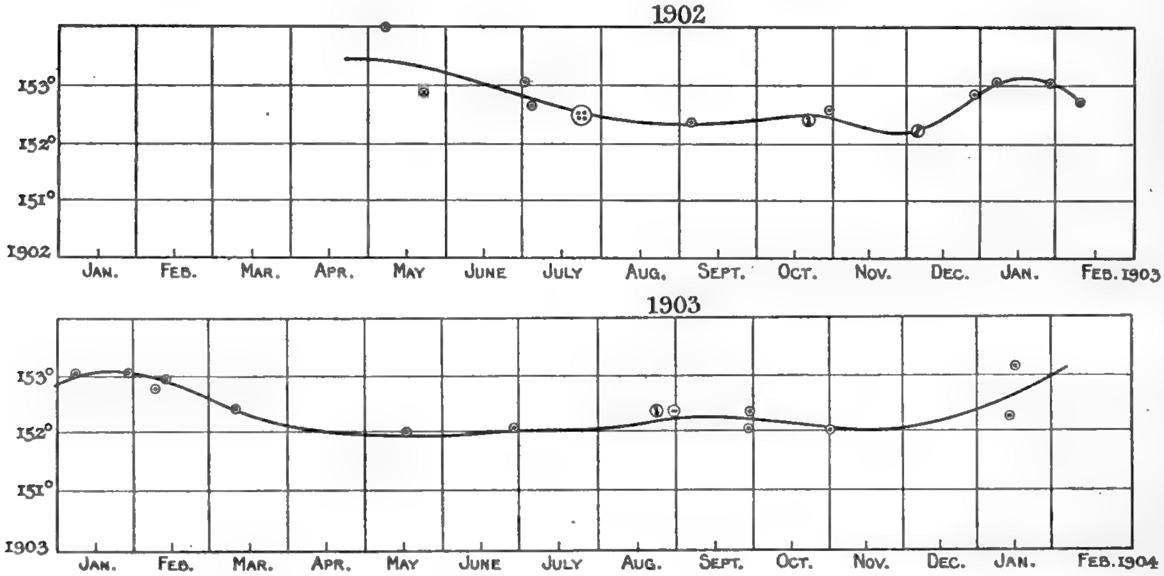
The mean of the results of all observations gives the value 121° 28′ 26″.

In reducing the absolute Declination observations, no correction for torsion has been made, the necessary data not having been recorded.

TABLE V.—Absolute Declination Results. (See figs. 4 and 5 below.)

Date.	Time.	Declination, E.
1902	h. m.	° ′
May 13	5 10 p.m.	153 59
„ 26	4 1 „	152 53
June 30	1 56 „	153 3
July 5	0 58 „	152 39
„ 21	1 5 „	152 36
„ 21	4 26 „	152 29
„ 22	0 30 „	152 23
„ 22	3 22 „	152 36
September 5	5 36 „	152 22
October 21	0 38 „	152 14
„ 21	3 34 „	152 9
„ 31	4 48 „	152 34
December 5	0 24 „	152 13
„ 5	3 51 „	152 12
„ 27	4 1 „	152 50
1903		
January 7	3 8 „	153 3
„ 30	4 8 „	153 4
February 10	3 22 „	152 44
„ 15	5 10 „	152 55
March 10	4 21 „	152 27
May 19	3 35 „	151 59
June 28	4 6 „	152 3
August 21	1 6 „	152 24
„ 21	4 10 „	152 20
„ 31	3 49 „	152 21
September 29	4 11 „	152 2
„ 30	3 37 „	152 22
November 2	3 38 „	152 0
1904		
January 12	5 7 „	152 16
„ 17	3 27 „	153 8

Figs. 4 and 5. Absolute Declination Diagrams.



		° ′
Mean for 8 months, May to December, 1902	. . . . .	152 33·9 E.
„ „ „ „ 1903	. . . . .	152 7·5 E.
Difference	. . . . .	26·4 decrease.
Mean for year 1903	. . . .	152 16·4 E.

These values have been obtained by measuring the ordinates of the curves in figs. 4 and 5, at the middle of each month.

SECTION V.

Horizontal Force, Inclination, and Declination Results at the Ice Station, McMurdo Sound.

Table VI.—Horizontal Force Results.

Date.	Time.	X, Horizontal Force, c.g.s.	m, moment of collimator magnet at temperature 0° C.
1903	h. m.		
November 4	4 7 p.m.	0·04327	943·6
„ 6	4 22 „	0·04303	942·3
„ 8	4 48 „	0·04358	942·2

Table VII.—Inclination Results.

Date.	Needle No. 1.		Needle No. 2.		Mean.	
	Time.	Inclination (S).	Time.	Inclination (S).	Time.	Inclination (S).
1903	h. m.	° ′	h. m.	° ′	h. m.	° ′
November 4. . .	0 44 p.m.	86 24·1	0 57 p.m.	86 23·3	0 50 p.m.	86 23·7
„ 6. . .	11 58 a.m.	86 24·5	0 11 „	86 21·0	0 4 „	86 22·7
„ 8. . .	0 45 p.m.	86 25·1	0 55 „	86 22·6	0 50 „	86 23·8
1904						
January 30. . .	5 5 „	86 22·6	5 18 „	86 23·2	5 11 „	86 22·9

Declination Result.

Date.	Time.	Declination.
1904	h. m.	° ′ ″
January 30	3 57 p.m.	147 45 52 E.

SECTION VI.

Inclination, Total Force, and Declination Results during South-Eastern Sledge Journey, November, 1903.

Observations for Inclination and Total Force were made by Mr. Bernacchi with Dip Circle No. 27.

The Ice Station, McMurdo Sound, was used as a base station, and observations for Inclination and to determine the Constant A, for reducing Total Force observations, were made here on November 8 as follows:—

Date.	Time.	Observations.
	h. m.	
1903 November 8 . .	0 12 p.m.	Inclination, with Needles 1 and 2, poles direct.
	0 47 „	Observation, with Needles 3 and 4, to determine A.
	1 29 „	Inclination, with Needles 1 and 2, poles reversed.
	4 48 „	Observation for absolute Horizontal Force, with Unifilar No. 25.

The results of these observations give the value of Constant A = $\log^{-1} \bar{1}\cdot 55706$, which has been used in reducing the Total Force observations.

The observations for Inclination have been corrected for instrumental differences (see Section III.).

In all the Total Force observations, in that part made with Needle No. 4 weighted, for one particular position of instrument and needle, viz., when the face of the instrument was west and face of the needle towards the face of the instrument, the recorded readings are nearly constant with value 63¾°, whereas the readings for the three other positions of instrument and needle vary from 68° to 61°, but are in each observation consistent.

The maintenance, at different stations, of a constant reading for the one position seems to indicate that the direction of the needle was governed by some mechanical cause; the reading obtained in this position has, therefore, been discarded and the mean of the three other combinations adopted.

The needle appears to be well balanced, and the error introduced by the omission is inconsiderable.

TABLE VIII.—Inclination and Total Force Results.

Date.	Latitude, S.	Longitude, E.	Needle 1.		Needle 2.		Mean.		Total Force, c.g.s.
			Time.	Inclination, S.	Time.	Inclination, S.	Time.	Inclination, S.	
1903	° ′	° ′	h. m.	° ′	h. m.	° ′	h. m.	° ′	
November 14	78 13	168 30	—	85 58 ·6	—	85 58 ·9	9 17 p.m.	85 58 ·7	0 ·6993
„ 17	78 33	170 22	9 2 p.m.	85 45 ·8	9 4 p.m.	85 42 ·4	9 3 „	85 44 ·1	0 ·6933
„ 20	78 47	172 16	8 28 „	85 26 ·4	8 35 „	85 26 ·4	8 31 „	85 26 ·4	0 ·6923
„ 23	79 2	173 8	8 26 „	85 4 ·8	8 37 „	85 1 ·0	8 31 „	85 2 ·9	0 ·6945
„ 26	79 17	174 55	8 38 „	84 57 ·7	8 49 „	84 57 ·4	8 43 „	84 57 ·5	0 ·6905
„ 28	79 32	176 1	5 5 „	84 50 ·4	4 59 „	84 45 ·6	5 2 „	84 48 ·0	0 ·6896
December 8	78 18	169 33	8 13 „	86 0·0	9 29 „	85 58 ·7	8 51 „	85 59 ·3	0 ·7280

TABLE IX.—Declination Results.

From Observations taken by Lieutenant C. ROYDS, *R.N., with a Prismatic Compass.*

Date.	Latitude, S.	Longitude, E.	Declination, E.
1903	° ′ ″	° ′ ″	° ′
November 13	78 4 15	167 49 25	149 55
„ 14	78 11 4	168 14 30	146 1
„ 15	78 16 6	168 46 15	143 22
„ 18	78 31 54	170 25 15	144 58
„ 20	78 51 29	172 8 15	141 47
„ 22	79 5 20	173 16 5	139 1
„ 25	79 20 10	174 55 10	137 53
„ 28	79 32 42	176 2 15	137 34
December 2	79 1 41	172 31 15	139 47
„ 7	78 24 2	169 32 0	148 24

SECTION VII.

RESULTS AT CAPE CROZIER, CAPE ADARE, AND FALKLAND ISLANDS.

From Observations by Mr. BERNACCHI *with Circle No.* 27.

	Date.	Time.	Inclination, S.	Total Force, c.g.s.
	1902	h. m.	° ′	
Cape Crozier	January 23	0 48 p.m.	85 44 ·1	0 ·6891
Cape Adare	„ 9	6 48 „	86 34 ·2	0 ·6806
	1904			
Cape Adare	February 24	7 0 „	86 34 ·7	0 ·7055

No explanation can be found for the large difference in the Total Force results at Cape Adare.

Results at Falkland Islands.

From Observations by Mr. Bernacchi *with Unifilar No.* 25.

Date.	Time.	Inclination, S.	Absolute Horizontal Force, c.g.s.
1904	h. m.	° ′	
July 13	10 59 a.m.	46 9·2	—
„ 14	10 1 „	—	0·26937
„ 19	0 10 p.m.	46 6·8	—
„ 19	10 4 a.m.	—	0·26972

SECTION VIII.

Inclination, Total Force, and Declination Results during Western Sledge Journey, December, 1902, and January, 1903.

From Observations by Lieutenant Armitage.

Table X.—Inclination and Total Force Results with Circle No. 27.

Date.	Latitude, S.	Longitude, E.	Time.	Inclination, S.	Time.	Total Force, c.g.s.
1902	° ′	° ′	h. m.	° ′	h. m.	
December 1. .	77 46	164 49	8 37 a.m.	86 31·9	—	—
„ 10. .	77 52	162 35	0 12 p.m.	86 19·0	0 7 p.m.	0·6855
1903						
January 4. .	77 47	158 43	6 42 „	86 23·1	6 40 „	0·6849
„ 11. .	77 52	162 7	4 50 „	86 15·4	—	—

Table XI.—Declination Results.

From Observations with a Prismatic Compass.

Date.	Latitude, S.	Longitude, E.	Time.	Declination, E.
1902	° ′	° ′	h. m.	° ′
December 1	77 46	163 32	7 27 p.m.	155 44
„ 15	77 53	161 17	6 8 „	158 22
„ 21	77 52	160 42	6 4 „	164 34
„ 26	77 48	159 38	6 22 „	163 55
„ 27	77 46	159 13	1 50 „	165 25
„ 27	77 42	159 3	6 28 „	164 2
1903				
January 4	77 47	157 26	5 50 „	170 50
„ 5	77 52	156 59	4 22 „	172 23

SECTION IX.

Inclination Results.

From Observations by Lieutenant Armitage *and Mr.* Bernacchi, *on board the "Discovery" at Sea between dates January 23 and February 8,* 1902.

The "Discovery" was swung for deviation of compasses—

January 22, in latitude 77° 24′ S., longitude 169° 5′ E.; and
February 8, „ 77° 51′ S., „ 165° 30′ E.

The resulting deviations are in close agreement and indicate that the magnetic condition of the vessel was the same on both occasions, and it may therefore be assumed that this condition did not alter between the above dates.

Adopting the notation of the 'Admiralty Manual of Deviations of the Compass,' the mean value of the coefficients of deviation for the compass in the observatory cabin are:—

A.	B.	C.	D.	E.
−0° 25′	−13° 55′	−3° 49′	+1° 24′	+0° 02′

On January 23, in latitude 77° 25′ S., longitude 169° 30′ E., observations for Inclination were made on board, with the ship's head in four nearly equidistant directions, approximating to north, east, south and west. The results of these observations are the only data, obtained in the Antarctic, available for reducing the observations made in these regions.

Observations for $\lambda = \dfrac{\text{Mean Horizontal Force on board}}{\text{Absolute Horizontal Force}}$, that constant ratio which has such an important bearing on all observations made on board, were obtained at

Spithead, August, 1901	giving result	0·975
Lyttleton, June, 1904	„	0·976
Falkland Islands, July, 1904	„	0·970
Spithead, September, 1904	„	0·973
Mean		0·973

From the results of observations for Inclination made by Mr. Bernacchi and Lieutenant Armitage during their sledge journeys, and from those made by Mr. Bernacchi at the Ice Station, McMurdo Sound, a preliminary chart of lines of equal Inclination was drawn, from which the absolute Inclination at the position of swinging, January 23, was estimated to be 86° 25′ S.

The values observed on board were,

with ship's head,	(1) N. 4° E.	(magnetic),	87° 41′	Inclination S.
„	(2) S. 81½ E.	(„),	86 21	„
„	(3) S. 3 W.	(„),	85 37	„
„	(4) S. 82 W.	(„),	87 12	„

The formulæ adopted for determining the errors of Inclination due to the direction of the ship's head are

$$s \cos \zeta + N = (\cos \zeta + \sin B) \sec \zeta' \tan \theta'$$

for all observations made with ship's head between

NE and NW,
SE „ SW,

and

$$s \cos \zeta + N = \{(1 - 2 \sin D) \sin \zeta - \sin C\} \operatorname{cosec} \zeta' \tan \theta'$$

for all observations made with ship's head between

N.E. and S.E.,

N.W. „ S.W.

In these formulæ

- ζ' represents the direction of ship's head as shown by the compass.
- ζ represents the magnetic direction of the ship's head.
- θ' represents the uncorrected Inclination as observed.
- B, C, and D represent the coefficients of deviation of the compass.
- N represents the natural tangent of the Inclination value after correction for errors due to the direction of ship's head.
- s represents the maximum effect on the Inclination, which would be caused by the induced magnetism in a horizontal soft-iron rod in the fore and aft direction, one end of which is immediately below the dip circle (rod g of the 'Admiralty Manual of Deviations').

By means of these formulæ, values of $s \cos \zeta + N$, for positions (1), (2), (3), and (4), were calculated to be

(1)	$\tan^{-1} 18 \cdot 365$	= 86° 53′	Inclination S.
(2)	$\tan^{-1} 15 \cdot 821$	= 86 23	„
(3)	$\tan^{-1} 16 \cdot 198$	= 86 28	„
(4)	$\tan^{-1} 17 \cdot 793$	= 86 47	„
Mean		= 86° 38′	„

Observations at Spithead in August, 1901, showed that s was zero, and therefore the above values represent N (the natural tangent of the Inclination, corrected for errors due to the direction of ship's head).

The values of the Inclination so reduced should agree for all directions of the ship's head; the differences of the above results from the mean are, however, considerable, viz. :—

	′
(1)	+ 15
(2)	− 15
(3)	− 10
(4)	+ 9

These differences are consistent with an error which has a maximum when the ship's head is N.W. or S.E., varying as the cosine of the azimuth of the ship's head measured from these points.

Such an error might be caused by an elongated mass of horizontal soft iron situated at an angle of 45° to the keel of the ship, and having one end directly under the position of the dip circle. The error is similar to that which is indicated in the formulæ, by $s \cos \zeta$, but having a maximum value when the ship's head is N.W. or S.E. instead of N. or S.

The differences as found were plotted and a curve drawn, from which the correction for any direction of ship's head could be measured, and these corrections were applied as a constant for the particular direction of the ship's head during each observation.

The corrections were applied to the observed readings after the correction for instrumental differences.

From the value of Inclination so deduced, the value of N was calculated by means of the formulæ

$$N = (\cos \zeta + \sin B) \sec \zeta' \tan \theta'$$

and

$$N = \{(1 - 2 \sin D) \sin \zeta - \sin C\} \operatorname{cosec} \zeta' \tan \theta'.$$

To ascertain the correct values of the coefficients of compass deviation for different Inclinations and thus determine the necessary corrections to compass readings, it was assumed that over the area under consideration the Total Force might be treated as constant.

This assumption is supported by the Total Force results during Mr. BERNACCHI'S S.E. sledge journey and by the results of Lieutenant ARMITAGE's observations during his western journey, also by consideration of the values given on SABINE's charts.

Assuming the Total Force to be ·6876, as determined from Mr. BERNACCHI's observations at the Ice Station, McMurdo Sound, values of Horizontal Force were calculated for each degree of Inclination between 82° and 87° S.

The same assumption, viz., that the Total Force did not vary, was also employed in determining the correction to Inclination observations due to the vertical force of the ship.

This correction at the position of swinging, January 23, 1902, was ascertained by comparison of the Inclination value estimated from the preliminary chart with the value of N taken as the mean of the results of the four observations near N., E., S., and W., the true vertical component and the vertical component on board being also calculated.

Now if θ be the absolute Inclination,

θ_n „ Inclination on board as indicated by N,
H „ absolute Horizontal Force,
H_1 „ mean Horizontal Component on board,
V „ absolute Vertical Force,
V_1 „ mean Vertical Component on board,

then

$$\tan\theta = \frac{V}{H} \qquad \text{and} \qquad \tan\theta_n = \frac{V_1}{H_1},$$

from which

$$\tan\theta = \tan\theta_n \times \frac{VH_1}{V_1H};$$

but

$$H_1 = \lambda H, \qquad \text{therefore} \qquad \tan\theta = \tan\theta_n \times \frac{\lambda V}{V_1}.$$

Over the area under consideration the ratio V/V_1 will not vary to any appreciable extent and may be considered constant.

λ is constant, therefore $\lambda V/V_1$ is constant.

Its value as determined from observations of January 23 is

$$0\cdot 9393 = \log^{-1} \bar{1}\cdot 9728,$$

which has been applied as a constant to the values of N as determined from each observation.

The corrections for instrumental differences were determined from observations made at the Ice Station, McMurdo Sound, with Circle No. 27, and the two instruments used for the observations considered in this section, viz.,

Fox Circle No. 29, used by Mr. BERNACCHI; and
Lloyd-Creak Circle No. 143, used by Lieutenant ARMITAGE.

The results showed that the readings by these instruments were in excess of the standardised value derived from observations with Circle No. 27 by the following amounts:—

	Excess over Standard.	
Fox Circle No. 29	2′·7	
	Needle No. 1.	Needle No. 2.
Lloyd-Creak Circle No. 143	3′·2	5′·7

These differences have been applied to the observations for Inclination made with the instruments quoted.

To sum up: The following corrections have been applied to the observed readings in the order given below:—

1. Correction for instrumental differences.
2. „ „ unsymmetrical iron.
3. „ due to direction of ship's head.
4. „ „ vertical force of ship.

The resulting values of Inclination are given in Tables XII. and XIII.

TABLE XII.—Inclination Results.

From Observations by Mr. BERNACCHI *with Fox Circle No.* 29.

Date.	Latitude, S.	Longitude, E.	Inclination, S.
1902	° ′	° ′	° ′
January 24	78 15	176 30	85 5
„ 25	78 28	183 26	84 1
„ 26	78 27	188 31	83 27
„ 28	78 24	191 31	83 50
„ 29	78 24	197 24	84 5
„ 31	76 15	207 40	82 36
February 2	77 2	202 6	83 46
„ 5	78 12	190 12	84 35
„ 6	77 52	180 43	85 48
„ 7	77 10	169 40	86 35
„ 8	77 23	164 37	86 5

TABLE XIII.—Inclination Results.

From Observations by Lieutenant ARMITAGE *with Lloyd-Creak Circle No.* 143.

Date.	Latitude, S.	Longitude, E.	Inclination, S.
1902	° ′	° ′	° ′
January 24	78 26	178 24	84 33
„ 25	78 30	186 10	83 56
„ 27	78 6	187 6	84 36
„ 28	78 30	193 29	83 34
„ 29	78 25	199 19	82 48
February 1	76 31	207 37	82 38
„ 2	77 36	201 33	83 7
„ 7	77 9	167 13	86 33

It is satisfactory corroboration of the method of reduction that the result of the observation made by Mr. BERNACCHI, January 31, when the ship's head was S. 71° W., is in close agreement with the result of the observation by Lieutenant ARMITAGE, February 1, in nearly the same latitude and longitude, when the ship's head was S. 55° E.

SECTION X.

INCLINATION RESULTS.

From Observations made by Mr. BERNACCHI *and Lieutenant* ARMITAGE *on board the "Discovery" at Sea, in the Antarctic, February and March,* 1904.

The instruments used were :—

By Mr. BERNACCHI, Fox Circle No. 29.
„ Lieutenant Armitage, Lloyd-Creak Circle No. 143.

The instrumental differences were ascertained by comparison of instruments at the Ice Station, McMurdo Sound (see Section IX.).

The "Discovery" was swung for deviation of the compass, February 21, 1904, in latitude 74° 26′ S., longitude 165° 30′ E. The resulting coefficients of the deviation were as follows, the notation being that of the 'Admiralty Manual of Deviation of the Compass' :—

A.	B.	C.	D.	E.
0	− 2° 48′	− 3° 01′	0	0

The remarkable difference between these results and those obtained in the year 1902 (see Section IX.), in approximately the same locality, indicates that the magnetic conditions at the compass position in the observing cabin had, in the interval, undergone very great change; possibly this change was due to alterations in the stowage of stores in the ship. The difference is so large that it has been considered advisable to reduce the observations made in 1904, by means of data obtained in the same year only.

In addition to the swing for compass error already mentioned, the vessel was also swung at Auckland Islands, Lyttleton, Falkland Islands, and Spithead. Relative observations for horizontal and vertical force on board were made at Lyttleton, Falkland Islands, and Spithead.

The results are given in the following Table XIV., the notation being that of the 'Admiralty Manual of Deviations of the Compass,' and of the 'Antarctic Manual':—

TABLE XIV.

Place.	Date.	λ.	μ.	g.	s.	A_1.	A.	B.	C.	D.	E.
	1904						° ′	° ′	° ′	° ′	° ′
Wood Bay . . .	February 21	—	—	—	—	—	0 0	−2 48	−3 1	0 0	0 0
Auckland Islands .	March 29	—	—	—	—	—	−0 14	+0 39	−0 15	+1 14	−0 30
Lyttleton	June 7	0·976	1·013	−0·014	−0·013	0·996	−0 40	+0 19	−0 22	+1 43	−0 13
Falkland Islands .	July 19	0·970	0·961	−0·011	−0·011	0·993	−1 18	+1 29	+0 22	+1 0	+0 3
Spithead	September 10	0·973	0·985	+0·0016	0	0·990	−0 58	+1 27	+0 18	+1 7	−0 2

The results of the observations at Lyttleton, on investigation, show certain inconsistencies, and are on some points doubtful; they have therefore not been used in the following reductions, except in the case of λ, the mean values of the constant coefficients used being

$$\lambda = 0{\cdot}973, \qquad A_1 = +0{\cdot}991,$$
$$s = -0{\cdot}0055, \qquad D = +1^\circ\ 7'.$$

From the data in Table XIV. (omitting the Lyttleton results), by separate combinations, the values of the parameters P, Q, c, and f ('Admiralty Manual of Deviations of the Compass'), were calculated, with the following results:—

Combination.	P.	Q.	c.	f.
Spithead and Wood Bay	+0·0027	+0·0001	+0·0040	+0·0016
" Auckland Islands	+0·0029	+0·0008	+0·0031	+0·0002
" Falkland Islands	+0·0038	+0·0006	+0·0014	−0·0005
Means	+0·0031	+0·0005	+0·0028	+0·0004

From these mean values, curves were drawn showing the values of

$$\frac{c \tan\theta}{\lambda}, \quad \frac{f \tan\theta}{\lambda}, \quad \frac{P}{\lambda H}, \quad \text{and} \quad \frac{Q}{\lambda H},$$

for all values of

θ (the Inclination) and H (the Horizontal Force),

the values of H being calculated on the assumption that over the area under consideration the Total Force did not vary (see Section IX.), and the value of θ was taken from N, the natural tangent of the Inclination as calculated from each observation.

By means of the data obtained from the curves and employing the formulæ

$$B = \frac{1}{\lambda}\left(c \tan\theta + \frac{P}{H}\right) \quad \text{('Admiralty Manual of Deviations')},$$

and

$$C = \frac{1}{\lambda}\left(f \tan\theta + \frac{Q}{H}\right),$$

the values of the coefficients B and C were obtained, and the deviation of the compass calculated by means of the formula ('Admiralty Manual of Deviations')

$$\text{Deviation} = B \sin \zeta + C \cos \zeta + D \sin 2\zeta,$$

assuming the coefficients A and E to be zero.

To obtain the values of V, the vertical force on board due to permanent magnetism, and d, the coefficient of the vertical force due to induction in soft iron, of the formula

$$\frac{V}{A_1 H} + d \tan \theta = \Delta \text{ ('Antarctic Manual')},$$

the following procedure was adopted :—

If Z be the absolute vertical force,

$$(a) \quad 1 + d + \frac{V}{Z} = \mu \text{ ('Admiralty Manual of Deviations')}.$$

At Spithead . . . $Z = +0 \cdot 438$ and $\mu = 0 \cdot 985$,
„ Falkland . . . $Z = -0 \cdot 280$ „ $\mu = 0 \cdot 961$.

Using these values in the above formula (a), the resulting values of V and d are

$$V = +0 \cdot 0037,$$
$$d = -0 \cdot 0218.$$

Then for each inclination observation the correction due to the vertical force of the ship (Δ) was calculated by means of the formula

$$\Delta = \frac{V}{A_1 H} + d \tan \theta.$$

The process of reduction of the observations for Inclination was as follows :—

The deviation of the compass having been calculated and the observed readings of the Inclination corrected for instrumental differences, the value of N was calculated for each observation by means of the formulæ

$$s \cos \zeta + N = (\cos \zeta + \sin B) \sec \zeta' \tan \theta'$$

and

$$s \cos \zeta + N = \{(1 - 2 \sin D) \sin \zeta - \sin C\} \operatorname{cosec} \zeta' \tan \theta' \text{ (see Section IX.).}$$

The correction due to the vertical force of the ship was calculated from the formula

$$\Delta = \frac{V}{A_1 H} + d \tan \theta$$

and applied to the values of N.

The resulting values of absolute Inclination are given in the following table :—

TABLE XV.—Inclination Results.

From Observations on board the "Discovery" at Sea, by Mr. BERNACCHI *and Lieutenant* ARMITAGE.

Date.	Latitude, S.	Longitude, E.	Inclination, S.	Observer.
1904	° ′	° ′	° ′	
February 20	75 34	164 42	87 24	Lieutenant ARMITAGE with L.C. Circle No. 143.
„ 23	73 13	170 2	86 58	
„ 27	70 4	172 25	86 1	
„ 21	Off Cape Washington.		87 45	Mr. BERNACCHI with Fox Circle No. 29.
„ 23	3′ E. of Coulman Island.		86 54	
„ 24	A few miles N. of Possession Islands.		86 20	
„ 27	70 20	171 10	86 4	
March 1	67 34	169 23	84 8	
„ 2	67 14	164 10	85 33	
„ 4	67 22	155 21	86 24	

SECTION XI.

Declination Results.

From Observations by Lieutenant Armitage *on board the "Discovery" at Sea.*

Table XVI.

Date.	Latitude.	Longitude.	Declination.	Remarks.
	° ′	° ′	° ′	
1901				
August 10 . . .	44 45 N.	9 30 W.	17 27 W.	Single observation.
„ 11 . . .	41 41 „	11 22 „	17 45 „	„ „
„ 11 . . .	40 45 „	12 2 „	19 15 „	„ „
„ 12 . . .	38 16 „	13 39 „	19 0 „	„ „
„ 13 . . .	36 49 „	15 0 „	18 0 „	„ „
„ 14 . . .	34 15 „	16 0 „	18 32 „	„ „
„ 17 . . .	31 34 „	17 13 „	17 30 „	„ „
„ 20 . . .	23 16 „	18 59 „	16 51 „	„ „
„ 23 . . .	15 19 „	20 22 „	18 8 „	„ „
„ 28 . . .	5 27 „	21 40 „	18 8 „	„ „
„ 29 . . .	4 13 „	20 46 „	20 27 „	„ „
„ 30 . . .	2 16 „	20 50 „	19 30 „	„ „
„ 31 . . .	0 10 „	22 22 „	19 32 „	„ „
September 1 . . .	0 12 S.	24 21 „	17 39 „	„ „
„ 2 . . .	2 1 „	25 47 „	17 59 „	„ „
„ 2 . . .	2 52 „	26 18 „	18 30 „	„ „
„ 3 . . .	3 32 „	27 45 „	18 3 „	„ „
„ 4 . . .	5 17 „	28 45 „	18 0 „	„ „
„ 5 . . .	7 4 „	30 7 „	17 25 „	„ „
„ 5 . . .	7 41 „	30 36 „	17 35 „	„ „
„ 6 . . .	8 54 „	31 20 „	16 40 „	„ „
„ 7 . . .	10 12 „	32 34 „	15 49 „	„ „
„ 8 . . .	12 7 „	33 29 „	15 47 „	„ „
„ 8 . . .	12 49 „	33 43 „	15 10 „	„ „
„ 9 . . .	13 41 „	34 28 „	15 43 „	„ „
„ 10 . . .	15 23 „	33 28 „	17 44 „	„ „
„ 10 . . .	16 5 „	32 56 „	18 49 „	„ „
„ 11 . . .	17 21 „	32 16 „	19 6 „	„ „
„ 12 . . .	18 57 „	31 12 „	16 15 „	„ „
„ 12 . . .	19 36 „	30 13 „	16 51 „	„ „
„ 13 . . .	20 33 „	29 20 „	17 27 „	Mean of swings to port and starboard.
„ 14 . . .	21 20 „	28 15 „	17 58 „	Single observation.
„ 15 . . .	23 25 „	27 20 „	17 55 „	„ „
„ 15 . . .	24 10 „	27 2 „	19 2 „	„ „
„ 16 . . .	25 36 „	25 15 „	20 0 „	„ „
„ 16 . . .	26 24 „	24 50 „	20 23 „	„ „
„ 17 . . .	28 16 „	24 12 „	20 26 „	„ „
„ 17 . . .	28 44 „	23 33 „	20 30 „	„ „
„ 18 . . .	30 22 „	21 55 „	20 51 „	„ „
„ 19 . . .	32 52 „	20 0 „	20 53 „	„ „
„ 20 . . .	33 41 „	17 57 „	22 23 „	„ „
„ 21 . . .	34 30 „	15 45 „	23 42 „	„ „
„ 22 . . .	35 2 „	13 59 „	23 20 „	„ „
„ 23 . . .	35 45 „	11 27 E.	24 50 „	„ „
„ 26 . . .	37 43 „	2 28 „	29 14 „	„ „
„ 27 . . .	38 15 „	0 6 „	29 18 „	„ „
„ 28 . . .	37 50 „	3 34 „	30 23 „	„ „
„ 29 . . .	37 37 „	5 45 „	30 0 „	„ „
„ 30 . . .	37 16 „	8 56 „	30 32 „	„ „
October 1 . . .	36 5 „	12 25 „	30 26 „	„ „
„ 2 . . .	35 18 „	14 57 „	29 17 „	„ „
„ 3 . . .	35 7 „	15 36 „	30 0 „	„ „
„ 16 . . .	36 55 „	22 0 „	28 12 „	„ „
„ 17 . . .	38 47 „	25 28 „	28 12 „	„ „
„ 17 . . .	39 26 „	26 48 „	28 4 „	„ „
„ 18 . . .	39 42 „	29 3 „	28 56 „	„ „
„ 19 . . .	40 3 „	32 25 „	30 2 „	„ „
„ 19 . . .	40 37 „	32 39 „	28 19 „	„ „
„ 19 . . .	40 53 „	32 52 „	28 50 „	„ „
„ 20 . . .	42 5 „	33 22 „	29 2 „	„ „
„ 22 . . .	44 59 „	40 15 „	28 45 „	„ „
„ 22 . . .	45 1 „	41 48 „	29 29 „	„ „
„ 23 . . .	45 0 „	43 0 „	30 46 „	„ „
„ 24 . . .	45 4 „	47 27 „	29 34 „	„ „
„ 24 . . .	44 54 „	47 46 „	29 36 „	„ „

TABLE XVI. (continued).

Date.	Latitude.	Longitude.	Declination.		Remarks.
1901	° ′	° ′	° ′		
October 25 . . .	45 28 S.	51 0 E.	28 37	W.	Single observation.
" 27 . . .	46 18 "	59 46 "	31 20	"	" "
" 27 . . .	46 26 "	60 11 "	32 8	"	" "
" 28 . . .	47 21 "	64 36 "	31 24	"	" "
" 28 . . .	47 22 "	64 52 "	31 58	"	" "
" 29 . . .	46 50 "	69 33 "	33 25	"	" "
" 31 . . .	47 50 "	80 36 "	35 55	"	" "
November 1 . . .	46 56 "	83 20 "	34 54	"	" "
" 2 . . .	46 55 "	88 37 "	34 30	"	" "
" 2 . . .	46 57 "	90 16 "	33 40	"	" "
" 3 . . .	46 36 "	93 0 "	32 15	"	" "
" 4 . . .	47 51 "	96 35 "	31 50	"	" "
" 5 . . .	48 28 "	99 16 "	32 38	"	" "
" 5 . . .	49 4 "	101 20 "	31 24	"	" "
" 6 . . .	49 57 "	103 35 "	33 45	"	" "
" 7 . . .	51 5 "	107 55 "	30 22	"	" "
" 7 . . .	51 17 "	110 29 "	29 36	"	" "
" 8 . . .	51 43 "	111 50 "	27 4	"	" "
" 8 . . .	51 45 "	111 59 "	27 16	"	" "
" 10 . . .	50 51 "	123 32 "	12 46	"	" "
" 10 . . .	50 51 "	123 54 "	10 35	"	" "
" 10 . . .	51 1 "	124 3 "	13 5	"	" "
" 11 . . .	51 20 "	125 52 "	8 5	"	" "
" 12 . . .	52 16 "	131 36 "	3 20	"	" "
" 13 . . .	54 10 "	132 29 "	1 32	"	" "
" 13 . . .	55 14 "	132 48 "	3 48	"	" "
" 14 . . .	57 27 "	134 40 "	6 4	"	" "
" 15 . . .	59 1 "	137 28 "	0 26	"	" "
" 15 . . .	59 50 "	138 23 "	0 4	"	" "
" 18 . . .	61 25 "	142 37 "	6 5	E.	" "
" 18 . . .	60 34 "	144 25 "	10 8	"	" "
" 19 . . .	59 45 "	147 28 "	12 0	"	" "
" 19 . . .	58 43 "	148 41 "	14 46	"	" "
" 20 . . .	57 41 "	151 20 "	14 37	"	Mean of swings to port and starboard.
" 21 . . .	56 52 "	155 25 "	18 34	"	Single observation.
" 21 . . .	56 8 "	156 20 "	17 56	"	" "
" 23 . . .	54 8 "	159 55 "	16 27	"	" "
" 23 . . .	53 21 "	161 11 "	18 40	"	" "
" 24 . . .	52 29 "	163 18 "	19 1	"	" "
" 24 . . .	51 41 "	164 23 "	20 1	"	" "
" 26 . . .	48 30 "	170 22 "	19 40	"	" "
December 24 . . .	46 17 "	170 41 "	18 35	"	" "
" 25 . . .	48 54 "	170 12 "	19 42	"	" "
" 25 . . .	49 50 "	170 10 "	20 0	"	" "
" 26 . . .	52 29 "	170 20 "	20 50	"	" "
" 27 . . .	53 24 "	170 43 "	22 42	"	" "
" 27 . . .	54 8 "	170 55 "	25 40	"	" "
" 28 . . .	54 43 "	171 17 "	20 34	"	" "
" 28 . . .	55 20 "	170 59 "	19 46	"	" "
" 29 . . .	57 31 "	170 35 "	25 6	"	" "
" 30 . . .	58 42 "	170 47 "	26 10	"	" "
" 31 . . .	60 52 "	173 9 "	28 0	"	" "
1902					
January 6 . . .	68 13 "	175 25 "	40 40	"	" "
" 7 . . .	68 43 "	175 37 "	43 13	"	" "
" 8 . . .	70 5 "	173 42 "	50 37	"	" "
" 8 . . .	70 8 "	173 36 "	51 22	"	" "
" 8 . . .	70 3 "	173 5 "	50 37	"	" "
" 8 . . .	70 10 "	172 49 "	54 22	"	" "
" 10 . . .	71 28 "	171 15 "	64 40	"	Mean of swings to port and starboard.
" 11 . . .	72 3 "	171 59 "	66 31	"	Single observation.
" 12 . . .	72 41 "	172 28 "	74 2	"	" "
" 12 . . .	72 44 "	172 17 "	74 34	"	" "
" 13 . . .	73 23 "	170 54 "	87 30	"	" "
" 13 . . .	73 23 "	170 37 "	90 46	"	" "
" 14 . . .	73 19 "	169 52 "	75 8	"	" "
" 14 . . .	73 19 "	169 46 "	76 43	"	" "
" 14 . . .	73 19 "	170 0 "	79 0	"	" "
" 15 . . .	73 12 "	170 14 "	82 11	"	" "
" 15 . . .	73 18 "	170 1 "	76 13	"	" "
" 15 . . .	73 20 "	169 53 "	82 3	"	Mean of ten single observations in different positions between Coulman Island and mainland.

TABLE XVI. (continued).

Date.	Latitude.	Longitude.	Declination.	Remarks.
	° ′	° ′	° ′	
1902				
January 16 . . .	73 21 S.	169 21 E.	84 23 E.	Single observation.
„ 16 . . .	73 25 „	170 51 „	87 52 „	„ „
„ 16 . . .	73 37 „	170 46 „	87 14 „	„ „
„ 17 . . .	74 5 „	169 35 „	100 24 „	„ „
„ 17 . . .	74 21 „	168 31 „	111 8 „	„ „
„ 18 . . .	74 32 „	166 8 „	118 30 „	Mean of swings to port and starboard.
„ 18 . . .	74 48 „	164 50 „	123 27 „	Single observation.
„ 18 . . .	74 56 „	164 25 „	123 32 „	„ „
„ 19 . . .	75 22 „	164 54 „	129 52 „	„ „
„ 19 . . .	75 29 „	165 4 „	132 32 „	„ „
„ 19 . . .	75 54 „	165 12 „	137 19 „	„ „
„ 19 . . .	76 4 „	165 9 „	139 34 „	„ „
„ 20 . . .	76 35 „	163 41 „	152 26 „	„ „
„ 20 . . .	76 39 „	163 48 „	150 13 „	„ „
„ 21 . . .	77 8 „	164 9 „	151 38 „	„ „
„ 21 . . .	77 11 „	164 16 „	151 50 „	„ „
„ 22 . . .	77 0 „	166 47 „	147 44 „	„ „
„ 22 . . .	77 10 „	167 5 „	143 12 „	„ „
„ 22 . . .	77 17 „	167 43 „	143 36 „	„ „
„ 22 . . .	77 24 „	169 0 „	139 41 „	Mean of swings to port and starboard.
„ 24 . . .	78 12 „	176 8 „	130 37 „	Single observation.
„ 25 . . .	78 27 „	182 29 „	123 41 „	„ „
„ 25 . . .	78 28 „	183 11 „	121 31 „	„ „
„ 25 . . .	78 34 „	185 21 „	118 18 „	„ „
„ 26 . . .	78 35 „	186 10 „	117 28 „	„ „
„ 26 . . .	78 28 „	189 2 „	111 55 „	„ „
„ 26 . . .	78 28 „	188 26 „	113 47 „	„ „
„ 27 . . .	78 28 „	185 45 „	116 31 „	„ „
„ 27 . . .	78 24 „	185 50 „	116 5 „	„ „
„ 28 . . .	78 23 „	190 54 „	108 55 „	„ „
„ 28 . . .	78 24 „	191 36 „	107 44 „	„ „
„ 29 . . .	78 19 „	196 30 „	100 56 „	„ „
„ 29 . . .	78 10 „	199 23 „	96 56 „	„ „
„ 29 . . .	78 1 „	200 20 „	94 27 „	„ „
„ 31 . . .	76 1 „	207 33 „	78 10 „	Mean of two single observations.
February 2 . . .	76 58 „	202 58 „	85 33 „	Single observation.
„ 2 . . .	77 1 „	201 55 „	87 38 „	„ „
„ 2 . . .	77 35 „	201 33 „	91 48 „	„ „
„ 2 . . .	77 42 „	201 28 „	93 6 „	„ „
„ 3 . . .	78 7 „	197 28 „	97 11 „	„ „
„ 3 . . .	78 11 „	197 5 „	99 32 „	„ „
„ 5 . . .	78 12 „	190 18 „	105 40 „	„ „
„ 7 . . .	77 10 „	169 42 „	136 28 „	„ „
„ 8 . . .	77 48 „	165 44 „	151 31 „	„ „
„ 8 . . .	77 49 „	165 30 „	151 50 „	Mean of swings to port and starboard.
„ 8 . . .	77 51 „	165 16 „	154 35 „	Single observation.
1904				
February 19 . . .	77 36 E.	166 15 „	150 20 „	„ „
„ 20 . . .	75 31 „	165 2 „	133 18 „	„ „
„ 21 . . .	74 25 „	165 16 „	118 9 „	„ „
„ 21 . . .	74 25 „	165 16 „	118 35 „	„ „
„ 21 . . .	74 26 „	165 30 „	126 13 „	„ „
„ 21 . . .	74 26 „	165 30 „	126 8 „	Mean of swings to port and starboard.
„ 23 . . .	74 4 „	169 31 „	102 50 „	Single observation.
„ 23 . . .	73 53 „	169 49 „	99 2 „	„ „
„ 24 . . .	72 10 „	171 39 „	69 47 „	„ „
„ 24 . . .	72 6 „	171 37 „	72 27 „	„ „
„ 25 . . .	71 2 „	169 32 „	61 56 „	„ „
„ 26 . . .	70 20 „	169 17 „	52 31 „	„ „
„ 26 . . .	70 20 „	168 52 „	56 14 „	„ „
„ 29 . . .	67 46 „	174 26 „	41 17 „	„ „
„ 29 . . .	67 39 „	174 28 „	40 15 „	„ „
„ 29 . . .	67 24 „	172 25 „	44 36 „	„ „
March 1 . . .	67 31 „	169 51 „	40 40 „	„ „
„ 2 . . .	67 22 „	165 0 „	40 6 „	„ „
„ 2 . . .	67 15 „	163 44 „	36 32 „	„ „
„ 4 . . .	67 27 „	155 41 „	25 30 „	„ „
„ 7 . . .	62 5 „	156 56 „	23 28 „	„ „
„ 8 . . .	60 47 „	160 57 „	21 54 „	„ „
„ 9 . . .	59 56 „	163 20 „	22 15 „	„ „
„ 11 . . .	56 40 „	163 55 „	22 48 „	„ „
„ 12 . . .	55 28 „	164 33 „	22 52 „	„ „
„ 13 . . .	53 51 „	165 22 „	21 53 „	„ „

Table XVI. (continued).

Date.	Latitude.		Longitude.		Declination.		Remarks.
	° ′		° ′		° ′		
1904							
March 14 . . .	51 29	E.	164 17	E.	18 15	E.	Single observation.
„ 26 . . .	50 33	„	166 11	„	19 30	„	Swing inside the harbour.
„ 29 . . .	50 33	„	166 21	„	21 5	„	Mean of swings to port and starboard.
„ 30 . . .	47 45	„	168 1	„	18 8	„	Single observation.
June 10 . . .	44 55	„	177 56	„	17 19	„	„ „
„ 10 . . .	47 3	„	178 9	W.	19 17	„	„ „
„ 11 . . .	48 23	„	175 32	„	19 20	„	„ „
„ 13 . . .	51 0	„	168 25	„	20 8	„	„ „
„ 14 . . .	52 3	„	165 13	„	19 57	„	„ „
„ 16 . . .	53 40	S.	156 29	„	21 51	„	„ „
„ 17 . . .	53 52	„	152 28	„	22 18	„	„ „
„ 19 . . .	54 17	„	144 4	„	23 5	„	„ „
„ 24 . . .	58 50	„	125 8	„	29 58	„	„ „
„ 24 . . .	58 56	„	123 26	„	31 31	„	„ „
„ 25 . . .	59 11	„	121 4	„	31 17	„	„ „
„ 27 . . .	59 32	„	112 30	„	32 0	„	„ „
„ 30 . . .	57 31	„	99 42	„	28 42	„	„ „
July 1 . . .	55 48	„	95 52	„	29 21	„	„ „
„ 2 . . .	54 17	„	92 29	„	27 53	„	„ „
„ 3 . . .	53 42	„	88 33	„	26 49	„	„ „
„ 4 . . .	52 58	„	83 28	„	24 53	„	„ „
„ 5 . . .	52 27	„	79 9	„	23 8	„	„ „
„ 10 . . .	52 31	„	65 53	„	16 34	„	„ „
„ 22 . . .	48 45	„	52 3	„	5 32	„	„ „
„ 23 . . .	46 38	„	48 57	„	2 9	„	„ „
„ 24 . . .	45 0	„	45 57	„	1 28	W.	„ „
„ 25 . . .	43 14	„	43 32	„	2 11	„	„ „
„ 25 . . .	42 24	„	42 41	„	4 37	„	„ „
„ 26 . . .	41 2	„	41 23	„	5 5	„	„ „
„ 27 . . .	39 10	„	38 14	„	9 8	„	„ „
„ 27 . . .	38 43	„	37 46	„	9 24	„	„ „
„ 28 . . .	37 22	„	35 25	„	11 47	„	„ „
„ 30 . . .	32 11	„	30 27	„	16 52	„	„ „
„ 30 . . .	31 59	„	30 21	„	17 11	„	„ „
„ 28 . . .	36 45	„	34 39	„	11 16	„	„ „
„ 29 . . .	34 21	„	31 50	„	14 25	„	„ „
„ 30 . . .	31 24	„	29 42	„	17 28	„	„ „
„ 31 . . .	29 46	„	28 28	„	18 30	„	„ „
„ 31 . . .	28 59	„	27 54	„	18 0	„	„ „
August 1 . . .	27 34	„	26 58	„	19 36	„	„ „
„ 1 . . .	26 47	„	26 25	„	19 39	„	„ „
„ 2 . . .	25 25	„	25 48	„	21 22	„	„ „
„ 2 . . .	24 28	„	25 26	„	20 30	„	„ „
„ 3 . . .	22 54	„	25 32	„	20 47	„	„ „
„ 3 . . .	21 58	„	25 36	„	19 37	„	„ „
„ 4 . . .	20 47	„	26 16	„	20 51	„	„ „
„ 4 . . .	19 54	„	26 16	„	19 39	„	„ „
„ 5 . . .	18 43	„	26 12	„	20 54	„	„ „
„ 6 . . .	16 6	„	26 26	„	21 1	„	„ „
„ 6 . . .	15 30	„	26 26	„	20 4	„	„ „
„ 7 . . .	14 34	„	26 48	„	21 20	„	„ „
„ 7 . . .	13 51	„	26 55	„	19 57	„	„ „
„ 8 . . .	12 54	„	27 9	„	20 55	„	„ „
„ 9 . . .	10 32	„	27 23	„	20 17	„	„ „
„ 9 . . .	9 24	„	27 20	„	19 19	„	„ „
„ 10 . . .	7 36	„	27 18	„	20 6	„	„ „
„ 11 . . .	4 54	„	27 8	„	20 15	„	„ „
„ 12 . . .	2 37	„	27 31	„	19 56	„	„ „
„ 12 . . .	1 22	„	27 33	„	18 35	„	„ „
„ 13 . . .	0 40	„	27 41	„	19 58	„	„ „
„ 13 . . .	1 0	N.	27 32	„	18 38	„	„ „
„ 14 . . .	2 48	„	27 56	„	19 16	„	„ „
„ 15 . . .	5 45	„	27 30	„	19 23	„	„ „
„ 16 . . .	7 53	„	27 1	„	19 14	„	„ „
„ 17 . . .	10 22	„	27 4	„	19 33	„	„ „
„ 18 . . .	11 57	„	26 56	„	19 38	„	„ „
„ 19 . . .	14 18	„	27 35	„	19 39	„	„ „
„ 20 . . .	16 22	„	27 7	„	19 45	„	„ „
„ 21 . . .	18 5	„	27 0	„	20 0	„	„ „
„ 21 . . .	18 52	„	27 10	„	19 7	„	„ „
„ 22 . . .	19 45	„	27 43	„	19 46	„	„ „
„ 22 . . .	20 21	„	28 0	„	20 42	„	„ „
„ 23 . . .	21 33	„	28 42	„	20 1	„	„ „
„ 24 . . .	23 48	„	30 12	„	20 13	„	„ „

TABLE XVI. (continued).

Date.	Latitude.	Longitude.	Declination.		Remarks.
1904	° ′	° ′	° ′		
August 25 . .	26 10 N.	31 45 W.	20 52	W.	Single observation.
,, 26 . .	28 25 ,,	32 10 ,,	20 54	,,	,, ,,
,, 26 . .	29 20 ,,	31 51 ,,	19 42	,,	,, ,,
,, 27 . .	30 28 ,,	30 45 ,,	20 55	,,	,, ,,
,, 27 . .	31 2 ,,	30 19 ,,	20 32	,,	,, ,,
,, 28 . .	31 35 ,,	30 10 ,,	21 6	,,	,, ,,
,, 28 . .	32 3 ,,	29 49 ,,	20 18	,,	,, ,,
,, 29 . .	32 47 ,,	29 18 ,,	21 17	,,	,, ,,
,, 30 . .	34 29 ,,	27 59 ,,	21 49	,,	,, ,,
,, 31 . .	36 40 ,,	26 27 ,,	21 53	,,	,, ,,
September 2 . .	37 50 ,,	25 6 ,,	22 7	,,	,, ,,
,, 3 . .	39 4 ,,	24 25 ,,	21 54	,,	,, ,,
,, 3 . .	40 8 ,,	23 45 ,,	21 52	,,	,, ,,
,, 4 . .	41 36 ,,	22 44 ,,	22 49	,,	,, ,,
,, 5 . .	43 52 ,,	20 26 ,,	22 41	,,	,, ,,
,, 5 . .	44 33 ,,	18 32 ,,	20 35	,,	,, ,,
,, 6 . .	45 23 ,,	16 20 ,,	21 43	,,	,, ,,
,, 7 . .	46 55 ,,	13 9 ,,	20 5	,,	,, ,,
,, 8 . .	48 38 ,,	9 0 ,,	19 36	,,	,, ,,

SECTION XII.

DECLINATION RESULTS.

From Observations made by Captain R. F. SCOTT, *R.N., with a Prismatic Compass. Western Sledge Journey.*

TABLE XVII.

Date.	Latitude, S.	Longitude, E.	Declination.	
1903	° ′ ″	° ′ ″	° ′	
October 14, a.m. . . .	77 41 30	164 38 45	158 9	E.
,, ,, p.m. . . .	77 38 50	163 53 20	157 13	,,
,, 16, a.m. . . .	77 44 50	163 17 30	160 7	,,
,, 17, ,, ...	77 51 20	162 32 40	163 4	,,
November 2, ,, ...	77 47 10	161 3 30	164 11	,,
,, 15, ,, ...	77 43 0	159 2 15	172 27	W.
,, 19, ,, ...	77 43 0	156 16 0	178 45	,,
,, 20, ,, ...	77 43 0	155 29 15	177 19	,,
,, 22, ,, ...	77 42 49	154 31 30	174 42	,,
,, 23, ,, ...	77 42 49	153 54 25	170 38	,,
,, 24, p.m. . . .	77 45 7	152 23 10	171 0	,,
,, 26, ,, ...	77 47 49	150 57 20	165 19	,,
,, 27, ,, ...	77 48 32	149 43 35	163 3	,,
,, 29, ,, ...	77 54 47	147 52 30	159 44	,,
,, 30, ,, ...	77 58 39	147 0 10	157 50	,,
December 7, a.m. . . .	77 56 9	153 25 15	170 18	,,
,, 7, p.m. . . .	77 57 16	154 9 30	174 37	,,
,, 10, ,, ...	77 50 53	156 50 5	178 38	E.
,, 15, a.m. . . .	77 45 0	160 10 15	169 1	,,

TABLE XVIII.—Declination Results.

From Observations by Lieutenants M. BARNE *and* G. MULOCK, *R.N., with a Prismatic Compass.*
South-South-West Sledge Journey.

Date.	Latitude, S.	Longitude, E.	Declination.	
1903	° ′ ″	° ′ ″	° ′	
October 15	78 14 30	168 12 30	149 57	E.
„ 16	78 22 40	168 22 0	150 3	„
„ 20	78 45 35	167 51 36	152 11	„
„ 19	78 40 12	168 4 30	150 58	„
„ 21	78 55 10	167 38 0	153 44	„
„ 29	79 7 20	166 26 0	165 7	„
November 2	79 26 25	165 9 0	167 0	„
„ 7	79 39 25	163 56 0	164 49	„
„ 9	79 43 10	163 41 30	165 26	„
„ 13	79 49 0	163 13 0	166 33	„
„ 14	79 54 10	162 47 0	168 50	„
„ 20	80 7 0	161 4 25	172 30	„
„ 24	79 54 35	161 49 30	169 56	„
„ 25	79 47 40	161 17 0	170 30	„
„ 30	79 19 50	164 16 0	162 43	„
December 2	79 9 25	165 32 0	159 54	„
„ 11	78 22 25	168 7 0	149 54	„

TABLE XIX.—Declination Results.

From Observations by Captain SCOTT, *R.N., with a Prismatic Compass. Southern Sledge Journey.*

Date.	Latitude, S.	Longitude, E.	Declination.		Remarks.
1902	° ′ ″	° ′ ″	° ′		
December 15	80 27 0	161 42 30	171 22	E.	
„ 22	81 22 36	162 13 30	171 25	„	
„ 23	81 32 10	162 42 10	171 43	„	
„ 25	81 47 23	163 5 40	170 36	„	
„ 26	81 51 28	163 19 38	171 37	„	
„ 28	82 5 38	163 41 45	170 32	„	
„ 28	82 11 37	163 52 0	170 28	„	p.m. observation.
„ 30	82 11 37	163 52 0	169 54	„	a.m. „
1903					
January 3	81 56 0	163 22 30	170 59	„	
„ 6	81 32 15	162 41 45	171 26	„	
„ 7	81 25 24	162 22 7	172 28	„	
„ 10	81 2 45	161 43 21	173 50	„	
„ 11	80 40 15	161 39 0	171 22	„	
„ 14	80 25 17	161 48 32	171 14	„	
„ 20	79 47 30	163 40 0	165 22	„	
„ 21	79 33 50	164 8 30	167 24	„	
„ 25	79 10 25	165 42 15	161 56	„	
„ 26	79 0 0	166 34 0	157 41	„	

All Declination results were plotted, and lines of equal Declination drawn therefrom, as shown on Chart No. 1 (Plate 17).

SECTION XIII.

DETERMINATION OF THE POSITION OF THE SOUTH MAGNETIC POLE.

In order that the determination of the position of the pole, by means of the Declination results, might be entirely independent of the determination by means of the Inclination results, I handed the Declination results to my assistant, Commander F. CREAGH-OSBORNE, R.N., with instructions to plot their positions and to extend the direction of the magnetic meridian, as indicated by the observations, towards the South Magnetic Pole.

The result of his work is shown on Chart No. 2, where it will be seen that these lines of direction intersect within a space triangular in form (Plate 18).

The radius of the circle inscribed in the triangle measures about 38 geographical miles, and the centre of the circle indicates the probable position of the pole, and is in latitude 72° 50′ S., longitude 156° 20′ E.

Determination of the Position of the Magnetic Pole by Means of the Inclination Results.

All the Inclination results were plotted on a chart, and lines of equal Inclination drawn (Chart No. 3), from a consideration of which the probable position of the pole is indicated to be in latitude 72° 52′ S., longitude 156° 30′ E. The agreement between this position and that determined by the Declination results is remarkable, and may be considered as corroboration of the results.

The mean of the two positions, viz., latitude 72° 51′ S., longitude 156° 25′ E., is in all probability a close indication of the centre of the polar area (Plate 19).

SECTION XIV.

Comparison of Results with those given by General Sabine.

Total Force.

In Sabine's chart of lines of Total Force the highest value for which a line is drawn is that of 15 B.U. (= 0·6916 c.g.s.). This line passes outside all the positions at which observations were made during the 1902–1904 expedition.

The observation position nearest to Sabine's line is that in latitude 79° 32′ S., longitude 176° 1′ E., during the south-eastern sledge journey by Mr. Bernacchi.

The result of this observation gives the value of Total Force = 0·6896 c.g.s.

The change of intensity thus indicated is very small.

Declination.

To compare the Declination as given on Sabine's chart with present results, the values were obtained from the respective charts at the positions given in the following table:—

Table XX.

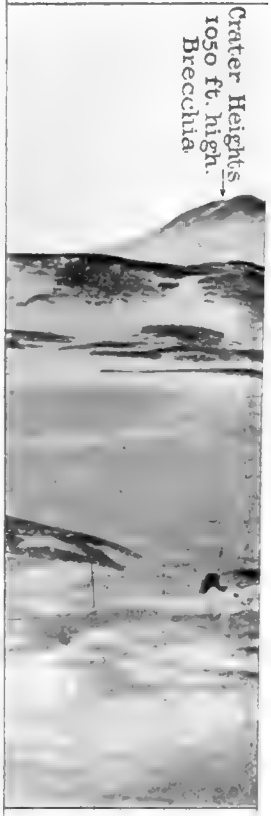
Position.	Declination. 1841.		Declination. 1903.		Increase in 62 years.
	° ′		° ′		° ′
Ice Station, McMurdo Sound	124 0	E.	147 45	E.	23 45
At Cape Adare	40 20	”	62 30	”	22 10
Latitude 78°, longitude 180°	102 0	”	122 30	”	20 30
” 78° ” 200°	87 30	”	95 0	”	7 30
” 76° ” 205°	69 0	”	79 0	”	10 0
” 74° ” 165°	65 0	”	109 0	”	44 0

The change indicated at McMurdo Sound, viz., 23° 45′ in 62 years, gives a mean annual increase of 23′.

The yearly difference as derived from the absolute observation diagrams (Section IV. for 1902–1903) shows a decrease of 26′.

Hut Point and Winter Quarters.
The cross × shows position of magnetic houses.

View of magnetic houses at Winter Quarters.



nt, September, 1903.

1902.

ns).

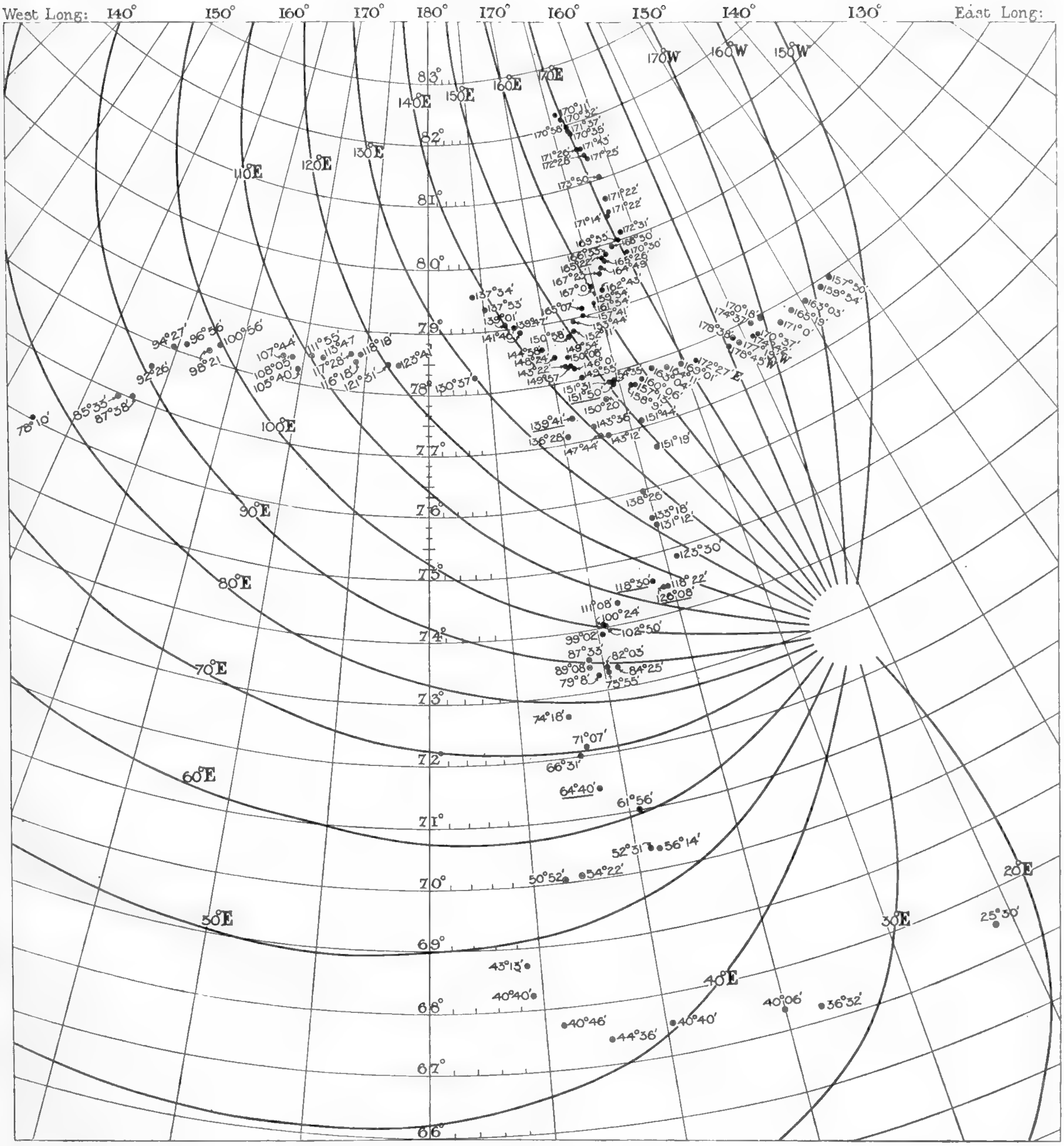


Chart I. Lines of equal magnetic declination. (See p. 155.)

From observations made by the Officers of the National Antarctic Expedition, 1902–1904.

By Commander L. W. P. Chetwynd, Royal Navy.

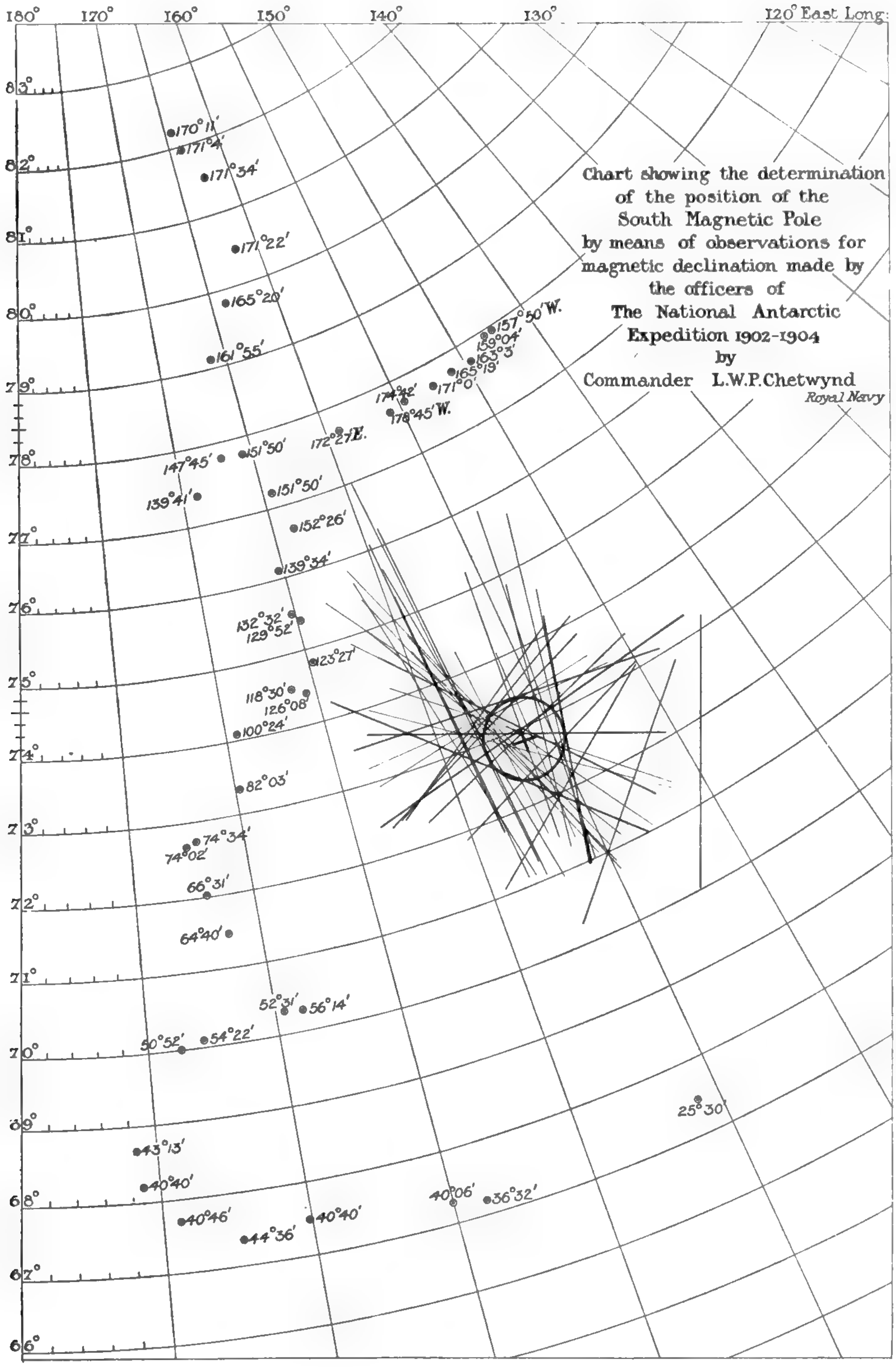


Chart II. (See p. 156.)

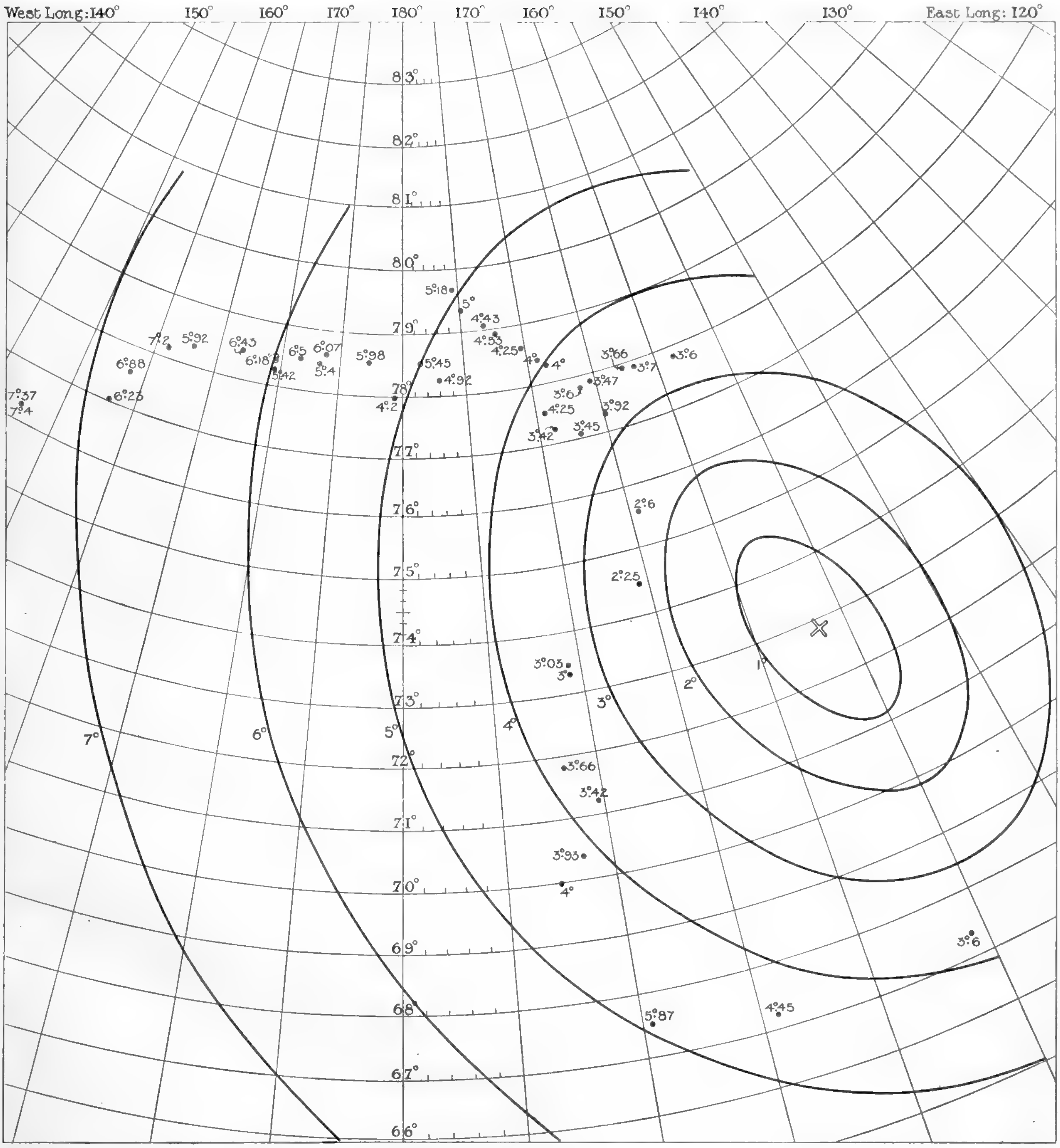


Chart III. Lines of equal magnetic inclination. (See p. 156.)

From observations made by Mr. L. C. Bernacchi and Lieutenant A. B. Armitage, R.N.R., during the National Antarctic Expedition, 1902–1904.

By Commander L. W. P. Chetwynd, Royal Navy.

The figures plotted on this chart represent values of Co-inclination.

Comparison of Inclination Results.

The lines of equal Inclination on SABINE'S chart were completed, where necessary, to conform as nearly as possible with those already drawn, and the values of Inclination obtained by inspection of the respective charts are as given in the following table:—

TABLE XXI.

Latitude, S.	Longitude 170°, E.			Longitude 175°, E.			Longitude 180°, E.		
	1841.	1903.	Difference.	1841.	1903.	Difference.	1841.	1903.	Difference.
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
73	86 55	86 45	−0 10	86 15	85 50	−0 25	85 45	85 5	−0 40
75	87 40	86 45	−0 55	87 5	85 55	−1 10	86 35	85 10	−1 25
77	87 25	86 22	−1 03	87 5	85 43	−1 22	86 40	85 10	−1 30
Means			−0 43			−0 59			−1 12

Mean for the whole area, −0° 58′ in 62 years.
Mean annual change, −1′ nearly.

The yearly difference as derived from the absolute Inclination diagrams, 1902–1903 (Section II.) is − 6′·7.

The position of the pole as now determined differs from SABINE'S position by approximately 200 geographical miles, being 52′ of latitude to the northward and 9°·1 of longitude to the eastward of SABINE'S, indicating a presumptive change of position to the eastward.

L. W. P. CHETWYND.

III. HOURLY VALUES OF DECLINATION, HORIZONTAL FORCE AND VERTICAL FORCE

On Term Days during 1902–1903, in connection with the National Antarctic Expedition, 1902–1904, comprising Results at the following Observatories :—

GREENWICH, KEW, FALMOUTH, POLA, BOMBAY and MAURITIUS, and also at the "DISCOVERY'S" WINTER QUARTERS.

THE Royal Society arranged for simultaneous magnetic observations to be made at certain observatories on pre-arranged term days during the National Antarctic Expedition, 1902–1904, simultaneous observations being also made at the "Discovery's" Winter Quarters. The term days arranged for were the 1st and 15th of each month, each term day commencing at 0h., G.M.T., and ending at midnight.

The resulting data received, viz., the hourly values of the Declination, Horizontal Force, and, in some cases, of the Vertical Force, as measured from the magnetograms of the day, have been tabulated and compiled by Commander L. W. P. CHETWYND, R.N. The values derived from the "Discovery's" magnetograms have been measured and tabulated by the Staff of the Observatory Department of the National Physical Laboratory, under superintendence of Dr. C. CHREE, F.R.S.

The Observatories from which results have been received are as follows :—*

Greenwich	Declination.	Horizontal Force.	Vertical Force.
Kew	"	"	
Falmouth	"	"	
Pola	"	"	"
Bombay	"	"	"
Mauritius	"	"	
"Discovery's" Winter Quarters . . .	"	"	

The maximum and minimum hourly values on each day are printed in heavy type; where such maximum or minimum was recorded at more than one hour on each day, all such maximum and minimum values are so printed.

In the tabulated values for Mauritius Observatory the data in brackets have been obtained by interpolation, and where one hourly value is lacking the mean, and where necessary the range, is marked with the letter "a" (denoting approximate).

In the tabulated values for the "Discovery's" Winter Quarters, on several days one hourly value was lost, the hour coming when the sheets were changed; on other occasions a good many hours' data are lacking, owing to no sheet being on the drum, or through the trace being too faint. When only one hour was lacking a mean has been calculated, to which the letter "a" is attached (to signify approximate). When several hours were lacking no mean is given. When the trace was off the sheet the value answering to the edge of the sheet is given with the sign > or < before it, according as the trace was off in the one direction or in the other.

When the trace was off the sheet for only one hour a mean is formed with > or < in front. When the trace was off for several hours no mean or range is given, except in cases where the general drift of the curve justified confidence that the maximum and minimum were both included.

* As these pages were going to press, the magnetic returns from Christchurch, New Zealand, were received. These have been tabulated by Dr. CHREE and will be found on pp. 177, 178, 179.

GREENWICH DECLINATION (WEST).

Date.	D = 16° +																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	25·8	26·0	25·8	25·9	25·9	25·9	25·7	25·3	24·8	**24·6**	26·3	27·7	**27·9**	**27·9**	27·5	26·9	26·6	26·8	26·2	25·8	25·5	25·0	25·1	25·1	25·4	26·1	3·3
,, 15, ,,	24·5	24·8	24·9	25·0	25·0	25·3	24·8	24·5	24·5	**24·4**	26·0	27·3	**27·9**	27·8	27·2	26·1	25·3	25·2	24·9	25·0	25·0	24·9	24·9	24·8	24·7	25·4	3·5
March 1, ,,	24·9	24·9	24·9	24·9	24·8	24·8	24·1	23·8	**23·4**	23·5	24·5	26·3	**27·2**	27·1	26·0	25·1	24·5	24·9	25·6	25·3	25·2	24·9	24·8	24·8	24·9	25·0	3·8
,, 15, ,,	23·9	24·0	24·0	24·0	23·9	23·5	23·2	22·8	**22·0**	22·7	25·0	27·2	**29·0**	28·9	28·0	26·5	24·8	23·9	24·3	24·0	24·0	23·9	23·9	23·9	23·9	24·6	7·0
April 1, ,,	22·3	22·5	22·8	22·2	21·1	21·6	20·9	**19·4**	20·6	21·2	24·2	27·3	**30·2**	29·9	28·7	27·3	25·9	24·4	23·9	23·9	21·2	23·6	21·4	21·1	21·9	23·6	10·8
,, 15 ,,	22·3	22·2	22·0	21·9	21·8	21·4	21·4	21·0	19·8	**19·7**	21·0	23·0	25·0	**26·9**	26·5	24 6	23·8	23·4	23·0	22·9	23·2	23·4	23·3	23·2	23·2	22·8	7·2
May 1, ,,	22·7	22·7	22·2	21·9	22·1	21·5	21·4	**20·7**	20·9	21·7	23·1	24·7	24·9	**25·2**	24·8	24·1	24·1	24·2	23·0	22·9	23·0	23·6	23·5	23·2	23·0	23·0	4·5
,, 15, ,,	22·3	21·8	21·7	22·9	20·9	20·2	20·7	20·9	20·9	**20·1**	20·6	22·3	24·0	**24·4**	23·8	22·7	22·5	21·9	22·2	22·7	22·8	22·7	22·5	22·2	22·0	22·1	4·3
June 1, ,,	22·5	22·3	**20·3**	22·0	22·3	20·6	21·6	20·8	21·0	22·2	24·1	27·8	**28·7**	26·1	25·3	25·0	22·7	21·8	21·6	21·0	21·9	22·4	22·9	23·9	22·9	23·1	8·4
,, 15, ,,	22·2	21·8	21·4	21·2	20·1	19·1	18·0	17·9	**17·6**	19·3	21·0	24·1	26·8	**28·9**	27·9	24·9	22·8	22·1	21·7	21·8	21·6	21·8	22·0	22·0	22·6	22·0	11·3
July 1, ,,	22·5	22·5	21·9	21·7	21·7	19·8	**18·8**	**18·8**	19·7	19·6	20·9	22·2	23·5	**24·0**	23·8	23·0	22·8	22·2	21·8	21·6	21·6	21·9	21·6	21·7	21·8	21·6	5·2
,, 15, ,,	23·1	23·0	22·5	21·7	20·8	19·7	**18·8**	18·9	19·8	20·3	22·2	24·0	25·1	**25·7**	24·8	23·9	24·0	24·2	24·7	24·1	23·8	23·9	23·8	22·0	22·0	22·7	6·9
August 1, ,,	24·1	23·9	23·8	23·5	23·1	21·7	20·9	20·2	**20·0**	21·3	24·2	27·1	28·5	**29·9**	29·3	26·8	24·3	23·0	22·8	23·0	23·7	23·6	23·8	24·2	23·9	24·0	9·9
,, 15, ,,	23·5	23·7	23·2	22·9	22·4	21·5	20·7	20·0	**19·9**	21·3	23·8	26·9	29·4	**30·6**	28·8	25·5	23·1	21·9	22·0	22·5	23·0	23·3	23·1	23·1	23·3	23·6	10·7
September 1, ,,	22·9	22·8	22·6	22·4	22·1	22·0	21·2	20·6	20·9	21·6	23·3	**25·9**	24·8	25·8	24·9	23·9	22·8	21·4	20·7	20·2	20·6	20·2	20·1	**19·9**	20·1	22·2	6·0
,, 15, ,,	20·8	20·6	20·4	19·9	19·9	19·8	19·2	**18·9**	19·2	20·7	23·6	26·2	**27·6**	26·9	25·5	23·8	21·8	20·9	21·1	21·1	20·9	20·9	21·1	20·0	20·6	21·7	8·7
October 1, ,,	16·6	**16·5**	17·4	17·1	18·2	18·6	18·2	18·2	18·4	19·9	22·1	23·8	26·2	**26·6**	25·3	24·1	22·9	22·0	21·6	21·0	21·2	21·5	20·6	21·1	21·8	20·9	10·1
,, 15, ,,	21·8	21·9	21·8	21·6	21·2	21·0	20·6	19·4	**18·8**	20·0	22·0	24·5	25·9	**26·7**	25·9	24·8	22·6	21·5	22·0	21·5	21·9	21·3	20·9	20·6	20·5	22·1	7·9
November 1, ,,	**12·9**	17·6	17·9	20·0	21·2	21·8	21·5	21·0	20·7	21·3	23·0	23·8	**25·2**	25·0	24·1	23·0	23·0	22·9	22·3	21·9	21·3	21·5	21·2	21·0	21·2	21·7	12·3
,, 15, ,,	19·2	20·1	20·8	20·9	20·8	21·1	21·0	20·8	20·6	20·9	22·2	22·5	**23·6**	22·5	22·6	22·3	22·5	22·0	22·2	21·8	21·4	20·3	**19·1**	20·8	20·7	21·4	4·5
December 1, ,,	20·5	21·1	21·8	21·8	21·9	21·2	21·2	21·0	20·9	21·1	22·5	23·9	24·3	**24·7**	23·6	21·7	21·8	20·0	20·8	20·7	**19·5**	19·7	20·0	20·8	20·9	21·5	5·2
,, 15, ,,	18·3	20·8	**17·7**	18·5	18·8	18·5	18·4	18·2	18·1	18·1	18·2	20·0	**20·7**	20·6	19·8	19·0	18·8	18·8	18·4	18·2	18·3	17·9	18·1	18·3	18·8	18·8	3·0
January 1, 1903	**19·4**	19·9	20·1	20·3	20·5	20·3	20·1	19·9	19·5	19·9	20·8	21·1	22·7	**23·5**	23·1	22·5	21·8	21·5	21·1	20·8	20·4	20·2	20·0	19·9	20·9	20·8	4·1
,, 15, ,,	20·9	21·3	21·5	21·8	21·7	21·5	21·6	21·1	21·0	21·1	22·0	22·5	23·2	23·9	**24·1**	23·0	22·6	22·3	21·9	21·4	20·6	20·6	**20·5**	**20·5**	21·0	21·8	3·6
February 1, ,,	20·2	20·5	20·8	20·9	21·3	21·1	21·2	20·6	19·8	**18·8**	19·6	21·9	23·0	25·0	**25·7**	24·5	22·8	22·1	22·5	22·0	21·1	20·7	20·5	20·9	21·0	21·6	6·9
,, 15, ,,	20·5	20·9	21·9	21·2	21·5	20·9	20·3	20·1	19·9	19·3	21·3	22·2	23·2	25·7	**25·9**	23·0	22·2	**17·2**	21·5	21·8	21·1	20·8	20·9	21·1	21·1	21·4	8·7

GREENWICH—HORIZONTAL FORCE.

Date.	H = ·18 . . . C.G.S.																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	494	496	493	496	497	498	**500**	**500**	497	490	**481**	483	487	490	492	492	485	482	492	495	495	492	**492**	491	491	492	19
,, 15, ,,	478	477	**479**	478	484	483	483	483	482	478	475	473	**471**	473	476	477	481	481	**485**	484	484	484	**485**	**485**	484	480	14
March 1, ,,	485	484	485	484	485	**486**	485	482	480	475	471	472	478	482	480	475	468	**467**	468	469	472	471	473	472	473	477	19
,, 15, ,,	508	507	505	504	506	507	505	504	492	478	**473**	**473**	482	485	494	499	499	499	502	**509**	507	505	504	504	502	498	36
April 1, ,,	516	516	516	**518**	**518**	516	511	505	504	502	492	491	**489**	492	499	503	509	512	516	516	511	513	517	512	508	508	29
,, 15, ,,	494	492	491	493	493	493	493	499	503	496	**485**	489	495	496	498	500	498	506	**507**	504	503	505	505	**507**	505	498	22
May 1, ,,	504	505	503	503	505	503	503	495	494	497	493	491	**487**	491	493	495	497	503	509	**514**	509	509	507	507	509	501	27
,, 15, ,,	499	503	499	496	499	498	498	499	499	**495**	**495**	**495**	**495**	497	504	508	**517**	515	**517**	515	514	**517**	516	516	516	505	22
June 1, ,,	508	**524**	504	502	503	504	504	494	492	**491**	**491**	502	509	514	515	515	499	504	509	510	514	509	502	507	500	505	33
,, 15, ,,	506	507	507	504	508	504	502	499	501	498	**496**	499	503	514	513	510	510	514	511	**520**	516	513	515	516	513	508	24
July 1, ,,	509	507	505	503	506	507	505	503	497	493	493	**485**	493	500	504	508	512	512	**519**	**519**	516	516	515	514	509	506	34
,, 15, ,,	506	505	515	517	518	503	500	500	497	**494**	495	505	512	518	517	519	510	507	516	**521**	517	515	514	506	500	509	27
August 1, ,,	512	510	509	507	506	508	507	505	500	495	**489**	**489**	495	502	509	517	**522**	521	511	509	512	510	509	509	510	507	33
,, 15, ,,	522	519	518	517	515	513	511	503	499	492	**490**	494	513	527	522	519	519	525	528	530	**532**	**532**	530	527	527	517	42
September 1, ,,	513	510	506	504	502	499	497	493	489	**488**	493	501	511	518	517	515	510	512	514	521	**523**	521	515	513	515	508	35
,, 15, ,,	507	504	507	502	503	501	497	487	480	**476**	488	493	505	513	**515**	510	505	508	511	512	513	509	507	511	512	503	39
October 1, ,,	516	520	**522**	**522**	**522**	**522**	519	513	508	500	**496**	502	508	510	511	511	511	511	516	517	517	519	517	519	520	514	26
,, 15, ,,	518	520	519	520	521	519	516	514	497	487	**480**	489	498	500	504	514	518	518	520	521	522	**524**	522	519	521	512	44
November 1, ,,	495	498	504	498	504	502	508	506	504	500	**493**	495	506	511	515	516	518	519	523	**525**	524	524	520	522	522	510	32
,, 15, ,,	**514**	502	505	505	506	507	508	501	500	498	497	**494**	500	500	503	498	501	507	508	506	506	504	505	501	500	503	20
December 1, ,,	528	526	527	529	530	531	528	526	524	516	**510**	517	521	521	524	520	526	519	527	529	528	525	529	**532**	**532**	525	22
,, 15, ,,	530	**539**	535	526	526	528	527	528	527	524	519	520	526	531	536	531	527	527	527	523	519	520	**518**	519	519	526	21
January 1, 1903	501	501	503	502	503	502	503	502	499	496	**495**	497	502	504	512	511	511	508	509	510	510	511	510	**513**	510	505	18
,, 15, ,,	512	515	515	515	514	514	517	517	517	511	510	509	511	516	521	**522**	513	515	514	511	512	507	**505**	**505**	506	513	17
February 1, ,,	508	507	509	509	509	508	509	**511**	506	495	487	482	**477**	482	489	498	505	504	501	498	501	502	501	500	503	500	34
,, 15, ,,	500	501	502	503	501	504	**508**	**508**	504	495	489	**478**	480	486	495	482	489	491	**492**	503	505	502	503	504	502	497	30

GREENWICH—VERTICAL FORCE.

Date.	Z = ·43 . . . C.G.S.																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ 15, „	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, „	735	733	**730**	733	735	736	736	737	737	737	733	736	735	734	**739**	**739**	738	737	**739**	738	735	732	**730**	732	**730**	735	9
„ 15, „	702	700	699	698	699	700	700	703	**704**	700	695	695	697	695	695	701	**704**	700	702	702	698	697	697	**694**	697	699	10
March 1, „	690	688	689	690	692	695	695	699	**700**	695	691	687	686	**685**	687	688	689	690	687	690	687	689	687	687	688	690	15
„ 15, „	734	740	742	750	753	758	760	**763**	**763**	758	734	727	726	728	731	730	729	726	**721**	723	723	724	726	727	729	737	42
April 1, „	752	751	750	749	747	749	750	755	752	747	742	741	**738**	743	749	757	766	768	768	770	**772**	770	766	762	760	755	34
„ 15, „	722	721	722	721	722	723	725	726	724	719	719	709	**701**	707	717	722	725	729	732	736	736	741	742	743	**744**	725	43
May 1, „	726	726	727	729	729	728	730	729	730	724	714	706	**702**	705	715	722	726	726	730	732	**733**	730	729	725	724	724	31
„ 15, „	**733**	731	**733**	**733**	729	732	730	730	730	726	720	715	**709**	713	715	723	725	725	728	724	725	725	724	722	725	725	24
June 1, „	714	712	710	710	712	712	715	713	710	707	700	697	**694**	703	713	729	728	731	734	**736**	731	732	735	735	**736**	718	42
„ 15, „	724	724	722	722	722	722	721	718	717	717	707	696	**689**	693	706	712	719	724	724	**725**	722	720	719	718	720	716	36
July 1, „	704	702	703	704	705	709	709	710	709	697	692	686	**683**	685	696	709	**712**	709	703	707	705	707	710	708	710	703	29
„ 15, „	704	703	701	700	701	701	701	703	702	698	691	**681**	685	691	697	705	**711**	709	706	706	705	705	705	705	710	701	30
August 1, „	694	695	**696**	692	694	695	694	693	694	691	684	673	**669**	678	688	688	694	693	690	683	681	680	679	680	679	687	27
„ 15, „	703	703	704	702	704	705	703	702	705	703	696	691	**683**	688	693	702	**706**	**706**	704	702	701	703	704	705	**706**	701	23
September 1, „	**689**	**689**	686	687	687	687	687	**689**	685	681	680	675	**674**	679	680	681	684	686	683	682	682	685	685	688	688	684	15
„ 15, „	680	678	677	675	673	672	673	673	669	664	663	**661**	663	671	680	**685**	**685**	**685**	681	680	681	682	683	683	683	676	24
October 1, „	720	715	712	710	709	708	710	709	706	706	700	**693**	697	705	709	713	718	719	718	**721**	719	**721**	**721**	720	719	712	28
„ 15, „	721	721	721	721	722	723	723	**724**	**724**	721	712	707	**703**	709	713	720	722	717	717	717	717	717	717	719	720	718	21
November 1, „	715	713	709	709	711	711	711	711	709	706	**704**	705	710	714	715	**716**	715	714	711	708	708	705	707	707	709	710	12
„ 15, „	692	691	690	691	692	690	690	690	691	689	687	688	689	**686**	693	**697**	695	694	690	692	692	692	690	690	692	691	10
December 1, „	738	739	740	741	742	744	742	742	744	746	742	739	**736**	742	**749**	**749**	748	748	746	742	741	739	738	737	737	742	13
„ 15, „	735	738	**733**	735	738	736	739	741	744	742	745	750	**751**	750	**751**	749	748	748	748	746	747	748	746	746	748	744	18
January 1, 1903	685	691	691	697	697	**703**	697	698	696	695	685	684	682	684	687	684	679	679	676	676	674	673	671	**670**	**670**	685	32
„ 15, „	692	693	693	692	692	692	691	690	690	688	690	**699**	694	693	691	**686**	695	**699**	698	696	695	693	691	691	690	693	13
February 1, „	661	662	662	665	662	659	661	657	661	659	653	**652**	657	656	663	665	**666**	662	660	661	655	656	657	657	658	659	14
„ 15, „	643	642	643	643	645	648	646	645	645	645	641	**637**	641	**637**	646	651	659	**663**	658	652	651	648	649	649	649	647	25

KEW—DECLINATION (WEST).

Date.	D = 16° +																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	46·6	46·7	46·8	47·0	47·0	47·4	46·9	46·7	45·9	45·9	47·4	47·7	48·4	48·9	48·0	46·8	46·8	46·7	46·6	46·5	46·4	46·3	46·2	46·2	46·0	46·9	3·0
" 15, "	45·8	45·9	46·8	46·8	47·1	46·9	46·7	45·8	44·8	44·8	46·1	47·5	48·9	49·7	49·8	48·9	51·6	49·1	49·1	46·8	46·7	40·9	36·1	35·3	24·8	45·7	25·0
February 1, "	46·3	46·9	46·9	47·0	47·3	46·6	46·3	46·1	45·2	45·2	47·2	48·3	48·5	48·3	48·2	47·3	47·2	47·3	46·4	46·3	46·1	45·9	45·9	46·3	46·3	46·8	3·3
" 15, "	46·1	46·3	46·4	46·3	46·4	46·7	46·2	45·4	45·3	45·3	47·2	48·5	49·2	48·3	47·6	47·2	45·9	45·8	45·4	45·8	45·7	45·5	45·5	45·6	45·4	46·4	3·9
March 1, "	46·1	46·2	46·2	46·2	46·2	46·1	45·3	44·9	44·2	44·2	45·2	47·3	48·2	47·9	47·1	46·1	45·2	45·7	46·2	46·1	46·0	45·5	45·5	45·7	45·9	46·0	4·0
" 15, "	46·0	46·0	46·6	46·6	46·1	45·9	45·0	44·3	43·3	44·0	46·4	49·4	51·0	50·9	49·9	48·0	46·1	45·1	46·0	46·5	46·0	45·9	45·8	45·6	45·8	46·5	7·7
April 1, "	44·8	44·9	45·2	44·8	43·6	44·0	43·0	41·2	42·3	43·0	46·5	49·3	52·6	53·0	50·9	49·2	47·9	46·0	45·2	45·6	43·0	45·5	43·6	43·1	44·0	45·7	11·4
" 15, "	46·0	46·0	46·0	45·8	45·4	45·0	45·0	44·2	42·9	42·9	44·0	46·0	48·3	49·9	49·0	47·0	46·2	46·0	45·4	45·8	46·0	46·2	46·0	45·9	45·9	45·9	7·0
May 1, "	44·8	45·0	44·9	44·7	44·8	43·9	43·8	42·8	42·8	43·7	44·9	46·5	47·8	48·0	47·4	46·8	46·8	46·8	45·8	45·7	45·6	45·7	45·8	45·8	45·6	45·5	5·2
" 15, "	45·1	44·6	44·6	46·0	44·2	42·8	43·6	43·6	43·5	42·5	43·2	45·1	46·6	46·9	46·5	45·4	44·7	44·2	44·6	44·9	45·1	45·0	44·8	44·6	44·6	44·7	4·4
June 1, "	44·6	44·5	42·8	44·4	44·5	42·5	44·0	42·9	43·4	44·9	46·3	49·6	51·2	48·7	47·9	47·7	45·3	44·3	43·6	41·9	43·4	44·0	44·5	45·7	44·7	45·1	9·3
" 15, "	45·2	45·0	44·7	44·3	43·2	42·2	41·1	41·0	40·4	42·6	43·9	46·9	49·2	51·5	50·7	47·6	45·3	44·5	44·2	44·2	44·1	44·1	44·2	44·3	45·2	44·8	11·1
July 1, "	44·0	44·3	44·0	43·4	43·4	41·4	40·3	40·3	41·3	40·6	42·0	43·4	46·3	46·6	46·4	45·4	45·3	44·4	44·1	44·2	44·1	44·3	43·7	44·2	44·3	43·6	6·3
" 15, "	44·6	44·7	44·3	43·2	42·5	41·2	40·2	40·2	40·5	41·5	43·5	45·9	46·9	47·4	47·2	46·1	46·2	46·2	46·4	46·0	45·4	45·8	45·3	43·9	44·0	44·4	7·2
August 1, "	44·8	44·7	44·7	44·5	43·8	42·5	41·6	40·7	40·1	41·7	44·7	47·7	49·7	50·9	50·5	48·0	45·2	43·7	43·5	43·7	43·9	44·1	44·7	44·8	44·6	44·8	10·8
" 15, "	43·9	44·1	44·0	43·3	43·1	42·1	41·1	40·1	40·1	41·6	44·3	47·9	50·1	51·1	49·1	46·2	44·1	42·9	42·9	43·4	44·1	44·2	44·1	44·1	44·1	44·2	11·0
September 1, "	44·2	44·3	44·1	44·1	43·9	43·7	42·5	41·6	42·1	42·6	44·6	47·1	48·5	49·4	48·6	47·4	47·0	45·1	44·2	44·1	44·0	44·0	44·0	43·9	44·1	44·8	7·8
" 15, "	43·4	43·2	43·3	42·9	43·0	42·2	41·8	41·5	41·2	42·8	45·8	48·7	50·0	49·1	47·8	45·8	43·7	43·1	43·2	43·6	43·1	43·1	43·3	42·1	43·1	44·1	8·8
October 1, "	38·9	38·9	40·7	40·1	41·1	41·6	40·9	40·9	40·7	41·9	44·8	46·1	47·6	47·8	46·6	45·2	43·9	42·5	42·1	41·8	41·9	41·9	41·2	42·1	42·9	42·6	8·9
" 15, "	43·9	44·1	44·2	43·4	43·4	43·1	42·3	41·3	40·3	41·3	43·4	46·3	47·7	48·6	47·5	45·7	43·6	42·9	43·3	43·2	43·3	43·3	43·3	43·2	43·2	43·8	8·3
November 1, "	34·6	39·9	40·5	42·8	43·8	44·3	43·7	43·4	42·5	43·4	45·2	45·6	46·1	45·5	44·7	44·1	43·6	43·7	43·4	43·1	42·4	42·4	42·4	42·4	43·0	43·3	11·5
" 15, "	40·6	41·6	42·4	42·6	42·5	42·9	42·3	42·3	42·4	42·6	44·2	44·4	46·3	44·4	44·4	44·4	44·4	44·2	44·2	43·5	43·4	42·3	41·3	42·9	42·3	43·2	5·7
December 1, "	42·1	43·0	43·5	43·5	43·5	42·7	42·7	42·5	42·5	42·8	44·5	45·7	46·5	47·3	45·7	44·0	43·5	42·4	42·4	42·4	41·3	41·4	42·0	42·6	42·6	43·4	6·0
" 15, "	42·3	45·0	41·5	42·5	42·9	42·4	42·0	41·8	41·8	41·7	42·5	43·8	45·3	44·7	44·3	42·8	42·5	42·4	42·5	42·2	42·1	41·5	41·6	42·3	42·3	42·7	3·8
January 1, 1903	42·6	43·0	43·7	43·7	43·7	43·2	42·9	42·6	42·3	42·4	43·4	44·1	44·5	45·4	45·1	43·6	43·4	43·4	43·0	42·4	42·3	42·0	41·8	41·3	42·3	43·1	4·1
15, "	41·5	41·8	42·1	42·6	42·6	41·8	41·8	41·3	41·3	41·5	42·6	43·3	44·3	45·2	45·2	44·3	43·3	43·2	42·8	42·2	41·4	41·8	41·5	41·4	42·0	42·5	3·9
February 1, "	41·5	41·7	42·5	42·7	42·7	42·6	42·4	41·6	40·7	39·2	40·0	42·0	43·2	45·4	46·2	44·3	43·2	42·2	42·2	42·1	41·1	41·0	40·2	40·6	41·2	42·1	7·0
" 15, "	41·2	41·5	42·7	42·1	42·3	41·6	41·3	40·8	40·5	40·5	41·9	42·7	44·0	46·0	46·6	43·9	43·0	37·4	41·9	42·0	41·5	41·1	41·0	41·1	41·9	42·0	9·2

KEW—HORIZONTAL FORCE.

Date.	H = ·18 . . . C.G.S.																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	455	454	456	458	458	458	459	459	460	454	449	**447**	**447**	455	460	**464**	463	**464**	461	460	460	459	458	456	455	457	17
" 15, "	470	469	466	470	471	471	473	474	472	464	462	455	461	463	476	464	463	**478**	477	470	453	**395**	420	432	424	460	83
February 1, "	470	470	464	469	470	473	**475**	**475**	474	466	461	**458**	461	464	468	467	464	463	467	469	470	469	469	467	467	468	17
" 15, "	465	462	**458**	463	465	466	466	467	467	464	465	461	459	463	465	465	469	468	470	471	**472**	**472**	471	471	471	466	14
March 1, "	471	467	467	468	469	471	**473**	472	470	467	464	**461**	468	474	470	468	465	467	467	469	472	471	469	466	467	468	12
" 15, "	470	470	469	470	470	471	471	469	461	448	**447**	448	457	460	466	474	472	474	476	475	474	476	**478**	**478**	477	468	31
April 1, "	478	477	478	**481**	**481**	478	476	473	473	470	459	462	**457**	460	465	469	472	473	477	480	474	476	**481**	476	473	473	24
" 15, "	470	466	464	466	466	466	468	475	479	472	**463**	466	472	477	477	476	475	479	478	**474**	474	476	477	**480**	477	472	17
May 1, "	481	479	476	477	477	474	474	470	469	473	470	469	**463**	467	469	469	471	477	481	**489**	482	483	485	480	481	475	26
" 15, "	480	483	475	**474**	**474**	**474**	476	477	477	475	475	**474**	**474**	478	483	485	**490**	486	488	487	487	487	486	486	486	481	16
June 1, "	480	**493**	473	472	475	474	476	465	**462**	**462**	465	473	483	484	483	485	472	475	479	482	483	477	472	477	474	476	31
" 15, "	481	480	480	480	481	480	477	476	475	**470**	474	474	480	**496**	489	492	490	493	488	**496**	493	491	492	494	491	484	26
July 1, "	482	480	473	475	478	479	479	475	472	469	467	**459**	467	473	477	487	489	489	**491**	489	489	486	487	485	480	479	32
" 15, "	490	485	493	501	500	489	482	481	481	**480**	**480**	485	494	499	493	496	492	491	496	**502**	500	499	495	486	**480**	491	22
August 1, "	485	481	478	474	478	481	479	477	473	467	465	**461**	468	475	484	487	**494**	493	484	483	486	486	483	483	482	479	33
" 15, "	481	475	473	474	474	473	469	470	465	461	459	**453**	471	**484**	478	473	474	476	477	483	**484**	481	479	478	478	473	31
September 1, "	**490**	488	481	480	478	475	471	468	464	**460**	467	470	479	488	485	480	479	479	479	484	488	486	483	481	482	478	30
" 15, "	486	485	485	482	482	482	477	466	463	**460**	463	470	478	487	**494**	487	481	483	484	485	485	480	478	480	484	479	34
October 1, "	480	481	479	481	**483**	**483**	480	476	469	463	**460**	466	471	476	477	475	473	469	476	477	478	479	479	480	481	475	22
" 15, "	**488**	**488**	484	487	486	**486**	483	480	471	459	**456**	457	468	470	474	476	478	480	484	486	486	486	487	487	487	479	32
November 1, "	455	455	457	457	459	459	465	462	462	456	455	**453**	460	465	469	475	474	475	476	**478**	476	476	476	477	476	466	25
" 15, "	492	484	485	484	485	488	**493**	486	483	484	**481**	482	489	487	492	485	486	**493**	**493**	491	492	490	492	488	486	488	12
December 1, "	483	478	482	484	483	**486**	484	483	481	477	**470**	478	483	481	484	480	480	474	483	482	480	478	481	481	480	481	16
" 15, "	486	**492**	489	480	479	485	486	487	486	483	**478**	**478**	480	488	490	488	486	488	488	484	479	480	482	481	482	484	12
January 1, 1903	477	**474**	476	480	480	481	482	483	479	477	476	477	483	486	491	**492**	491	485	485	486	485	485	483	486	483	483	18
" 15, "	483	486	487	488	487	485	489	489	489	483	**482**	**482**	486	491	494	**496**	489	488	488	488	487	487	486	485	483	487	14
February 1, "	478	478	477	484	485	485	485	**487**	485	475	469	**459**	**459**	461	470	479	484	**487**	483	485	**487**	**487**	**487**	481	482	479	28
" 15, "	483	488	488	487	485	488	490	**491**	488	475	475	**463**	467	471	482	467	475	478	480	489	488	486	485	487	486	482	28

FALMOUTH—DECLINATION (WEST).

Date.	D = 18° + Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings.
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	22·1	22·5	22·5	22·7	22·7	22·9	23·0	22·7	22·5	21·9	22·6	23·6	24·4	**24·8**	24·7	23·6	22·8	22·8	23·4	22·7	22·7	22·5	22·5	21·8	**21·7**	22·9	3·1
,, 15, ,,	22·1	22·6	23·2	23·7	23·9	24·0	23·9	23·8	23·1	22·6	23·7	24·7	26·6	27·0	27·8	26·8	**28·4**	26·4	26·5	23·8	23·8	20·7	13·6	11·8	**1·7**	23·1	26·7
February 1, ,,	22·5	22·7	22·6	22·8	22·8	22·8	22·7	22·6	22·0	**21·5**	23·2	24·7	**25·6**	25·4	25·2	24·6	24·4	23·8	23·9	23·5	22·9	22·7	22·7	22·6	22·8	23·3	4·1
,, 15, ,,	22·8	23·0	23·5	23·6	23·5	23·8	23·4	22·9	22·8	**22·7**	24·1	25·6	**26·6**	**26·6**	25·8	25·1	24·2	23·6	23·4	23·5	23·5	23·2	22·9	23·2	22·8	23·9	3·9
March 1, ,,	24·4	24·4	24·4	24·4	24·4	24·4	23·9	23·4	23·3	**23·1**	23·4	25·3	26·6	**27·1**	26·6	25·4	24·4	24·3	24·9	25·1	24·7	24·4	24·4	24·3	24·4	24·6	4·0
,, 15, ,,	22·5	22·8	23·0	23·1	23·0	22·4	22·3	21·9	21·0	**20·7**	22·3	24·3	27·4	**28·3**	27·8	26·4	24·3	23·3	23·3	22·9	23·0	22·7	22·9	22·8	22·8	23·5	7·6
April 1, ,,	23·7	23·9	24·1	23·8	22·7	23·1	22·4	**21·1**	22·1	21·9	24·9	27·6	30·9	**31·3**	30·6	29·4	27·9	26·0	25·1	25·1	22·9	24·8	22·7	22·2	23·1	25·0	10·2
,, 15, ,,	22·0	22·0	22·0	21·9	21·7	21·1	21·3	21·0	20·0	**19·1**	20·1	22·1	23·8	25·7	**25·9**	24·2	23·2	22·9	22·1	22·0	22·2	22·7	22·5	22·2	22·2	22·2	6·8
May 1, ,,	22·0	22·1	21·7	21·3	21·4	20·9	20·8	20·1	**19·9**	20·6	21·5	22·1	23·5	**24·3**	24·1	23·7	23·2	23·8	22·8	22·2	22·2	22·2	22·2	22·1	21·9	22·1	4·3
,, 15, ,,	22·2	21·5	21·8	**23·1**	21·2	20·3	20·4	20·9	20·5	**20·1**	20·4	21·2	22·6	**23·1**	**23·1**	22·3	21·6	21·2	21·4	22·1	21·5	21·8	21·5	21·2	21·1	21·5	3·0
June 1, ,,	21·3	20·3	19·1	20·9	21·1	19·1	20·1	**18·6**	18·8	19·8	21·1	24·4	**25·5**	24·4	24·0	24·6	21·8	20·8	20·2	19·0	19·9	20·5	20·8	21·7	21·0	21·1	6·9
,, 15, ,,	21·0	20·9	20·2	20·3	19·6	18·2	16·8	16·7	**16·1**	18·0	19·8	21·9	24·0	**26·2**	**26·2**	24·0	22·1	21·0	20·2	20·5	20·2	20·4	21·0	21·1	21·3	20·7	10·1
July 1, ,,	18·3	18·5	18·2	18·1	18·2	17·1	15·8	**15·1**	15·9	**15·1**	15·9	17·1	19·3	20·2	**21·0**	20·9	20·2	19·3	19·0	18·9	18·9	19·0	18·9	18·9	19·1	18·3	5·9
,, 15, ,,	22·9	22·7	22·2	21·5	20·8	20·1	**18·1**	18·8	19·2	19·5	21·1	23·1	25·0	**25·8**	25·1	24·3	24·6	24·3	24·5	24·0	23·2	23·2	23·2	22·0	22·1	22·4	7·7
August 1, ,,	23·3	23·1	22·9	22·7	22·2	21·4	20·2	19·4	**19·2**	20·4	23·1	25·3	28·0	29·1	**29·2**	26·3	24·3	22·3	22·1	22·1	22·5	23·2	23·4	23·5	23·4	23·3	10·0
,, 15, ,,	20·6	21·1	20·7	20·5	20·2	19·3	18·4	**17·4**	18·0	18·6	20·6	24·0	26·8	**28·8**	26·4	24·4	22·1	20·4	19·6	20·0	20·7	21·0	21·2	21·2	21·3	21·3	11·4
September 1, ,,	17·9	17·9	17·7	17·7	17·2	17·2	16·2	15·1	**14·9**	15·9	17·8	19·9	21·8	**23·7**	23·6	22·6	21·6	20·0	18·8	18·7	18·8	18·6	18·7	18·5	18·4	18·8	8·8
,, 15, ,,	22·6	21·9	21·9	21·7	21·5	21·5	21·8	**20·5**	**20·5**	21·8	24·4	27·5	**29·2**	**29·2**	28·6	26·7	24·1	23·0	22·8	23·4	23·0	22·8	23·6	22·6	22·8	23·6	8·7
October 1, ,,	17·1	**16·9**	18·2	**16·9**	18·8	19·0	18·9	19·0	18·6	20·0	21·2	23·3	25·2	**26·1**	25·2	24·0	22·4	21·2	20·8	20·1	20·3	20·3	20·2	20·5	21·1	20·7	9·2
,, 15, ,,	20·1	20·0	20·1	19·7	19·2	19·1	18·6	17·7	16·7	**16·3**	18·4	20·9	23·0	**24·0**	**24·0**	22·3	20·3	19·3	20·1	19·6	20·0	19·9	19·9	19·6	19·5	19·9	7·7
November 1, ,,	**9·5**	14·2	14·3	16·5	17·6	18·4	17·7	17·5	17·0	17·2	18·6	19·3	**20·4**	**20·4**	19·5	18·5	17·9	18·0	17·6	17·3	16·8	16·7	16·6	16·6	17·1	17·4	10·9
,, 15, ,,	**17·5**	19·4	19·5	19·7	19·6	20·2	19·7	19·6	19·5	19·5	20·5	20·6	**22·6**	21·6	22·3	21·6	21·5	21·5	21·6	21·3	20·8	20·2	18·6	20·5	20·5	20·5	5·1
December 1, ,,	20·1	20·7	21·4	21·4	21·4	21·2	21·2	20·9	20·8	20·8	21·7	23·4	24·4	**24·7**	24·2	22·0	21·4	20·3	20·3	20·4	19·3	**18·9**	19·5	20·3	20·4	21·3	5·8
,, 15, ,,	19·5	21·9	**18·5**	19·8	20·2	19·7	19·7	19·8	19·7	19·6	19·9	21·3	**22·4**	**22·4**	22·3	21·0	20·5	20·2	19·8	19·7	19·9	19·3	19·5	20·2	20·5	20·3	3·9
January 1, 1903	19·6	19·8	20·1	20·3	20·4	20·3	19·7	19·7	19·4	19·1	20·2	20·8	21·6	**22·5**	22·4	21·7	20·8	20·5	19·9	19·6	19·2	18·8	18·8	**18·0**	19·2	20·1	4·5
,, 15, ,,	20·0	20·6	20·7	21·2	20·9	20·8	20·8	20·7	20·7	20·7	21·8	22·7	23·7	23·9	**24·5**	23·7	22·4	21·8	21·5	20·8	**19·9**	20·2	20·2	20·3	20·7	21·5	4·6
February 1, ,,	15·3	15·9	16·2	16·3	16·7	16·6	16·4	16·0	15·2	**14·2**	14·6	16·2	18·1	20·2	**21·3**	20·9	19·0	18·2	18·2	18·0	17·0	16·4	16·1	16·2	16·2	17·1	7·1
,, 15, ,,	19·2	19·9	21·0	20·3	20·7	20·1	19·5	19·2	19·1	18·3	19·7	20·1	21·4	23·6	**25·2**	22·9	21·8	**15·9**	20·1	20·4	19·9	19·9	19·9	19·9	20·1	20·3	9·3

FALMOUTH—HORIZONTAL FORCE.

Date.	H = ·18 . . . C.G.S.																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	717	716	717	717	718	719	720	721	719	712	705	**703**	705	709	717	721	**723**	722	721	720	721	720	719	718	718	717	20
,, 15, ,, ...	723	723	723	723	724	726	726	727	725	719	713	709	709	713	726	717	718	725	**728**	721	708	660	661	677	**622**	711	106
February 1, ,, ...	736	738	736	738	739	741	**742**	**742**	741	733	**727**	**727**	728	734	736	735	729	**727**	734	736	740	736	735	736	735	735	15
,, 15, ,, ...	727	725	725	726	730	729	730	730	728	724	723	719	**717**	**717**	718	723	730	731	734	**735**	734	734	733	**735**	**735**	728	18
March 1, ,, ...	739	739	740	738	739	**742**	**742**	741	738	735	**730**	**730**	736	740	739	736	734	734	734	736	739	738	737	737	737	737	12
,, 15, ,, ...	741	740	739	740	741	743	741	741	735	719	**713**	714	721	727	733	737	737	737	741	**750**	749	746	745	745	745	737	37
April 1, ,, ...	752	752	752	**755**	**755**	**755**	750	746	746	744	732	732	**729**	731	736	741	743	745	749	750	746	750	752	751	744	745	26
,, 15, ,, ...	730	728	727	728	728	727	728	734	**739**	732	722	**716**	722	730	733	732	734	**739**	735	735	735	736	737	738	736	731	23
May 1, ,, ...	746	746	743	743	745	742	741	738	736	737	734	732	**727**	730	731	735	735	741	746	**751**	**747**	749	749	747	747	740	24
,, 15, ,, ...	744	747	744	741	742	740	741	742	741	738	**736**	737	737	**741**	746	747	**755**	753	753	750	750	750	747	748	747	745	19
June 1, ,, ...	738	**751**	731	731	733	733	734	724	724	**721**	**721**	730	733	736	736	739	**721**	727	733	734	739	733	730	734	731	732	30
,, 15, ,, ...	741	742	742	740	741	739	737	735	734	**730**	**730**	**730**	740	751	749	746	748	751	748	**754**	751	750	752	753	750	743	24
July 1, ,, ...	744	743	739	738	742	744	742	739	736	730	730	**725**	732	737	739	751	**755**	**755**	**755**	**755**	752	752	753	751	747	743	30
,, 15, ,, ...	750	750	758	762	**764**	754	747	746	744	742	**739**	746	756	760	757	758	755	754	757	763	761	762	759	751	744	754	25
August 1, ,, ...	741	740	739	737	737	738	737	735	731	729	718	**716**	721	728	737	745	**750**	749	742	740	736	736	739	739	737	736	34
,, 15, ,, ...	744	739	737	736	736	735	732	726	722	716	**711**	714	727	743	740	736	736	737	744	744	**746**	**746**	743	743	743	735	35
September 1, ,, ...	**764**	761	759	757	755	751	750	744	741	**737**	740	747	753	761	762	758	756	758	759	760	763	762	759	756	758	755	27
,, 15, ,, ...	751	751	751	748	750	750	745	736	728	**723**	724	731	741	751	**759**	756	749	750	751	753	754	750	746	751	751	746	36
October 1, ,, ...	747	749	749	750	751	**752**	750	746	740	734	**730**	731	738	742	743	742	741	740	743	745	745	746	748	749	750	744	22
,, 15, ,, ...	751	**753**	751	752	752	752	751	750	740	727	**720**	721	728	731	737	740	742	743	748	750	750	750	750	750	750	743	33
November 1, ,, ...	**710**	712	718	714	719	719	723	722	721	718	714	**710**	714	720	723	727	730	730	732	**736**	**736**	**736**	732	733	733	723	26
,, 15, ,, ...	745	746	750	749	750	753	**756**	750	750	750	744	**739**	747	745	750	746	747	754	755	753	753	750	750	749	747	749	17
December 1, ,, ...	746	746	747	748	749	**750**	749	748	745	739	**733**	739	744	744	747	745	746	740	746	747	744	741	744	746	746	745	17
,, 15, ,, ...	742	**754**	748	**738**	739	741	742	744	745	742	**738**	**738**	741	748	750	750	749	750	750	748	744	745	748	747	745	745	16
January 1, 1903	760	760	761	762	763	764	764	764	763	760	**750**	760	760	764	768	**770**	**770**	767	769	769	768	768	765	767	764	764	20
,, 15, ,, ...	750	752	753	752	752	753	757	758	758	753	**749**	**749**	752	760	**763**	**763**	759	759	759	759	759	758	755	752	751	756	14
February 1, ,, ...	762	761	759	760	763	764	766	**768**	766	756	746	**740**	**740**	742	747	757	764	**768**	765	766	766	766	765	762	763	759	28
,, 15, ,, ...	763	764	765	766	765	767	769	**770**	**770**	761	755	**741**	744	746	758	746	754	752	755	765	765	764	764	766	765	760	29

POLA—DECLINATION (WEST).

Date.	D = 9°+																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
January 1, 1902	17·1	17·2	17·3	17·3	17·2	17·2	17·1	16·2	**16·0**	17·1	18·2	19·4	**20·8**	19·6	18·5	17·4	17·2	17·1	17·1	17·1	17·1	16·9	17·1	17·0	17·1	17·5	4·3
" 15, "	16·7	16·9	17·3	17·3	17·4	17·2	16·9	15·9	15·3	16·0	17·2	18·7	**19·9**	**19·9**	19·8	18·8	20·2	18·8	18·6	16·9	16·6	11·0	9·4	9·7	**2·8**	16·5	17·0
February 1, "	**17·3**	**17·4**	17·4	17·4	17·4	17·2	17·1	16·2	**15·7**	16·9	18·3	18·9	**19·3**	19·2	18·6	18·1	18·3	17·5	17·4	17·2	17·1	17·0	17·1	17·1	17·2	17·5	3·6
" 15, "	**16·0**	16·3	16·5	16·2	16·2	16·4	15·9	**15·5**	15·6	16·2	17·7	**18·1**	17·4	17·3	17·2	16·3	16·3	16·2	16·0	16·1	16·1	16·0	16·1	16·0	16·0	16·4	2·6
March 1, "	**20·2**	20·0	20·2	20·3	20·6	20·9	21·3	**21·8**	21·6	20·6	19·0	**18·4**	18·6	19·3	20·0	20·7	20·9	19·9	19·2	20·3	20·3	20·2	20·3	20·3	20·2	20·2	3·4
" 15, "	**16·4**	16·7	16·8	16·8	16·5	15·9	15·6	**13·8**	**13·8**	16·2	18·8	20·5	**21·2**	20·3	19·1	17·4	16·3	16·9	16·7	16·1	16·2	16·1	16·2	16·2	16·2	16·9	7·4
April 1, "	15·5	15·3	15·7	15·4	14·8	15·1	13·4	**11·4**	12·5	15·0	18·4	21·4	**22·9**	21·4	19·9	17·9	17·2	16·8	16·7	16·4	14·3	15·7	14·7	14·8	15·3	16·4	11·5
" 15, "	15·7	15·6	15·5	15·2	14·8	15·2	13·8	12·7	**12·2**	13·0	15·4	18·4	**19·5**	18·9	17·5	16·0	15·6	15·7	15·6	15·7	15·7	15·8	15·9	15·8	15·7	15·6	7·3
May 1, "	15·6	15·6	14·6	14·7	14·7	14·4	13·9	**13·3**	14·5	15·8	17·3	18·8	**19·0**	18·1	17·3	17·1	17·4	16·9	15·8	15·8	15·9	16·2	16·2	15·9	15·8	16·1	5·7
" 15, "	15·7	15·6	15·5	15·8	14·7	14·5	14·4	14·2	13·9	**13·7**	14·7	16·8	**18·4**	17·5	16·6	15·5	15·5	15·5	15·7	15·8	15·8	15·8	15·8	15·6	15·6	15·5	4·7
June 1, "	15·1	15·5	13·8	14·8	14·4	**12·8**	13·5	13·2	14·3	16·7	18·6	**19·6**	19·2	19·2	16·5	16·6	15·5	14·5	14·4	13·4	14·4	15·1	15·2	15·8	15·2	15·5	6·8
" 15, "	15·4	15·4	15·3	14·9	13·3	12·2	**12·1**	**12·1**	12·2	14·3	17·4	19·2	20·9	**21·5**	19·2	16·6	15·4	15·4	15·9	15·7	15·1	15·0	15·3	15·4	15·6	15·6	9·4
July 1, "	14·4	14·5	14·3	14·0	13·5	11·4	**11·2**	11·4	12·9	14·5	17·4	18·2	**18·9**	**18·9**	17·2	15·8	15·6	15·4	15·0	14·7	14·7	15·0	14·9	14·7	14·7	14·9	7·7
" 15, "	14·4	14·4	14·3	13·6	12·3	**10·3**	**10·3**	11·1	12·1	13·4	15·1	**16·8**	16·5	16·7	16·0	15·5	15·6	16·3	16·0	15·4	15·3	15·1	14·5	13·4	13·0	14·3	6·5
August 1, "	14·1	14·0	13·8	13·4	12·7	12·1	11·1	**10·8**	11·1	13·3	15·3	17·5	**19·2**	**19·2**	17·3	15·2	13·7	13·2	13·6	14·2	14·1	13·8	13·9	14·1	13·8	14·2	8·4
" 15, "	14·0	13·8	13·7	13·4	12·6	11·8	10·7	**10·0**	10·6	13·4	16·3	19·1	**19·7**	18·7	17·3	15·3	14·0	13·0	13·8	13·9	14·2	14·2	14·2	14·1	14·0	14·2	9·7
September 1, "	13·5	13·5	13·4	13·1	12·6	12·2	11·6	**11·3**	12·8	15·0	16·6	17·3	**18·7**	17·9	16·8	15·7	14·8	15·0	14·4	14·2	13·9	13·9	13·9	13·5	13·6	14·4	7·4
" 15, "	13·8	13·6	13·6	13·2	13·1	12·5	**11·4**	12·0	13·8	16·4	17·6	**19·9**	19·5	17·5	16·5	15·1	14·4	14·4	14·6	14·3	14·1	14·1	13·7	13·7	13·6	14·7	8·5
October 1, "	**11·2**	11·3	11·4	12·0	12·4	12·3	11·3	**11·2**	12·1	14·4	17·2	**18·5**	**18·5**	17·4	15·7	14·4	14·5	14·3	13·5	13·1	13·1	13·1	13·8	13·3	13·5	13·8	7·3
" 15, "	13·2	13·4	13·4	13·2	13·0	12·8	11·2	**9·6**	10·0	13·0	16·2	17·7	**18·3**	17·8	16·3	14·5	14·0	14·2	13·9	13·2	13·4	13·2	13·1	13·0	12·9	13·8	8·7
November 1, "	**7·4**	10·2	10·9	12·0	12·7	12·8	12·6	12·1	12·8	14·1	15·5	**15·7**	**15·7**	15·1	14·2	13·8	13·9	13·5	13·3	13·0	12·7	12·4	12·3	12·3	12·4	13·1	8·3
" 15, "	11·7	11·8	12·5	12·6	12·6	13·3	12·8	12·4	12·5	13·5	14·5	14·4	**15·3**	13·9	13·6	13·7	13·9	13·2	13·5	13·4	12·8	12·3	**11·3**	12·4	12 4	13·1	4·0
December 1, "	12·1	12·3	12·5	12·6	12·6	12·4	12·3	12·5	12·9	14·3	15·8	**16·6**	15·8	15·0	13·9	12·8	12·7	**11·2**	12·3	12·3	12·0	11·7	12·3	12·6	12·7	13·1	5·4
" 15, "	12·6	14·4	12·4	12·9	13·2	12·7	12·6	12·6	**12·3**	12·7	13·8	14·7	**15·3**	14·5	13·6	13·3	13·3	13·1	12·7	12·7	12·4	12·8	12·9	12·6	12·8	13·2	3·0
January 1, 1903	12·1	12·2	12·3	12·3	12·4	12·3	12·1	12·2	12·1	13·5	14·2	**14·4**	13·9	14·1	13·3	12·5	12·7	12·3	12·2	12·1	**11·9**	**11·9**	12·0	12·1	12·3	12·6	2·5
" 15, "	11·4	12·1	12·2	12·2	12·2	12·1	12·1	11·5	**11·2**	12·3	13·4	14·3	**14·5**	14·3	13·4	12·6	12·4	12·3	12·2	12·0	11·3	11·3	11·6	11·9	12·1	12·4	3·3
February 1, "	11·1	11·3	11·4	11·8	12·1	11·9	11·4	10·4	**9·1**	10·0	11·5	12·7	14·2	**15·5**	15·0	13·5	12·2	12·2	12·2	11·6	11·4	11·1	11·1	11·3	11·5	11·9	6·4
" 15, "	11·3	11·9	12·5	11·5	11·7	11·4	11·1	10·2	10·1	11·0	12·7	13·1	14·9	**15·5**	13·9	10·6	11·2	**8·4**	11·2	11·6	11·3	11·2	11·3	11·5	11·6	11·7	7·1

POLA—HORIZONTAL FORCE.

H = ·22 . . . C.G.S.

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean	Range from hourly readings. Unit 1γ.
January 1, 1902	226	226	226	227	228	230	230	228	221	213	212	216	222	226	229	232	232	232	231	229	229	228	231	230	228	227	20
,, 15, ,,	232	233	233	233	235	235	237	237	231	226	225	224	222	226	239	219	218	232	233	221	211	221	224	203	215	223	34
February 1, ,,	232	239	233	234	237	239	239	239	233	228	221	224	233	235	233	232	228	227	233	236	236	233	233	233	231	233	18
,, 15, ,,	228	229	230	227	231	230	233	234	229	225	226	228	226	230	230	228	229	229	233	233	232	233	234	235	235	230	10
March 1, ,,	231	233	234	233	232	233	235	234	232	230	231	235	239	237	232	228	221	223	223	226	228	227	227	227	227	230	18
,, 15, ,,	234	234	233	233	236	236	236	233	225	218	224	232	232	231	232	231	231	231	234	240	239	236	236	236	236	233	22
April 1, ,,	236	237	237	241	243	244	237	233	235	240	232	236	232	229	230	226	228	230	234	235	236	233	238	236	230	235	18
,, 15, ,,	226	225	223	225	226	226	230	233	231	226	233	247	244	237	231	229	227	229	229	227	228	231	231	234	231	230	24
May 1, ,,	236	235	233	233	236	233	230	226	229	239	249	260	253	241	232	226	227	232	235	238	234	238	239	237	238	236	34
,, 15, ,,	238	241	239	235	239	241	244	244	241	244	249	257	251	252	248	246	244	239	240	242	242	243	243	243	242	244	22
June 1, ,,	244	253	243	239	243	240	237	228	221	233	241	249	250	249	241	237	229	233	239	243	243	239	236	240	240	240	32
,, 15, ,,	242	243	246	245	247	242	241	238	244	244	253	255	262	278	248	241	246	245	246	255	252	251	254	253	250	249	34
July 1, ,,	233	232	232	231	235	237	233	226	219	223	227	233	236	235	230	233	233	236	237	237	238	239	239	237	235	233	20
,, 15, ,,	240	240	250	255	255	246	238	235	237	242	242	247	257	250	241	241	240	245	251	250	247	248	245	239	232	245	25
August 1, ,,	240	239	239	238	238	240	241	234	227	226	229	240	247	242	236	238	238	240	238	240	240	240	238	237	237	238	21
,, 15, ,,	243	240	240	240	239	235	228	221	214	217	223	236	253	252	244	236	234	234	240	243	242	241	240	241	240	236	39
September 1, ,,	245	242	239	237	234	229	222	211	206	213	227	238	245	244	243	239	230	235	237	242	243	242	239	237	241	234	39
,, 15, ,,	251	251	252	250	250	249	241	230	225	237	248	262	265	263	262	255	250	249	252	252	251	248	244	250	248	249	40
October 1, ,,	236	238	238	242	237	234	228	221	216	215	224	231	236	235	230	231	223	226	225	228	228	229	232	233	232	230	27
,, 15, ,,	242	244	243	244	243	242	238	229	221	219	225	233	241	240	237	233	235	239	241	239	238	239	240	241	240	237	25
November 1, ,,	208	200	207	201	203	203	206	201	203	201	199	203	209	209	212	214	217	219	221	224	222	222	220	222	222	211	25
,, 15, ,,	233	230	230	230	234	237	240	233	234	235	231	231	239	234	232	226	228	235	234	234	235	230	235	231	230	233	14
December 1, ,,	238	238	239	240	241	242	240	238	234	231	236	246	246	238	238	236	237	234	238	237	237	234	234	236	237	238	15
,, 15, ,,	236	242	243	234	234	238	238	240	240	237	238	240	240	241	243	241	240	242	242	237	234	237	239	235	235	239	9
January 1, 1903	239	240	242	243	243	244	244	243	242	239	245	248	249	250	251	252	248	246	249	248	248	248	246	250	244	246	13
,, 15, ,,	243	245	245	244	244	246	249	248	243	238	238	241	247	245	247	247	243	246	246	245	246	243	243	241	242	244	11
February 1, ,,	238	238	238	239	241	243	246	250	243	234	227	224	225	225	232	242	242	242	239	241	244	244	244	243	243	239	26
,, 15, ,,	244	243	247	247	247	250	254	254	246	239	239	230	236	241	243	227	226	239	237	245	245	245	245	248	245	242	28

POLA—VERTICAL FORCE.

Date.	Z = ·38 . . . C.G.S.																									Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	825	835	826	826	826	826	826	828	827	824	825	824	826	828	**829**	**829**	827	827	826	826	826	826	823	**822**	823	826	7
,, 15, ,, ...	813	812	812	812	812	812	811	811	810	808	806	**800**	801	806	809	809	810	810	810	811	815	**823**	819	815	816	811	23
February 1, ,, ...	807	807	812	812	812	812	812	**813**	809	809	809	808	**806**	**806**	809	810	809	809	810	810	811	810	810	809	809	810	7
,, 15, ,, ...	814	812	812	813	814	814	813	813	812	**810**	**810**	814	**818**	817	817	817	815	815	815	814	814	813	812	811	**810**	814	8
March 1, ,, ...	813	813	811	812	813	**814**	**814**	813	809	802	**801**	803	810	810	811	812	809	811	**814**	**814**	**814**	813	813	813	813	811	13
,, 15, ,, ...	794	793	793	791	792	794	795	797	792	782	**777**	**777**	780	**777**	793	798	798	796	798	798	798	798	798	798	**799**	792	22
April 1, ,, ...	794	794	793	793	790	790	794	794	787	777	**772**	**772**	777	784	791	793	**796**	794	795	795	**796**	793	794	793	792	790	24
,, 15, ,, ...	798	797	797	797	796	795	799	**801**	799	789	780	**777**	780	788	792	795	797	797	797	798	798	798	798	798	797	794	24
May 1, ,, ...	785	785	786	786	786	**787**	**787**	785	776	773	770	766	**763**	766	772	776	780	785	786	786	786	786	786	786	785	781	24
,, 15, ,, ...	818	818	817	818	818	818	**819**	817	812	808	807	**801**	**801**	**801**	804	809	811	812	813	813	814	814	814	813	813	812	18
June 1, ,, ...	795	795	793	794	794	795	796	794	787	781	**776**	777	780	787	791	795	**797**	796	795	796	795	795	796	796	796	792	21
,, 15, ,, ...	**786**	785	784	784	**786**	782	779	780	778	776	776	**772**	**772**	778	781	**786**	784	784	782	782	784	784	785	785	**786**	782	14
July 1, ,, ...	780	780	780	780	781	**782**	778	777	768	764	763	**760**	764	772	776	778	779	780	780	779	779	779	780	779	779	776	22
,, 15, ,, ...	767	765	763	762	763	759	753	753	755	751	747	**746**	747	751	757	760	761	761	764	766	766	766	767	767	**768**	759	22
August 1, ,, ...	760	760	761	762	763	762	762	764	760	756	750	750	**749**	752	763	768	**770**	768	766	765	766	766	764	764	764	761	21
,, 15, ,, ...	735	735	736	736	738	739	739	738	735	730	**727**	732	736	734	739	**745**	743	743	743	743	743	744	744	744	744	739	18
September 1, ,, ...	750	749	748	748	748	747	748	747	744	742	**741**	742	745	746	745	748	751	751	**752**	**752**	**752**	751	751	751	751	748	11
,, 15, ,, ...	771	771	772	772	772	773	**774**	773	772	769	767	**766**	768	771	772	769	770	768	768	768	768	768	768	768	767	770	8
October 1, ,, ...	750	750	750	750	750	751	753	754	751	749	**747**	749	752	755	757	760	759	760	762	764	**765**	**765**	**765**	**765**	**765**	756	18
,, 15, ,, ...	763	763	764	764	764	765	766	766	764	758	**757**	760	762	763	765	766	765	764	765	**767**	**767**	**767**	766	766	766	764	10
November 1, ,, ...	**795**	792	789	787	788	788	788	786	784	780	**779**	780	781	784	787	787	787	788	787	789	788	789	790	789	789	787	16
,, 15, ,, ...	758	757	754	753	751	750	748	747	743	**742**	744	747	747	750	751	749	753	754	755	755	758	**761**	**761**	760	760	752	19
December 1, ,, ...	807	807	807	807	807	807	807	807	804	**802**	**802**	**802**	809	816	**817**	815	815	**817**	815	814	814	816	814	814	814	810	15
,, 15, ,, ...	800	798	801	800	800	800	800	801	800	**795**	**795**	**795**	800	804	**806**	803	804	805	805	**806**	**806**	803	803	800	798	801	11
January 1, 1903	803	802	802	802	801	801	801	799	796	798	801	800	799	800	**804**	803	803	803	802	802	802	800	798	798	**795**	801	9
,, 15, ,, ...	**809**	**809**	**809**	808	808	808	807	806	803	802	802	803	805	**809**	806	804	802	802	802	802	802	801	**800**	**800**	**800**	804	9
February 1, ,, ...	793	792	792	792	792	792	792	795	795	789	**786**	787	787	795	803	**807**	805	802	801	801	801	800	800	799	799	796	21
,, 15, ,, ...	801	800	802	802	803	803	802	802	800	793	789	793	**788**	796	804	**806**	804	805	802	801	800	800	799	799	798	800	18

BOMBAY (COLABA)—DECLINATION (EAST).

Date.	D = 0° +																										Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	20·0	20·0	19·9	20·3	21·4	22·8	21·8	20·3	20·0	19·2	19·2	20·3	21·1	21·0	20·8	20·6	20·5	20·7	20·6	20·5	20·4	20·5	20·2	20·1	20·0	20·5	3·6
,, 15, ,,	20·6	20·4	20·2	20·2	20·4	20·8	21·0	21·2	21·3	21·4	20·8	20·4	20·2	20·5	20·6	20·7	20·7	20·7	20·7	20·7	20·7	20·6	20·5	20·3	20·1	20·6	1·3
March 1, ,,	20·2	20·2	20·5	20·7	20·5	19·9	19·1	19·2	19·4	20·0	20·8	21·1	21·6	21·2	21·2	21·2	21·3	21·3	21·6	21·4	21·1	21·4	21·3	21·3	21·2	20·8	2·5
,, 15, ,,	20·1	20·2	20·8	21·6	22·0	21·6	20·8	19·9	19·8	20·2	20·4	20·5	20·5	20·2	20·2	20·3	20·4	20·4	20·4	20·3	20·3	20·3	20·2	20·2	20·1	20·5	2·2
April 1, ,,	20·2	20·3	21·4	22·5	22·6	22·2	21·0	19·4	19·2	19·7	20·4	20·6	20·4	20·1	19·7	19·8	20·0	20·1	20·1	20·3	20·7	20·2	20·2	20·2	20·2	20·5	3·4
,, 15, ,,	20·2	20·4	21·3	22·2	22·2	21·8	20·5	19·0	18·6	19·1	20·0	20·2	20·0	19·8	19·9	19·9	19·9	20·0	20·1	20·1	20·1	20·1	20·1	20·1	20·1	20·2	3·6
May 1, ,,	20·1	20·4	21·4	21·4	20·7	19·7	19·3	19·0	19·5	19·9	20·1	20·0	19·8	19·7	19·8	19·6	19·7	19·9	20·0	20·0	20·0	19·9	19·9	19·9	19·9	20·0	2·4
,, 15, ,,	19·9	20·2	21·1	21·0	20·7	19·7	18·7	18·1	18·1	18·8	19·4	19·6	19·8	19·7	19·7	19·7	19·7	19·8	19·8	19·8	19·5	19·9	19·9	19·8	19·8	19·7	3·0
June 1, ,,	20·0	21·0	20·8	21·0	20·4	20·1	19·7	18·9	19·0	19·7	20·4	20·9	20·7	19·8	19·7	19·7	19·6	19·7	19·6	19·8	20·2	19·9	19·8	19·8	20·1	20·1	2·1
,, 15, ,,	19·7	20·5	21·0	21·5	21·0	19·7	18·4	17·3	17·7	18·2	18·9	19·2	18·5	17·9	18·5	18·9	18·8	19·1	19·3	19·7	20·0	19·9	19·9	19·7	19·8	19·3	4·2
July 1, ,,	19·6	19·8	20·4	20·3	20·0	18·7	18·0	18·1	18·1	18·7	19·1	19·2	18·4	18·8	19·0	19·1	19·1	19·3	19·4	19·5	19·0	19·4	19·5	19·5	19·5	19·2	2·4
,, 15, ,,	19·6	20·3	21·7	22·3	21·7	21·0	19·2	17·7	17·5	17·4	17·9	18·8	19·3	19·2	18·9	18·9	18·9	19·1	19·2	19·5	19·6	19·6	19·7	20·1	20·1	19·5	4·9
August 1, ,,	19·4	20·1	20·7	20·8	20·4	18·1	17·4	17·8	18·3	19·0	19·5	19·8	19·6	19·1	18·6	18·9	18·9	19·0	19·1	19·2	19·2	19·2	19·3	19·3	19·5	19·2	3·4
,, 15, ,,	19·2	20·2	21·5	22·1	21·7	19·8	18·2	17·0	16·7	16·7	18·0	19·2	19·9	19·7	19·0	18·8	18·8	18·9	18·9	18·0	18·3	18·0	18·1	18·0	18·3	18·9	5·4
September 1, ,,	19·5	20·0	21·1	21·0	20·0	18·8	17·9	17·5	17·0	17·7	18·6	19·5	20·0	19·4	18·9	18·9	18·9	18·9	19·2	19·3	19·3	19·3	19·4	19·4	19·5	19·1	4·1
,, 15, ,,	19·4	19·7	20·8	20·8	19·7	18·6	17·6	17·4	17·8	18·7	19·8	20·5	20·2	19·7	19·3	19·0	19·1	19·0	19·1	19·3	19·1	19·4	19·4	19·3	19·4	19·3	3·4
October 1, ,,	19·2	19·3	20·1	20·4	19·8	18·8	17·6	16·9	17·0	17·7	18·9	19·4	19·1	18·7	18·7	18·7	19·0	19·0	18·9	18·8	19·0	18·9	18·9	18·9	19·0	18·8	3·5
,, 15, ,,	18·8	19·1	19·9	20·6	20·6	19·3	17·9	17·1	17·6	17·7	18·2	18·8	18·7	18·8	18·8	18·8	18·9	18·8	19·0	19·1	19·1	19·1	19·0	19·0	19·0	18·9	3·5
November 1, ,,	19·3	19·2	18·5	18·3	17·6	17·4	17·2	17·5	18·2	19·1	19·6	20·1	19·4	18·7	18·7	18·6	18·5	18·6	18·6	18·7	18·6	18·6	18·6	18·6	18·5	18·6	2·9
,, 15, ,,	18·3	18·5	18·0	18·2	18·1	18·2	18·2	18·2	18·7	19·1	18·7	18·4	18·5	18·6	18·4	18·4	18·4	18·3	18·4	18·5	18·7	18·7	18·5	18·4	18·3	18·4	1·1
December 1, ,,	18·5	18·5	18·0	17·9	17·9	17·8	17·5	17·6	18·3	18·9	18·9	19·6	19·5	19·7	19·2	19·2	18·9	19·0	18·7	18·7	18·6	18·7	18·4	18·3	18·2	18·6	2·2
,, 15, ,,	17·7	17·4	17·3	17·4	17·6	17·4	16·7	16·0	16·9	18·1	18·6	18·0	18·1	18·1	18·1	18·1	18·0	18·0	18·1	18·2	18·1	18·0	17·8	17·8	17·7	17·7	2·6
January 1, 1903	18·6	18·4	18·2	18·5	19·1	19·6	19·3	18·8	18·1	18·4	19·1	19·4	19·4	19·2	19·1	19·0	19·0	18·8	18·8	18·8	18·7	18·7	18·6	18·4	18·1	18·8	1·5
,, 15, ,,	18·7	18·6	18·6	19·0	19·4	19·4	18·1	17·7	18·7	18·8	19·0	18·9	18·9	19·1	19·0	19·1	19·0	19·1	19·2	19·1	19·1	19·1	18·9	18·8	18·6	18·9	1·3
February 1, ,,	18·1	17·8	17·6	17·5	17·8	18·6	19·1	18·8	17·7	16·9	16·7	17·2	17·7	18·1	18·4	18·5	18·6	18·3	18·5	18·5	18·4	18·3	18·1	17·8	17·7	18·0	2·4
,, 15, ,,	17·7	17·4	17·3	18·1	19·1	19·2	18·8	18·1	18·0	18·1	18·5	18·9	18·5	18·2	18·2	18·6	18·5	18·7	18·4	18·3	18·2	18·2	18·1	18·1	17·9	18·3	1·9

BOMBAY (COLABA)—HORIZONTAL FORCE.

H = ·37 . . . C.G.S.

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings. Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	440	439	441	444	448	456	469	473	468	465	460	453	449	443	438	436	432	430	436	437	438	437	438	438	438	446	43
,, 15, ,,	433	434	433	437	445	446	449	447	441	439	440	437	430	432	432	429	430	430	434	434	435	436	435	432	429	436	20
March 1, ,,	441	443	446	447	458	468	474	480	471	458	449	447	449	447	442	440	436	434	432	433	435	434	434	435	436	447	48
,, 15, ,,	435	435	437	445	459	477	485	483	466	450	442	441	438	436	438	434	431	431	432	438	438	435	435	436	437	445	54
April 1, ,,	436	441	445	456	473	485	483	469	456	445	437	435	428	426	430	432	431	431	431	429	438	430	436	434	429	443	59
,, 15, ,,	413	413	415	424	439	449	459	458	449	441	435	433	430	426	423	421	420	421	420	418	419	420	422	427	421	429	46
May 1, ,,	428	426	422	425	436	449	459	457	454	444	437	436	432	430	426	423	421	417	422	424	424	426	426	424	427	432	42
,, 15, ,,	415	414	414	415	423	434	446	445	441	439	434	430	427	422	418	417	418	418	420	421	421	422	423	422	422	425	32
June 1, ,,	426	425	429	434	445	453	452	453	445	439	430	422	420	422	423	422	420	424	422	428	424	421	420	421	422	430	33
,, 15, ,,	426	426	427	430	441	449	460	463	443	442	435	434	443	457	436	430	433	436	433	434	436	435	437	438	434	439	37
July 1, ,,	416	418	422	423	425	435	437	443	445	439	438	430	426	421	420	422	422	422	422	423	423	423	423	422	420	427	29
,, 15, ,,	423	424	437	449	457	454	461	468	463	458	447	442	437	437	431	429	432	434	433	432	431	429	428	424	423	440	45
August 1, ,,	424	426	428	430	434	439	444	445	442	439	430	425	422	421	423	422	423	424	422	422	422	422	422	421	421	428	24
,, 15, ,,	425	425	423	422	426	434	440	439	441	440	436	428	425	421	420	419	419	420	420	420	420	420	420	420	421	426	22
September 1, ,,	420	420	419	421	427	426	431	434	434	432	425	420	420	419	416	412	413	414	414	416	419	419	417	417	420	421	22
,, 15, ,,	420	419	415	409	418	429	434	435	434	433	423	422	422	420	419	418	414	417	416	414	413	410	411	416	418	420	26
October 1, ,,	419	418	414	421	427	437	439	436	431	424	420	417	417	417	415	411	408	406	409	412	413	413	416	417	417	419	33
,, 15, ,,	420	419	419	427	437	449	459	461	446	433	421	418	422	419	417	416	413	415	412	415	416	415	416	416	416	425	49
November 1, ,,	384	378	383	392	404	410	419	416	412	402	396	399	402	401	401	402	403	402	404	404	405	405	406	408	409	402	41
,, 15, ,,	426	429	436	445	460	467	464	448	441	431	440	426	426	424	428	423	425	428	430	426	422	422	430	428	428	434	45
December 1, ,,	414	415	421	431	440	445	445	440	433	425	419	420	415	409	408	410	410	422	417	414	413	409	413	414	417	421	37
,, 15, ,,	419	419	425	425	429	437	442	438	437	430	425	424	422	420	423	422	420	422	420	415	416	415	416	417	418	424	27
January 1, 1903	420	423	425	427	428	438	448	445	440	433	435	430	429	429	428	426	423	423	425	426	428	429	427	428	427	430	28
,, 15, ,,	424	427	428	425	426	432	438	433	432	430	429	423	421	419	419	419	418	420	419	419	419	419	418	420	419	424	20
February 1, ,,	425	424	430	435	442	446	446	441	442	441	437	431	428	429	429	429	427	426	425	428	431	432	433	432	432	433	22
,, 15, ,,	427	430	430	429	424	416	412	408	409	412	426	430	426	425	423	422	411	430	423	425	426	425	425	430	430	423	22

BOMBAY (COLABA)—VERTICAL FORCE.

Z = ·14 . . . C.G.S.

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings. Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	800	798	799	804	**811**	808	785	**777**	785	783	795	805	807	802	800	800	802	801	801	802	802	802	802	802	802	799	34
,, 15, ,,	800	799	798	799	799	799	796	794	793	791	790	**789**	794	801	801	801	801	801	801	801	**802**	801	801	801	801	798	13
March 1, ,,	817	819	**821**	818	812	**807**	809	819	816	818	**821**	816	812	814	816	816	814	816	817	816	817	817	817	816	816	816	14
,, 15, ,,	810	811	**813**	811	803	794	788	**787**	798	802	806	808	804	805	806	806	807	807	808	809	810	810	809	810	810	805	26
April 1, ,,	813	815	**821**	819	811	804	791	**788**	799	809	810	810	808	805	807	810	812	812	813	813	812	812	813	812	812	809	33
,, 15, ,,	810	811	**816**	812	809	800	**792**	793	802	810	811	808	803	806	807	806	808	808	809	810	809	808	809	810	809	807	24
May 1, ,,	823	826	**827**	818	809	**807**	811	812	813	820	821	820	818	820	819	819	820	822	822	822	822	822	823	822	822	819	20
,, 15, ,,	818	**823**	822	813	804	**795**	798	804	813	815	814	813	814	814	814	814	815	815	815	815	816	817	816	816	816	813	28
June 1, ,,	824	**827**	825	824	817	812	809	**807**	816	820	719	820	815	813	817	817	818	819	820	819	819	820	820	819	822	818	20
,, 15, ,,	824	**829**	826	822	811	805	**799**	801	803	808	815	816	816	816	822	823	823	824	824	826	826	825	824	824	826	818	30
July 1, ,,	833	**838**	**838**	834	826	815	**813**	817	822	824	826	827	822	824	829	827	827	830	830	830	830	830	830	830	830	827	25
,, 15, ,,	838	843	**847**	841	831	823	812	**810**	815	816	829	835	831	830	831	832	833	834	834	836	835	835	836	835	836	831	37
August 1, ,,	859	863	863	860	847	**832**	854	862	862	867	**869**	867	857	852	854	855	855	856	855	856	856	857	855	857	856	857	37
,, 15, ,,	859	**868**	**868**	861	840	**824**	**824**	829	836	851	861	865	863	856	853	854	856	856	858	858	859	858	858	858	860	853	44
September 1, ,,	849	853	**856**	843	826	**818**	823	828	833	840	843	848	848	845	845	847	846	847	848	849	848	850	850	850	851	843	38
,, 15, ,,	853	859	861	853	842	831	**823**	829	837	852	**862**	857	849	847	848	849	849	849	849	851	852	849	850	852	852	848	39
October 1, ,,	862	864	**867**	858	844	839	**836**	842	848	856	861	858	856	856	857	860	860	859	859	859	860	860	861	861	862	856	31
,, 15, ,,	858	861	**862**	860	847	**831**	835	839	854	855	858	858	855	855	855	857	856	858	858	858	857	857	858	858	858	854	31
November 1, ,,	874	871	872	871	**868**	870	870	878	**882**	**882**	879	874	870	869	871	872	872	873	873	873	872	872	872	872	872	873	14
,, 15, ,,	876	876	875	**878**	**878**	874	874	871	875	873	**868**	872	871	873	873	873	872	874	876	875	875	874	873	874	875	874	10
December 1, ,,	867	866	865	866	866	**863**	**863**	866	**871**	869	868	868	868	868	865	865	866	867	866	866	866	864	864	866	866	866	8
,, 15, ,,	870	869	868	869	868	859	**852**	854	868	**873**	869	868	871	870	871	870	870	871	872	872	871	869	868	870	870	868	21
January 1, 1903	891	891	890	**895**	890	878	880	875	**874**	882	891	891	889	887	888	889	889	889	890	890	890	889	888	887	885	887	21
,, 15, ,,	895	895	897	897	892	884	**876**	885	898	**902**	897	895	895	895	894	895	895	896	897	896	896	895	895	894	894	894	26
February 1, ,,	887	885	885	887	**890**	**890**	889	878	869	**868**	875	883	887	888	889	887	887	888	888	888	888	888	887	887	887	885	22
,, 15, ,,	888	887	889	**896**	895	887	**878**	**878**	886	887	888	888	888	883	882	887	888	887	888	888	888	889	888	888	888	887	18

MAURITIUS—DECLINATION (WEST).

Date.	D = 9° +																										Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	17·7	**18·4**	18·7	**20·2**	(20·0)	19·7	**20·2**	**19·7**	20·0	18·6	17·3	16·5	**15·5**	15·9	16·5	17·4	17·7	17·9	**18·4**	**18·5**	18·4	18·4	18·5	18·5	18·5	18·3	**4·7**
,, 15, ,, ...	17·4	18·2	**19·1**	19·3	(19·1)	19·0	19·4	18·1	16·3	14·3	**13·4**	14·0	14·6	16·0	16·4	16·4	16·7	17·3	17·3	17·3	18·2	18·2	18·7	19·0	**19·9**	17·3	6·5
February 1, ,, ...	17·6	17·9	18·2	19·2	**19·4**	19·2	18·5	19·1	18·4	17·2	16·0	15·3	15·4	**15·2**	15·4	16·4	16·9	16·8	17·1	17·2	17·2	17·3	17·4	17·5	17·9	17·3	4·2
,, 15, ,, ...	17·3	17·7	18·1	20·2	20·2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,, ...	17·3	17·5	17·4	18·1	20·9	**22·3**	21·3	19·1	16·3	14·1	**12·4**	12·6	14·3	16·2	17·0	17·2	17·3	17·3	17·2	17·3	17·3	17·3	17·3	17·3	17·3	17·2	9·9
,, 15, ,, ...	17·5	17·7	18·2	18·8	21·1	**21·7**	**21·7**	18·8	15·7	13·5	**12·3**	12·4	13·7	15·8	17·1	17·3	17·3	17·4	17·1	17·1	17·1	16·9	17·1	17·1	17·3	17·1	9·4
April 1, ,, ...	17·9	17·8	17·9	18·7	19·8	21·0	**21·7**	20·0	16·7	14·5	**14·0**	14·6	15·7	16·6	17·6	17·7	17·7	17·7	17·6	17·5	17·8	17·7	17·5	17·6	17·7	17·6	7·7
,, 15, ,, ...	16·8	16·8	16·8	16·7	18·0	19·2	**20·6**	20·0	17·8	15·9	**15·0**	**15·0**	**15·0**	16·0	17·1	17·3	17·7	17·8	17·5	17·3	17·2	17·2	17·4	17·4	17·5	17·2	5·6
May 1, ,, ...	16·1	16·1	16·1	15·8	16·9	19·1	**21·2**	20·9	18·8	16·7	14·9	**13·9**	—	15·8	16·9	17·0	17·3	17·3	17·3	17·3	17·3	17·1	16·9	16·9	16·9	17·1a	7·3a
,, 15, ,, ...	16·2	15·8	15·8	15·4	16·4	18·6	**20·3**	19·2	17·8	16·9	16·6	—	**14·8**	15·0	15·8	16·5	16·5	16·4	16·4	16·5	16·5	16·4	16·3	16·0	15·8	16·8a	5·5a
June 1, ,, ...	15·1	14·1	14·5	14·3	14·4	16·4	**17·6**	17·2	15·8	15·4	14·1	**13·1**	13·8	15·2	16·1	16·1	16·2	16·2	16·2	16·2	16·1	16·1	16·1	15·6	15·4	15·5	4·5
,, 15, ,, ...	15·2	15·2	15·2	14·8	14·4	15·5	**17·1**	**17·1**	16·1	15·1	14·3	**14·1**	14·3	15·1	15·8	15·9	16·0	15·9	15·8	15·3	15·1	15·1	15·1	15·1	15·1	15·3	3·0
July 1, ,, ...	15·3	15·3	15·4	15·0	15·1	15·3	16·3	17·3	**17·7**	17·3	16·1	15·3	**14·4**	14·5	15·3	15·3	15·2	15·2	15·3	15·2	15·2	15·2	15·1	15·1	15·1	15·5	3·3
,, 15, ,, ...	15·5	15·5	15·0	14·5	14·6	15·5	16·5	**17·5**	16·4	15·1	13·8	**13·2**	13·6	14·6	15·5	15·5	15·6	15·5	15·5	15·4	15·1	14·9	14·7	14·3	14·6	15·1	4·3
August 1, ,, ...	15·1	15·0	14·9	14·1	14·4	16·1	**17·1**	16·8	15·9	14·9	14·2	**13·6**	14·0	14·9	15·3	15·6	15·4	15·5	15·3	15·3	15·2	15·5	15·6	15·5	15·2	15·2	3·5
,, 15, ,, ...	16·4	16·2	15·6	14·5	14·5	16·5	18·2	18·5	19·5	**20·3**	16·7	14·5	**14·3**	14·8	15·8	16·3	16·4	16·4	16·4	16·4	16·4	16·4	16·4	16·4	16·4	16·4	6·0
September 1, ,, ...	15·9	15·9	15·8	14·8	15·8	16·8	17·8	18·1	**18·8**	17·8	15·9	13·8	**12·8**	13·2	14·7	15·5	16·8	15·9	15·9	15·9	15·9	15·9	15·9	16·2	16·1	15·9	6·0
,, 15, ,, ...	16·3	16·2	16·1	14·3	16·2	18·6	20·8	**22·0**	21·2	19·0	16·1	13·7	**13·2**	14·2	16·1	16·2	16·2	16·1	16·1	16·1	16·1	16·2	16·2	16·1	16·2	16·6	8·8
October 1, ,, ...	16·4	16·4	15·4	15·3	16·9	18·4	**19·6**	19·3	17·4	15·4	14·5	**14·4**	14·9	15·8	16·4	16·4	16·4	16·4	16·3	16·4	16·4	16·5	16·7	16·9	16·9	16·5	5·2
,, 15, ,, ...	16·4	16·4	16·0	16·0	16·8	18·2	**19·2**	18·3	17·3	15·6	14·3	**14·0**	14·5	16·0	16·3	16·3	16·3	16·3	16·3	16·3	16·4	16·5	16·5	16·6	16·4	16·4	5·2
November 1, ,, ...	16·1	16·1	16·0	16·4	18·1	**18·3**	18·0	16·9	15·9	14·6	**14·1**	15·1	16·1	17·1	17·0	16·6	16·4	16·1	16·1	16·1	16·1	16·1	16·3	16·6	16·9	16·4	4·2
,, 15, ,, ...	15·8	15·8	16·8	18·8	(18·8)	**18·9**	17·8	16·9	15·7	14·7	**12·9**	13·0	13·8	14·8	15·7	15·5	14·8	14·9	15·0	14·9	14·9	14·9	15·5	15·7	15·9	15·7	6·0
December 1, ,, ...	15·4	15·9	16·4	**18·2**	**(18·2)**	18·1	16·5	15·0	12·4	10·2	**9·4**	10·4	12·4	13·4	14·4	14·4	14·4	14·6	15·2	15·1	15·4	15·4	15·6	16·3	16·3	15·0	8·8
,, 15, ,, ...	16·1	16·1	16·0	17·2	18·1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
January 1, 1903	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,, ...	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

MAURITIUS—HORIZONTAL FORCE.

Date.	H = ·23 . . . C.G.S.																										Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	772	771	785	791	794	794	792	796	787	781	784	784	787	790	787	782	781	781	781	782	782	783	784	784	785	785	25
,, 15, ,,	791	793	792	795	798	793	803	796	789	788	792	791	789	792	803	781	775	786	786	777	769	763	749	760	775	785	54
February 1, ,,	785	785	786	788	791	793	799	801	798	795	793	787	784	784	785	785	792	779	782	785	784	782	783	782	782	788	22
,, 15, ,,	774	774	774	773	783	(784)	785	785	785	785	779	774	773	775	775	773	773	773	773	773	774	774	777	780	783	777	12
March 1, ,,	773	775	779	776	775	774	784	793	793	788	786	784	781	777	773	775	772	769	767	767	767	767	767	770	769	776	26
,, 15, ,,	772	773	774	774	775	776	774	772	766	762	766	771	778	778	777	775	773	772	772	775	775	773	773	775	776	773	16
April 1, ,,	765	768	768	770	773	771	767	767	769	766	757	754	754	758	763	764	762	761.	761	761	764	761	766	765	763	764	19
,, 15, ,,	748	748	749	751	754	756	756	761	766	766	759	752	751	754	757	757	757	756	756	753	752	754	754	754	754	755	18
May 1, ,,	764	764	764	766	767	770	771	773	772	770	760	760	758	756	759	759	758	755	758	758	758	761	761	761	761	763	18
,, 15, ,,	750	752	752	754	758	758	759	761	762	763	759	755	752	751	753	753	753	754	755	755	755	755	755	755	755	755	13
June 1, ,,	750	751	752	751	753	753	750	750	750	750	753	751	746	747	749	749	748	749	750	753	751	750	749	750	751	750	7
,, 15, ,,	753	753	753	754	759	759	759	762	767	768	763	760	763	768	761	759	758	759	756	756	756	756	757	757	756	759	15
July 1, ,,	743	745	745	748	751	757	759	761	763	758	755	749	746	745	748	749	749	749	750	749	750	749	750	750	749	751	20
,, 15, ,,	746	746	751	757	763	766	769	774	769	760	755	753	756	756	755	755	756	756	755	754	754	754	753	752	751	757	28
August 1, ,,	746	747	749	750	752	752	752	758	764	772	761	754	752	747	746	746	746	748	740	747	748	749	749	740	749	751	26
,, 15, ,,	745	745	746	751	757	758	762	767	766	757	758	755	748	740	740	740	739	740	741	741	741	741	741	742	743	748	28
September 1, ,,	745	743	743	745	741	736	733	736	737	740	742	739	734	732	730	729	731	732	733	736	738	739	739	739	742	737	16
,, 15, ,,	738	739	737	743	747	749	749	745	740	735	727	728	728	729	733	735	734	(734)	(734)	734	734	734	734	738	740	737	22
October 1, ,,	742	732	733	736	731	732	737	742	743	742	738	734	729	726	727	725	721	720	719	724	725	727	730	729	729	731	24
,, 15, ,,	731	731	731	734	737	746	755	759	756	756	750	739	735	728	727	728	727	727	727	728	729	730	731	731	731	736	32
November 1, ,,	694	691	698	702	704	707	709	706	708	699	690	691	697	700	701	704	705	703	705	707	708	708	711	712	712	703	22
,, 15, ,,	733	732	730	731	740	—	750	745	742	734	728	726	728	727	727	729	728	728	731	730	731	731	736	733	733	733a	24
December 1, ,,	725	724	725	726	731	733	736	736	731	727	725	728	724	717	717	721	723	727	725	725	726	725	725	727	728	726	19
,, 15, ,,	730	729	732	731	732	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
January 1, 1903	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

"DISCOVERY'S" WINTER QUARTERS—DECLINATION (EAST).

Date.	D = 151° +																										Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	114	—	—	135	153	179	154	169	167	165	155	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	143	143	143	149	148	149	150	159	164	185	186	186	173	—	—
April 1, ,,	150	—	149	144	127	117	92	68	83	108	83	116	—	138	136	131	125	134	140	152	158	158	164	168	155	—	100
,, 15, ,,	174*	167*	155*	151	142	145	143	139	139	142	142	145	142	135	144	148	146	146	148	148	148	157	159	161	152	148	39
May 1, ,,	152	—	—	—	—	—	—	—	—	139	145	148	151	147	155	152	155	164	174	172	151	153	160	150	153	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	154	155	154	156	156	157	158	156	157	158	156	160	158	158	—	—
June 1, ,,	—	134	118	97	110	102	94	84	39	80	94	90	114	111	113	109	118	119	121	130	134	131	127	135	123	110a	96
,, 15, ,,	129	—	128	127	126	122	114	116	113	120	117	116	116	111	120	141	131	126	129	137	121	125	120	136	125	124a	30
July 1, ,,	90	—	88	90	92	83	85	69	76	84	82	91	88	95	96	87	—	—	—	—	—	—	100	94	93	—	—
,, 15, ,,	100	100	99	101	107	94	85	88	88	94	90	95	97	95	97	94	95	96	97	99	101	106	106	115	105	98	30
August 1, ,,	94	86	85	91	89	88	87	87	85	88	84	85	90	93	91	90	94	93	93	91	94	94	93	96	91	90	12
,, 15, ,,	109	104	103	97	97	97	98	94	90	99	100	100	105	103	107	103	107	106	106	107	111	108	110	112	109	103	22
September 1, ,,	105	128	84	89	89	86	84	82	88	93	95	94	95	93	92	97	96	99	98	99	100	102	100	93	102	95	46
,, 15, ,,	95	87	86	82	84	83	82	85	91	90	88	88	90	92	91	92	92	92	94	95	97	98	98	112	93	91	30
October 1, ,,	184	166	133	102	89	73	88	73	79	9	92	104	115	117	117	117	124	137	150	146	151	—	—	—	141	—	—
,, 15, ,,	139	141	134	133	114	85	92	81	101	85	91	107	119	123	128	118	120	113	115	108	119	112	118	102	100	112	60
November 1, ,,	191	82	81	62	37	54	35	73	77	84	88	120	137	130	135	113	125	105	154	154	173	162	142	144	170	110	156
,, 15, ,,	60	80	54	48	42	52	62	55	59	81	72	93	54	114	102	91	126	96	78	108	101	120	52	137	111	82	95
December 1, ,,	146	142	119	116	123	119	84	83	89	104	100	110	113	132	134	173	208	216	232	264	212	176	242	235	209	154	181
,, 15, ,,	—	196	114	59	52	58	53	66	71	75	71	69	64	88	90	122	129	71	52	79	60	172	133	107	96	89a	144
January 1, 1903	78	122	132	106	103	99	93	76	78	69	87	119	126	58	64	59	70	156	80	105	112	113	52	48	—	92a	108
,, 15, ,,	102	93	81	56	49	42	42	48	40	51	66	80	68	97	82	96	131	92	68	97	61	65	85	59	69	72	91
February 1, ,,	60	96	77	92	82	74	96	124	108	120	121	113	131	116	117	112	130	112	161	132	135	138	165	196	158	119	136
,, 15, ,,	—	183	159	119	120	106	117	110	114	107	91	117	122	129	103	150	146	175	186	135	183	165	189	181	174	141a	98

* A correction of −47′ has been applied on account of discontinuity in trace.

"DISCOVERY'S" WINTER QUARTERS—HORIZONTAL FORCE.

H = ·06 . . . C.G.S.

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings. Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	667	—	—	675	666	670	677	712	712	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	607	607	618	605	608	601	615	651	663	654	618	635	652	—	—
April 1, ,,	545	—	658	665	685	618	661	652	605	586	516	619	—	—	635	595	—	607	573	654	591	689	712	712	>713	—	>197
,, 15, ,,	630*	625*	622*	621	628	640	633	628	627	619	627	630	637	629	629	626	628	629	631	633	632	638	633	636	633	630	20
May 1, ,,	406	—	—	—	—	—	—	—	—	509	502	501	500	499	498	488	494	491	486	494	490	509	509	519	509	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	501	504	505	504	502	502	501	505	518	516	516	516	515	518	—	—
June 1, ,,	—	580	575	605	647	589	580	586	555	587	565	547	554	558	561	554	558	559	561	565	561	565	574	575	580	573a	100
,, 15, ,,	640	—	591	601	606	615	612	604	609	593	597	593	589	587	605	596	604	605	615	598	605	607	612	604	605	603a	53
July 1, ,,	634	—	644	669	676	647	640	634	654	622	626	618	611	615	601	611	611	618	619	622	620	620	625	623	636	629a	75
,, 15, ,,	642	645	656	664	679	—	644	648	646	643	641	639	639	636	632	632	632	634	634	632	637	639	642	648	658	643a	47
August 1, ,,	724	724	724	721	721	723	720	719	718	712	703	712	710	710	710	709	710	705	710	712	714	712	713	714	717	714	21
,, 15, ,,	717	724	721	723	728	727	726	728	724	707	695	678	682	695	692	689	695	695	693	698	699	704	707	712	713	707	50
September 1, ,,	729	734	715	723	729	737	717	715	712	703	704	705	706	706	706	705	698	705	705	706	705	708	709	715	727	712	39
,, 15, ,,	727	735	731	719	719	715	718	715	710	712	711	712	712	711	709	708	710	710	711	714	711	719	711	724	740	716	32
October 1, ,,	>783	>783	>783	>783	>783	>783	783	783	757	748	738	727	725	736	738	728	716	722	708	721	725	—	—	—	754	—	> 75
,, 15, ,,	769	757	760	772	778	>778	770	774	749	752	735	706	730	735	728	729	728	730	729	720	726	740	744	737	761	>745	> 72
November 1, ,,	>663	>663	>663	>663	>663	652	663	637	651	650	649	609	615	619	623	620	617	633	620	641	630	603	632	637	645	—	> 60
,, 15, ,,	666	643	663	642	666	650	655	634	632	618	618	589	618	589	597	594	602	610	596	664	577	<563	629	587	621	<620	>103
December 1, ,,	443	448	437	480	463	491	459	441	446	432	439	427	420	397	386	405	367	406	377	366	385	417	456	471	474	428	125
,, 15, ,,	468	477	>512	512	472	463	456	438	433	433	452	447	433	421	417	415	413	419	388	398	412	449	430	438	451	>441	>124
January 1, 1903	302	347	337	348	343	327	333	326	306	342	319	302	307	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	339	366	358	364	392	409	376	387	372	344	335	355	355	334	334	316	302	329	331	321	339	310	335	335	347	348	107
February 1, ,,	323	354	359	372	371	371	361	367	344	339	338	339	325	345	338	333	325	297	301	317	319	321	341	343	341	340	75
,, 15, ,,	—	>374	>374	>374	>374	>374	>374	372	343	335	365	312	321	318	302	262	263	<259	307	351	300	334	348	341	338	—	>115

* A correction of −58γ has been applied on account of discontinuity in the trace.

CHRISTCHURCH (NEW ZEALAND)—DECLINATION (EAST).

D = 16° +

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings.
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,,	13·5	15·6	16·6	**17·0**	16·6	15·8	14·7	14·4	14·6	14·5	13·7	13·3	13·3	13·4	13·3	13·3	13·3	13·3	12·7	11·1	9·5	**8·6**	9·6	11·7	13·9	13·5	8·4
,, 15, ,,	14·6	16·8	18·5	**19·1**	18·1	16·7	15·3	15·3	15·5	14·7	14·5	14·1	14·1	14·4	14·5	13·9	14·4	14·4	14·4	13·5	12·1	11·1	**10·4**	(11·5)	13·6	14·6	8·7
April 1, ,,	14·0	(16·6)	17·7	**17·9**	17·0	15·7	14·3	14·2	13·9	14·1	12·9	13·4	14·1	13·2	14·1	14·1	14·1	14·2	14·2	14·0	13·1	11·7	**10·7**	11·8	14·2	14·2	7·2
,, 15, ,,	13·5	14·9	16·7	**16·8**	15·9	14·9	14·7	14·5	14·5	14·0	13·9	13·8	13·7	13·5	13·6	13·7	13·7	13·7	13·7	13·6	13·1	11·9	**10·7**	11·0	12·9	13·9	6·1
May 1, ,,	13·7	15·8	16·8	**17·0**	16·5	15·8	15·3	15·0	15·0	14·6	14·4	14·0	14·0	14·0	14·1	14·4	14·6	14·4	14·7	14·1	13·7	12·5	**12·0**	12·5	13·8	14·5	5·0
,, 15, ,,	14·2	15·9	**17·4**	17·1	16·2	15·3	15·2	15·1	14·9	15·2	15·2	14·9	14·7	15·0	14·7	15·0	15·2	15·1	15·1	14·9	14·7	13·7	13·1	**12·6**	13·5	15·0	4·8
June 1, ,,	14·9	16·3	16·3	**16·8**	16·0	15·6	15·7	15·0	**13·9**	14·7	**13·9**	**13·9**	14·0	14·7	14·7	14·7	14·8	15·0	14·8	15·1	14·9	14·8	14·6	14·5	14·9	15·0	2·9
,, 15, ,,	14·9	15·6	16·6	**16·7**	16·3	14·9	14·6	14·4	14·4	14·2	14·0	13·8	13·7	14·4	14·5	14·5	14·6	14·5	14·5	14·2	14·4	14·2	13·8	**13·6**	14·6	14·6	3·1
July 1, ,,	14·4	15·1	**16·3**	**16·3**	15·5	14·4	14·3	14·3	14·2	14·4	14·5	14·3	14·3	14·5	14·9	14·4	14·5	14·6	14·6	14·6	14·6	14·2	13·3	**12·9**	13·3	14·5	3·4
,, 15, ,,	**13·6**	14·4	15·7	16·5	**16·7**	15·4	15·0	15·1	14·9	14·7	14·7	14·7	14·8	15·0	15·1	15·2	15·4	15·3	15·3	15·3	15·3	15·1	14·9	14·3	15·1	15·1	3·1
August 1, ,,	14·7	15·9	17·1	**17·7**	17·4	16·1	15·3	15·3	15·3	15·2	15·1	15·1	15·3	15·3	15·4	15·4	15·4	15·4	15·3	15·2	15·1	14·7	13·7	**13·4**	15·0	15·4	4·3
,, 15, ,,	14·4	15·3	16·2	17·0	**17·3**	17·0	16·4	16·2	16·1	16·0	15·9	15·7	15·8	15·8	15·7	15·7	16·0	16·0	15·9	15·9	15·9	15·5	(15·1)	**14·3**	14·8	15·9	3·0
September 1, ,,	15·1	17·0	17·3	17·7	**17·8**	16·4	17·7	17·2	16·4	16·3	16·1	15·9	16·1	16·1	16·3	16·4	16·1	16·4	16·3	16·1	15·0	13·7	**13·5**	14·3	16·3	16·2	4·3
,, 15, ,,	(14·9)	17·9	**19·2**	18·6	17·8	16·7	16·4	16·6	16·6	16·4	16·6	16·5	16·4	16·4	16·4	16·4	16·6	16·3	16·3	15·7	14·6	14·0	—	—	—	—	—
October 1, ,,	(18·9)	20·6	**21·1**	20·5	19·2	17·9	17·5	17·3	16·5	16·6	16·4	15·8	16·2	16·4	16·4	16·6	16·6	16·6	16·4	15·7	15·1	**14·7**	15·3	17·0	19·3	17·1	6·4
,, 15, ,,	16·1	17·9	**19·5**	18·8	17·6	16·3	15·6	15·4	15·7	15·3	15·1	14·2	15·4	15·3	15·4	15·3	15·3	15·3	14·8	14·3	13·1	**12·0**	12·1	14·4	17·5	15·5	7·5
November 1, ,,	16·6	17·7	18·7	**18·9**	18·1	17·3	16·3	15·5	15·4	15·0	14·5	14·0	14·8	15·1	15·0	15·0	15·0	14·8	14·0	12·4	11·2	**10·9**	12·0	14·0	—	15·1	8·0
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
December 1, ,,	16·5	17·9	19·5	**20·6**	20·1	19·0	17·9	16·5	16·3	16·1	16·0	15·5	14·7	14·0	14·3	15·2	14·4	14·7	13·5	12·1	11·2	**11·0**	12·2	14·7	17·4	15·6	9·6
,, 15, ,,	17·9	20·9	22·4	**22·5**	21·5	19·6	17·7	16·0	15·8	16·1	15·6	15·6	16·1	16·1	15·9	16·0	15·8	15·3	14·2	13·0	12·2	**11·4**	13·3	15·6	19·5	16·6	11·1
January 1, 1903	19·1	21·5	23·0	**23·1**	21·7	20·3	19·0	18·1	17·0	16·7	16·7	16·7	16·4	16·6	16·8	16·8	16·8	15·6	14·9	13·5	11·3	**10·0**	10·1	13·7	17·5	16·9	13·1
,, 15, ,,	16·5	17·3	18·5	**19·2**	18·6	18·0	17·7	17·1	17·0	15·9	16·6	(16·7)	17·2	16·5	16·8	16·5	17·0	17·2	16·7	15·4	13·5	**12·7**	(14·0)	15·7	17·7	16·6	6·5
February 1, ,,	15·3	18·0	19·9	**21·1**	20·4	19·4	18·3	16·6	16·1	16·5	16·6	16·6	16·5	16·6	16·6	16·6	16·5	16·5	16·3	14·9	13·1	**12·3**	13·1	15·0	16·6	16·6	8·3
,, 15, ,,	17·6	19·8	22·0	**22·2**	21·4	(20·1)	18·7	18·3	17·9	17·5	17·0	15·2	16·0	16·2	16·5	18·7	17·8	19·5	16·7	14·7	13·0	**11·5**	12·5	14·7	16·8	17·3	10·7

Figures in brackets are derived from the nearest readings, usually on both sides of the hour, readings at the exact hour being missing.

CHRISTCHURCH (NEW ZEALAND)—HORIZONTAL FORCE.

H = ·22 . . . C.G.S.

Date.	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Range from hourly readings. Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,,	672	675	688	698	707	709	710	712	**713**	712	709	707	707	708	706	707	704	705	706	701	693	679	670	**668**	671	699	45
,, 15, ,,	**676**	678	686	699	712	718	717	718	712	708	708	714	712	712	713	712	714	714	716	**719**	712	702	694	(690)	693	707	43
April 1, ,,	678	684	694	702	700	**703**	698	695	686	690	683	683	704	695	691	694	696	698	699	697	693	686	676	**670**	675	691	33
,, 15, ,,	684	685	689	694	694	689	694	695	696	695	695	697	695	696	697	698	698	699	**700**	698	698	694	688	684	**679**	694	21
May 1, ,,	697	692	692	695	701	708	**710**	**710**	**710**	707	705	706	705	705	706	704	704	704	706	709	709	706	699	691	**683**	703	27
,, 15, ,,	690	**685**	691	(693)	698	704	705	704	704	706	705	706	706	706	706	706	706	705	706	707	**708**	705	702	700	695	702	23
June 1, ,,	693	**683**	685	688	689	698	697	693	691	688	694	693	694	698	699	(702)	702	701	702	701	703	703	**704**	700	697	696	21
,, 15, ,,	694	**689**	**689**	691	698	702	702	704	703	703	703	705	703	708	702	701	701	706	704	708	708	**709**	708	706	701	702	20
July 1, ,,	697	698	692	**691**	696	705	704	701	703	703	701	701	701	703	708	705	705	706	708	709	710	**713**	708	702	694	703	22
,, 15, ,,	697	**693**	697	699	704	711	711	711	709	711	706	707	706	705	705	704	705	708	708	708	711	**716**	**716**	705	694	706	23
August 1, ,,	679	677	677	677	681	685	686	686	685	685	684	682	683	684	684	684	685	**687**	686	686	686	**687**	685	677	**672**	683	15
,, 15, ,,	697	692	**689**	**689**	693	697	697	696	695	697	696	697	698	697	697	697	697	697	698	698	699	702	**(705)**	704	697	697	16
September 1, ,,	680	676	681	688	689	687	690	690	689	692	691	692	694	693	694	694	695	698	699	**701**	699	693	683	671	**670**	690	31
,, 15, ,,	**(674)**	679	690	691	**700**	**700**	695	691	691	691	691	692	693	693	695	696	695	696	697	698	695	689	—	—	—	—	26
October 1, ,,	(675)	674	681	682	686	684	682	682	682	684	683	685	687	686	685	686	686	**689**	**689**	**689**	684	675	**667**	672	679	682	22
,, 15, ,,	672	676	687	**694**	691	688	685	683	681	682	678	676	682	682	682	682	682	682	683	681	676	668	659	**656**	661	679	38
November 1, ,,	**625**	641	646	651	660	666	671	665	667	666	664	660	665	665	665	668	668	669	**671**	670	664	653	645	645	—	660	46
,, 15, ,,	**648**	665	674	683	**695**	688	683	673	676	678	680	676	681	678	684	679	678	683	687	689	687	669	656	656	660	677	47
December 1, ,,	**641**	648	664	675	**682**	**682**	674	672	673	673	673	680	676	673	668	673	670	676	**682**	679	668	660	654	650	658	670	41
,, 15, ,,	647	654	663	671	**676**	675	672	666	666	667	668	669	668	666	668	667	668	672	671	663	653	641	**634**	638	645	663	42
January 1, 1903	**647**	654	668	692	**697**	693	691	681	680	684	684	683	684	684	685	686	688	687	692	694	693	679	658	648	648	681	50
,, 15, ,,	673	688	688	687	690	692	**695**	694	688	687	688	(688)	687	691	690	691	687	691	692	689	679	666	(657)	**652**	659	684	43
February 1, ,,	**666**	668	675	688	695	**697**	**697**	695	693	693	693	693	692	693	691	693	693	692	696	693	684	675	670	674	673	688	31
,, 15, ,,	649	659	662	671	679	(685)	**686**	682	683	681	680	674	674	673	675	680	677	675	673	671	662	650	640	640	**638**	670	48

Figures in brackets are derived from the nearest readings, usually on both sides of the hour, readings at the exact hour being missing.

CHRISTCHURCH (NEW ZEALAND)—VERTICAL FORCE.

Date.		V = ·55 . . . C.G.S.																								Range from hourly readings.
	Midt. 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midt.	Daily mean.	Unit 1γ.
January 1, 1902	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
February 1, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
,, 15, ,,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
March 1, ,,	289	**290**	*d* 287	289	*d* 284	283	282	285	284	285	288	288	*d* 280	*d* **272**	**272**	**272**	*d* 276	276	275	275	276	276	277	276	277	280	18
,, 15, ,,	**287**	289	289	287	287	*d* 291	291	*d* 295	296	**297**	296	296	296	295	294	293	293	292	292	293	293	293	294	(291)	292	293	10
April 1, ,,	**259**	258	258	258	*d* **254**	**254**	**254**	**254**	256	257	256	258	**259**	257	257	257	256	256	256	256	256	256	256	256	256	256	5
,, 15, ,,	263	263	**264**	263	**264**	*d* **261**	262	262	262	**264**	263	263	**264**	**264**	**261**	**264**	**264**	263	**261**	**261**	262	263	263	263	263	263	3
May 1, ,,	**269**	**269**	272	272	272	270	270	270	270	**269**	270	270	270	271	273	273	273	**275**	273	273	272	273	273	273	274	272	6
,, 15, ,,	286	284	286	286	**287**	286	286	285	285	285	286	286	285	285	285	285	285	284	285	285	285	286	286	*d* **281**	**281**	285	6
June 1, ,,	290	291	291	293	293	**294**	293	293	291	292	292	293	293	291	289	(293)	**294**	293	292	*d* 288	287	**286**	**286**	**286**	288	291	8
,, 15, ,,	287	287	287	288	287	*d* 292	292	290	290	290	290	290	289	289	*d* **293**	**293**	**293**	292	292	292	292	290	290	*d* **283**	285	290	10
July 1, ,,	291	291	291	**292**	290	291	**292**	291	291	291	290	290	**292**	**292**	289	289	290	289	*d* **284**	285	285	**284**	285	285	284	289	8
,, 15, ,,	280	281	282	282	**284**	282	282	280	279	278	278	277	278	279	279	279	278	278	279	279	277	**276**	277	277	279	279	8
August 1, ,,	277	278	279	280	**281**	**281**	**281**	280	279	279	278	278	279	279	278	280	280	280	279	279	278	278	277	**275**	276	279	6
,, 15, ,,	272	273	274	274	275	*d* **278**	**278**	277	277	275	275	274	274	274	275	274	275	275	275	274	274	272	(273)	*d* **269**	**269**	274	9
September 1, ,,	**260**	263	263	264	265	265	**266**	**266**	**266**	265	265	265	263	263	262	263	263	265	265	265	264	263	261	263	263	264	6
,, 15, ,,	(**299**)	*d* 294	294	295	295	296	297	297	296	295	295	294	295	**293**	294	295	296	296	297	296	296	296	—	—	—	—	6
October 1, ,,	(**270**)	271	274	276	277	*d* 280	**282**	**282**	**282**	280	279	278	278	278	280	280	280	280	280	281	280	280	280	278	276	279	12
,, 15, ,,	296	**295**	**295**	297	298	300	301	302	301	302	301	301	301	300	301	302	302	302	**303**	**303**	301	302	300	299	299	300	8
November 1, ,,	287	287	287	289	289	288	289	289	289	**291**	290	290	289	289	*d* 286	**285**	286	286	287	288	288	288	(287)	(287)	—	288	6
,, 15, ,,	255	255	255	**252**	255	257	**260**	**260**	259	259	258	257	257	257	256	256	257	257	256	257	257	258	257	253	**252**	257	8
December 1, ,,	**242**	**242**	243	245	245	246	246	247	247	246	247	246	245	245	248	247	248	248	249	250	**252**	251	250	250	248	247	10
,, 15, ,,	**244**	**244**	245	(247)	(248)	249	250	250	250	**252**	251	250	250	250	250	250	250	251	251	**252**	**252**	**252**	**252**	248	247	250	8
January 1, 1903	270	268	267	269	269	272	275	275	276	275	276	**277**	276	276	274	274	274	272	272	272	272	273	*d* 268	267	**266**	272	11
,, 15, ,,	295	294	**292**	293	294	294	296	296	296	295	296	(295)	294	293	**292**	**292**	**292**	**292**	293	295	296	**297**	(**297**)	296	296	294	5
February 1, ,,	295	**293**	295	295	295	295	296	**297**	**297**	296	**297**	296	296	295	295	295	295	295	**293**	294	**293**	294	294	294	294	295	4
,, 15, ,,	285	284	284	285	285	(286)	287	287	**288**	**288**	**288**	**288**	**288**	**288**	287	287	284	284	**283**	284	284	285	286	287	287	286	5

Figures in brackets are derived from the nearest readings, usually on both sides of the hour, readings at the exact hour being missing.
d denotes that a discontinuity has presented itself in the trace since the last hourly reading.

IV. MAGNETIC OBSERVATIONS OF THE "SCOTIA," 1902-1904.

CONTENTS.

Introductory Remarks.

An account of the site where the magnetic observations were taken, and various historical details, will be found in the following notes by the observer, Mr. R. C. Mossman, F.R.S.E.

Accompanying the note is a Map of Laurie Island, showing the position of the magnetic hut (Copeland Observatory), also two Plates, of which Plate 20 shows the position of the hut in relation to the central cairn and house; Plate 21, fig. 1, shows the taking of preliminary observations on the site of the future hut, and, fig. 2, plan showing the positions of the magnetic instruments inside the hut when in use.

The instruments were compared with the standard instruments at Kew before the expedition set sail, and gave satisfactory results.

C. C.

NOTES ON THE MAGNETIC WORK OF THE EXPEDITION.

BY

R. C. MOSSMAN, F.R.S.E.

The Scottish National Antarctic Expedition was equipped with the primary object of engaging in Hydrographical, Biological and Meteorological investigation in the Antarctic area known as the Weddell Sea. The expedition was not fitted out to prosecute magnetic work, but oceanographical research on the lines of the "Challenger," "Valdivia" and other deep-sea expeditions, which work was to be carried on in high southern latitudes within the limits of floating ice. The ship was in no way suited for the taking of magnetic observations at sea, there being no specially constructed non-magnetic area, as in the case of the "Gauss" and the "Discovery." Besides this, the heavy trawling and other gear made it almost impossible that this should be the case. Further, it was foreseen at the outset that even if it had been possible to have a non-magnetic area, to carry on deep-sea work and magnetism was incompatible. Our magnetic equipment was accordingly restricted to a portable Magnetometer of the Kew pattern, made by the Cambridge Scientific Instrument Company, and a Barrow Dip Circle No. 24, kindly lent by the National Physical Laboratory. This circle was fitted with Lloyd needles for the taking of the Total Force, but at a very early stage the axle of the Statical needle was injured, putting a stop to further observations. No Variometers or systems of self-recording instruments were taken, as it was thought very unlikely that suitable winter quarters would be found in the far south. In July, 1902 (not having had any previous training in magnetic observations), I attended the usual three weeks' course of instruction at Kew Observatory, and in September, through the kindness of the late Professor COPELAND, Astronomer Royal for Scotland, engaged in a few days' practice at the Royal Observatory, Edinburgh.

At Port Stanley, Falkland Islands, enough wood and copper nails were taken for the construction of a small hut, in the event of a wintering station being established. The "Scotia" left Port Stanley on January 26, 1903, and after a cruise of 5364 miles, of which 4400 were in entirely unexplored seas, anchored in Scotia Bay, Laurie Island, South Orkneys, on March 25.

Immediately after our arrival a site was picked out for a house, meteorological station and the magnetic hut. The position selected was on a narrow beach, about 300 yards across, that here divides the north from the south side of the island, the distance from the ship being about 500 yards. On the 30th a temporary tent was rigged up for the taking of some preliminary magnetic observations, and on this site the hut was erected, and was named Copeland Observatory. The dimensions of the hut were 7 feet long and 5 feet broad, while the height of the roof varied from 6 feet 6 inches to 7 feet. It was entirely covered with canvas and painted, and was supported for half its height by a wall composed of stones without mortar. The door was situated on the north side, and there were two windows, one towards the east, the other, for viewing the distant mark, facing south. These windows were protected by sliding shutters on the outside.

The "distant mark," to which the declination observations were referred, was situated 300 yards south of the hut, and was a portion of the rocky face at the base of "Church Hill." It was painted red, with a white bull's-eye, but owing to the frequency with which it became snowed up, and the labour involved in digging it out, a stout post, about 8 feet high, was firmly fixed in position and used during the greater part of the winter. In order to guard against the possibility of this post shifting, an occasional check observation was taken on a fine day, outside the hut, the equivalent of a mark being obtained by observing a sun transit.

There was no concrete pillar for the instruments, which were placed on a brass triangle supported by a wooden tripod. Owing to the small size of the hut, it was necessary to change the position of the tripod so as to be able to make the various observations. Thus there was one position for the dip, another for the deflection series, and a third for the vibration and declination. The legs of the tripod, in the case of the dip observations, fitted into wooden **V**'s screwed into the floor of the hut. In the other observations two of the three legs were kept in position by **V**'s, while the place for the third, which rested against the side of the hut, was indicated by an arrow marked immediately in front of it (see Plate 21, fig. 2). In the declination observations the same leg of the tripod always pointed to the south. In the dip series the bar magnets were placed on the snow about 30 feet north of the hut. As far as possible all knives, keys, and other articles liable to invalidate the observations were removed from the hut. The chronometer, by HUGHES, was always kept in the hut, and its rate, which was remarkably steady, was checked as often as possible by the method of "equal altitudes." The structure was heated by a small copper lamp, which was, however, not very effective, the temperature in winter rarely rising to zero Centigrade. In the taking of the observations the lamp was usually lit from one to two hours before the series were commenced, and the magnets, dip needles and chronometer freely exposed, so that they might have time to get into thermic equilibrium with their surroundings before beginning the observations. During the first month or two little was done, the observations being prosecuted under many difficulties. A good deal of trouble was occasioned by the absence of a slow-motion screw in the vibration magnet, so that it was a troublesome matter to set the axis horizontal. In the preliminary adjustments the screws for clamping the magnet in its stirrup got overwound, and for some time the magnet had to be balanced in its stirrup at practically every observation, while a further source of annoyance was due to the frequent breaking of the torsion thread. Another disturbing effect was due to the unfavourable climatic conditions. On several occasions, for example after a silver thaw, *i.e.*, rain falling with a temperature below the freezing-point and congealing as it fell, it would take over an hour to get into the hut, which would be plastered on the weather side with solid ice over an inch thick. This had to be carefully cut away from the door and windows, so as to avoid injuring the woodwork. Inside the hut further difficulties had to be overcome. The instrument would often be found encrusted with ice spicules requiring thawing out. This effected, and everything in working order, the rattling of torrents of drift on the roof and sides was at times so great that the beats of the chronometer about two feet off could not be heard, thus making the time of vibration unsatisfactory, while in the deflection series the mirrors would become covered with ice resulting from the freezing of the moisture generated by the observer's breath. Frequently from one of these causes the first or second portion of the observations could not be completed.

During the winter Dr. W. S. Bruce, leader of the expedition, gave me every opportunity for the prosecution of magnetic work, and that more was not effected was largely due to the causes already referred to. In September, October and November sledge parties were in the field, and a good deal of my time was occupied in the routine associated with the taking of the hourly meteorological observations, which precluded any systematic series of magnetic measurements. On November 27, immediately after the break-up of the ice, the "Scotia" left for Buenos Aires to refit, leaving a party of six to continue the work during the summer. The summer party were accommodated in a stone house, situated 140 yards west of the observatory, so that it was now possible, owing to its proximity and to the better weather, to make a more extended series of observations, which include hourly readings of declination on 20 days. In taking this set, I was ably assisted by Mr. William Martin, General Scientific Assistant. On the return of the "Scotia," on February 14, the station was taken over by the Argentine Meteorological Office, and the meteorological and magnetic observations were carried on under my direction till the end of 1904, the work being still continued under the auspices of the Argentine Government.

The South Orkneys are a small group of islands situated between 60° and 61° S., and 44° and 47° W., about 700 miles S.E. by E. of the Falkland Islands, and about 250 miles E. of the nearest islands of the South Shetlands. The group consists of two large islands—Coronation and Laurie Island—and numerous smaller ones. The two large islands are separated from one another by two small islands and Washington and Leethwaite Straits. Laurie Island, although its greatest length is in an E.N.E. and W.S.W. direction, consists of numerous peninsulas and steep and lofty mountain ranges running in a general N.W. and S.E. direction. The length of this island is about 12 miles, its maximum breadth 6 miles, and its area fully 30 square miles. Coronation Island is 35 miles long, but as no detailed survey has been made, particulars regarding its area cannot be given. The central cairn is approximately in latitude 60° 43′ 42″ S. and longitude 44° 38′ 33″ W., this cairn being 79 feet west of Copeland Observatory.

The islands, it may be said, are largely composed of fine-grained greywacke of a bluish or greenish colour. Varieties of the greywacke are found, such as conglomerates, slate, and patches showing gneissic banding and folding. In one situation regular beds of shale were found alternating with layers of greywacke. The islands are thus composed of sedimentary rocks, and nothing was found to produce local disturbances in the magnetic elements through the presence of iron or other minerals.* It may be remarked that the islands rise very suddenly out of deep water of about 2000 fathoms, and that the bathymetric gradient is steeper on the north than on the south side of the islands. (See W. S. Bruce "Bathymetrical Survey of South Atlantic Ocean and Weddell Sea," 'Scot. Geog. Mag.,' August, 1905.)

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* See "On the Graptolite-bearing Rocks of the South Orkneys," by J. H. Harvey Pirie, B.Sc., 'Proc. Roy. Soc., Edin.,' vol. xxv., pp. 463–470.

DISCUSSION OF THE MAGNETIC OBSERVATIONS.

BY

DR. C. CHREE, F.R.S.

§ 1. The observations taken by Mr. MOSSMAN in Laurie Island, South Orkneys, were reduced by the staff of the Observatory Department of the National Physical Laboratory. They consisted of absolute observations of declination, inclination, and horizontal force, made between May, 1903, and February, 1904, and of hourly readings of declination during ten days in December, 1903, and ten days in January, 1904.

§ 2. *Declination.*—The observations were taken with a Unifilar Magnetometer No. 2, by the Cambridge Instrument Company, the absolute observations being always made with the scale both erect and inverted. The readings were referred to a distant mark, described in Mr. MOSSMAN'S notes, whose azimuth relative to the geographical meridian was determined by a number of sun transit observations. The sun observations were reduced at the Argentine Magnetic Observatory at Pilar, the mean value obtained for the azimuth of the mark from ten observations being 9° 15′ west of north. The conditions under which the sun observations were taken were not very favourable, and individual determinations of the azimuth of the mark differed by a few minutes of arc; the mean result, however, should not possess a large probable error.

Table I. gives the date and the mean (local) time of the individual observations, as well as the resulting values of the declination. The observations on June 15, and July 2, 3 and 12, appear abnormal, and have been omitted in forming the monthly means. No attempt has been made to allow for the diurnal variation. The observations were made, with few exceptions, between 11 a.m. and 7 p.m., and, as we shall see later, easterly declination was above the mean during this portion of the day, at least near midsummer. Thus the correction to the mean value for the 24 hours would almost certainly cause a reduction of the figures in Table I. in the great majority of cases. The diurnal range, however, as we shall see later, is not large even at midsummer, when it is usually about its maximum, and the corrections that remain to be applied to the monthly means in Table I. would probably, in most cases, not exceed 2 or 3 minutes of arc. The absolute observations themselves would suffice to show that the range of declination is not large, for, excluding the four observations already mentioned as doubtful, we have for the largest and smallest of 40 observed declinations 5° 35′·6 and 5° 24′·4 respectively, the difference being only 11′·2.

If we assign to May 31 the mean 5° 33′·6 of the monthly means for May and June, and to January 31 the mean 5° 29′·0 of the monthly means for January and February, we obtain a decrease of 4′·6 in eight months, *i.e.*, of 6′·9 in the year. There may, however, be a considerable annual period (*i.e.*, a regular change whose period is 1 year), and there are other sources of uncertainty, so that much weight cannot be assigned to this estimate of the rate of secular change.

§ 3. *Inclination.*—The observations of inclination were made with the Barrow Circle No. 24, having two needles, Nos. 1 and 2. On most occasions observations were made with both needles. The results from the two needles did not differ much, but on the average the inclination obtained with No. 2 exceeded that obtained with No. 1 by 0′·53. On the few occasions when observations were made with No. 1 only, an imaginary mean for the two needles has been obtained by adding 0′·3 to the result obtained.

Table II. gives full particulars of the individual observations. The monthly means and the mean for the whole series are based on the mean results for the two needles. The mean values obtained for July and August are lower than those for either the earlier or the later months, and no deduction seems possible as to either the secular change or the diurnal variation.

The difference 9′·7 between the extreme values 54° 35′·3 and 54° 25′·6 is, relatively considered, very considerably larger than the corresponding difference in the case of the declination.

§ 4. *Horizontal Force.*—Table III. gives particulars of the observations of horizontal force H. On some occasions the interval elapsing between the vibration and deflection experiments was a little long. In reducing the observations, a mean value was applied for P in the formula $2mr^{-3}(1+Pr^{-2}...)$, expressing the deflecting force at distance r due to a magnet of moment m. In calculating this mean value, the observations of June 3, 9 and 15, July 4 and 22, and December 17, 1903, and that of January 26, 1904, were omitted, as the differences between the results from the two deflection distances (30 and 40 centims.) on these occasions were clearly abnormal. The table gives the values of H for each observation and the mean derived from the observations in each month; it also gives the values deduced from the individual observations for the magnetic moment, m, of the collimator magnet at 0° C. The small variability in the values deduced for m is a marked tribute to the care with which the observations were taken. Another gratifying feature is the constancy of m from beginning to end of the observations. Though in regular use for eight months, the magnet shows no certain loss of magnetic moment.

The observations were taken at somewhat variable hours. Afternoon hours prevailed, but the mean hour of observation would vary considerably for the different months. No direct observations were made of the diurnal change of horizontal force, and an attempt to get a general idea of its character by grouping the data according to the hour of observation led to results which were too irregular to inspire confidence. If the diurnal variation had been large, the method adopted could hardly have failed to indicate it clearly. The fact that the variations, whether regular or irregular, were not very large is fairly obvious from the observations themselves. If we omit the observation of June 3, which presented some abnormal features, individual values of H varied only from 0·25655 to 0·25754. A range of 99γ from 36 observations is not compatible with numerous large disturbances. We may conclude that whilst appreciable corrections, differing slightly from month to month, are probably required to reduce the monthly means in Table III. to the mean value for the 24 hours, the uncertainties are still comparatively small. The monthly means suggest, on the whole, that the horizontal force is decreasing, but no great weight attaches to this conclusion.

§ 5. *Diurnal Variation of Declination.*—Hourly readings were taken of the collimator magnet of the Unifilar Magnetometer, with scale erect, throughout four periods each of five days. The periods commenced and ended with midnight, their dates being December, 1903, 6 to 10 and 21 to 25, and January, 1904, 4 to 8 and 19 to 23. Throughout each period the setting of the azimuth circle remained unaltered, the observer simply noting the scale division of the magnet. Table IV. gives the hourly readings as recorded in scale divisions, 1 scale division representing an angle of 1′·80. The table also shows the ranges for each day, uncorrected for non-cyclic change, both in scale divisions and in minutes of arc, and, finally, the hours of occurrence of the principal maximum and minimum. There is one feature in Table IV. that will appeal to everyone familiar with magnetic data, and that is the remarkable absence of disturbance. During the whole twenty days the daily range did not fall below 5′·9 nor rise above 11′·3, the arithmetic mean derived from all the days being 8′·7, and this mean value being exceeded on nine of the twenty days. The hour of the principal maximum occurred once at noon and four times at 1 p.m.; on the other fifteen days it occurred either at 2 p.m. or 3 p.m. The hour of minimum was more variable, this turning point being seldom very clearly marked.

§ 6. Table V. shows the mean diurnal inequality derived from each five-day period, the results being uncorrected for non-cyclic change, and also the mean diurnal inequalities corrected for non-cyclic change for the ten December, the ten January, and the whole twenty days. The results are all in minutes of arc. The ranges and the hours of occurrence of the principal maximum and minimum are also recorded. The inequality for the whole twenty days was derived independently of those for the two ten-day periods, and the non-cyclic corrections to the three sets of figures were also applied independently. As the reductions were not carried beyond 0′·01, there is naturally at some hours a difference between the twenty-day inequality and the arithmetic mean of the ten-day inequalities in the last figure retained.

The diurnal inequality for the whole twenty days is shown graphically in fig. 1, p. 187. For a curve based on only twenty days' observations it is, on the whole, extremely regular. There is clearly a little irregularity between 4 a.m. and 9 a.m. This arises from the variability in the hour of the minimum, which leads to the curve being abnormally flat. There is a nearly stationary part of the curve from 8 p.m. to 11 p.m., and possibly observations for individual months derived from a series of years might show a poorly developed secondary maximum and minimum, an hour or two apart, in the late evening.

§ 7. The "midsummer" diurnal inequality in Table V. was analysed in a Fourier series, the formula obtained being

$$2'\cdot 71 \sin (t+213^\circ\cdot 3)+1'\cdot 51 \sin (2t+45^\circ\cdot 1)+0'\cdot 55 \sin (3t+183^\circ\cdot 8)+0'\cdot 30 \sin (4t+4^\circ\cdot 0).$$

Here t denotes time counted from local midnight, an hour being taken as equivalent to 15°.

The corresponding formula for summer (May to August) at Kew (lat. 51° 28′ N.) from an eleven-year period for *quiet* days was

$$3'\cdot 19 \sin (t+214^\circ\cdot 8)+2'\cdot 50 \sin (2t+52^\circ\cdot 4)+1'\cdot 01 \sin (3t+241^\circ\cdot 4)+0'\cdot 12 \sin (4t+39^\circ\cdot 9).$$

The phase angles in the two cases differ but little, except in the case of the eight-hour term, and even there the difference represents less than one and one-third hours of time. The twelve-hour and eight-hour terms are less important relatively to the twenty-four hour term at Laurie Island than at Kew. Absolutely considered, the twenty-four, twelve and eight-hour terms are all smaller than at Kew.

§ 8. In considering the absolute size of the diurnal changes, it is fairer to compare Laurie Island with some northern station nearer its own latitude. Pawlowsk (59° 41′ N. lat.) seems the most suitable. Taking arithmetic means from the "all" day results for June and July, 1903, at Pawlowsk, we have the following comparative data for midsummer:—

	Range from mean diurnal inequality.	Mean of daily ranges *from hourly readings.*
	′	′
Laurie Island	7·40	8·65
Pawlowsk	10·98	12·21

According to these figures Pawlowsk has a regular diurnal inequality range 48 per cent. larger than that at Laurie Island, and individual daily ranges (from hourly readings) at the former station are on the average 41 per cent. larger than at the latter. The magnetic force, however, to which diurnal changes may be ascribed would seem to be fairly similar at the two places. The force required to cause a declination movement of 1′ varies directly as the intensity of the horizontal force at the station, and the horizontal force at Laurie Island is about 55 per cent. larger than that at Pawlowsk.

§ 9. On the days preceding and succeeding each of the five-day periods, observations were taken of the bearing of the distant mark, and also of the circle reading, when the centre or some definite division of the magnet scale coincided with the vertical wire in the telescope. Assuming the mean from the two readings of the mark—allowance being made for its known azimuth—to represent the bearing of true north during the five-day period, and allowing for the difference between the centre (or other definite division) of the scale and the mean scale reading derived from all the hourly observations of the period, one obtains what would be the mean value of the declination for the period if there were no difference between the readings of the magnet with scale erect and inverted. Allowing suitably for the difference between the erect and inverted readings, one obtains the true declination, the diurnal variation being eliminated. The values thus obtained for the declination during the four five-day periods were as follows:—

Period.	Declination East.
	° ′
December 6 to 10, 1903	5 27·7
" 21 " 25, 1903	5 26·9
January 4 " 8, 1904	5 26·5
" 19 " 23, 1904	5 25·1

The mean of the four, viz., 5° 26′·6, may be accepted as a close approximation to the true value of the declination at Laurie Island for the epoch January 1, 1904, always assuming that the value accepted for the azimuth of the distant mark was satisfactory.

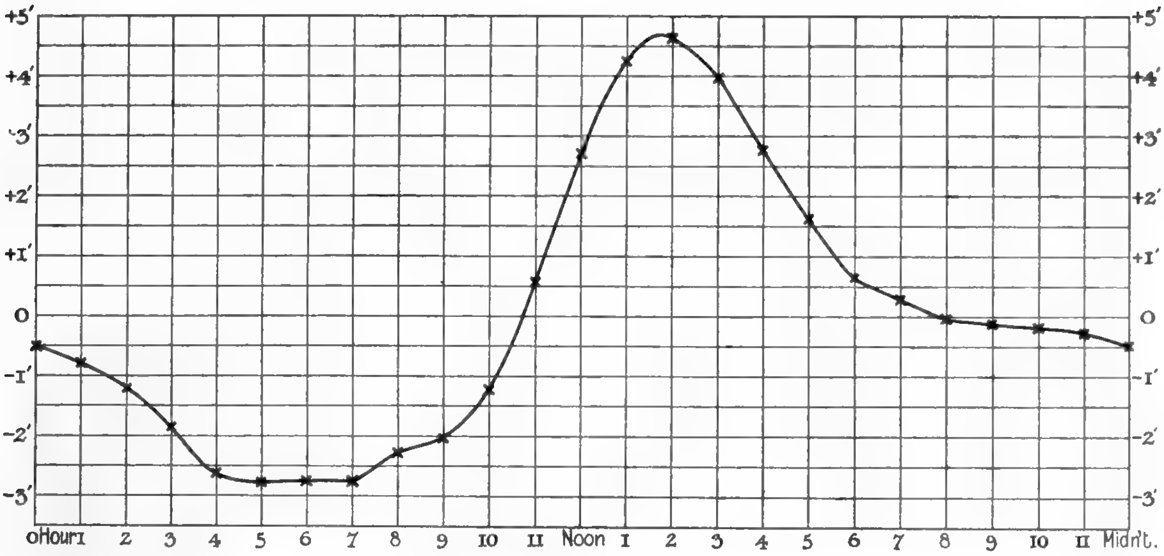

Fig. 1. Easterly declination, midsummer, at Laurie Island.—Diurnal inequality.

TABLE I.—Declination.

Date.	Hour.	Declination East.
1903	h. m.	° ′
May 23	3 12 p.m.	5 27·6
„ 28	3 14 „	5 34·1
„ 29	1 51 „	5 33·9
„ 29	2 35 „	5 33·1
„ 29	2 59 „	5 33·0
„ 30	10 7 a.m.	5 35·6
	Mean for May	5 32·9
1903	h. m.	° ′
June 4	11 46 a.m.	5 33·9
„ 5	2 27 p.m.	5 34·9
„ 10	12 10 „	5 34·2
(„ 15	2 27 „	5 42·6)
	Mean for June	5 34·3
1903	h. m.	° ′
(July 2	2 15 p.m.	5 13·2)
(„ 3	2 38 „	5 12·7)
(„ 12	2 43 „	5 43·8)
„ 18	11 9 a.m.	5 31·4
„ 22	11 34 „	5 26·3
„ 23	3 9 p.m.	5 31·9
„ 25	2 43 „	5 27·8
„ 26	9 43 a.m.	5 30·4
„ 29	3 18 p.m.	5 33·6
	Mean for July	5 30·2
1903	h. m.	° ′
August 14	3 34 p.m.	5 28·5
„ 18	2 14 „	5 33·2
„ 26	11 52 a.m.	5 35·3
	Mean for August	5 32·3
1903	h. m.	° ′
September 9	5 32 p.m.	5 30·6
„ 10	4 25 „	5 29·2
„ 22	5 14 „	5 32·0
„ 24	3 12 „	5 30·3
	Mean for September	5 30·5
1903	h. m.	° ′
October 31	7 22 p.m.	5 33·1
1903	h. m.	° ′
November 2	4 43 p.m.	5 32·8
„ 11	4 30 „	5 31·0
	Mean for November	5 31·9
1903	h. m.	° ′
December 1	3 51 p.m.	5 30·3
„ 2	5 38 „	5 25·6
„ 4	3 3 „	5 32·0
„ 11	2 40 „	5 29·3
„ 17	12 0 noon	5 30·1
„ 18	5 45 p.m.	5 27·8
„ 20	6 4 „	5 29·8
„ 28	4 24 „	5 27·6
„ 30	11 55 a.m.	5 31·0
	Mean for December	5 29·3
1904	h. m.	° ′
January 3	10 18 a.m.	5 24·4
„ 9	2 25 p.m.	5 33·7
„ 18	3 14 „	5 28·1
„ 25	2 20 „	5 29·0
	Mean for January	5 28·8
1904	h. m.	° ′
February 11	2 35 p.m.	5 29·7
„ 13	11 35 a.m.	5 28·6
	Mean for February	5 29·2
Mean of monthly means		5 31·2

TABLE II.—Inclination (South).

Date.	Mean time.	Needle 1.	Needle 2.	Mean.	Monthly mean.
1903	h. m.	° ′	° ′	° ′	° ′
May 1	3 56 p.m.	54 30·8	—	54 31·1	54 32·1
„ 3	11 18 a.m.	54 34·8	54 31·4	54 33·1	
June 6	2 48 p.m.	54 33·2	—	54 33·5	54 32·9
„ 9	11 29 a.m.	54 36·7	54 33·8	54 35·3	
„ 25	1 48 p.m.	54 28·4	54 31·1	54 29·8	
July 24	1 30 „	54 26·0	54 30·1	54 28·0	54 28·9
„ 28	11 55 a.m.	54 30·6	—	54 30·9	
„ 31	2 48 p.m.	54 27·6	54 27·8	54 27·7	
August 13	2 28 „	54 27·9	54 26·9	54 27·4	54 26·3
„ 14	11 35 a.m.	54 27·0	54 24·9	54 26·0	
„ 20	3 50 p.m.	54 25·3	—	54 25·6	
September 6	3 25 „	54 32·0	54 31·8	—	54 31·9
November 9	5 46 „	54 32·0	54 33·1	54 32·5	54 30·7
„ 17	4 25 „	54 28·6	54 29·5	54 29·0	
December 2	12 7 „	54 28·8	54 32·0	54 30·4	54 31·5
„ 4	5 38 „	54 30·6	54 32·9	54 31·8	
„ 18	3 6 „	54 30·9	54 29·8	54 30·3	
„ 30	5 22 „	54 31·9	54 35·1	54 33·5	
1904					
January 1	2 25 „	54 32·8	54 33·9	54 33·3	54 31·4
„ 13	3 46 „	54 32·1	54 30·3	54 31·2	
„ 26	4 1 „	54 30·0	54 31·5	54 30·7	
„ 29	3 35 „	54 28·9	54 31·6	54 30·3	
February 6	3 58 „	54 30·0	54 29·5	54 29·8	54 29·5
„ 12	11 15 a.m.	54 28·8	54 29·6	54 29·2	
				Mean of monthly means	54 30·6

TABLE III.—Horizontal Force.

Date.	Mean time of Vibration.	Mean time of Deflection.	H.	*m*.	Monthly means, H.
1903	h. m.	h. m.			
May 28	10 36 a.m.	11 46 a.m.	0·25744	772·4	0·25744
June 3	3 34 p.m.	2 12 p.m.	0·25812	771·6	0·25726
„ 4	2 7 „	3 45 „	0·25715	771·5	
„ 5	2 4 „	11 50 a.m.	0·25677	771·3	
„ 9	3 37 „	2 54 p.m.	0·25728	773·3	
„ 12	11 52 a.m.	2 55 „	0·25718	771·3	
„ 15	Not noted	12 11 „	0·25686	772·7	
„ 26	11 41 a.m.	2 23 „	0·25737	772·6	
„ 27	12 0 noon	2 21 „	0·25738	771·8	
July 4	11 55 a.m.	2 50 „	0·25706	771·3	0·25719
„ 22	11 19 „	12 47 „	0·25744	772·6	
„ 26	{ 10 42 „ 11 3 „ }	2 16 „	0·25706	770·8	
August 15	2 35 p.m.	3 24 „	0·25686	771·8	0·25699
„ 17	3 49 „	3 7 „	0·25725	771·8	
„ 18	1 57 „	4 1 „	0·25698	771·0	
„ 19	3 10 „	11 27 a.m.	0·25710	771·9	
„ 26	2 14 „	3 22 p.m.	0·25674	770·8	
September 10	4 17 „	3 38 „	0·25689	771·0	0·25708
„ 12	3 44 „	2 59 „	0·25692	771·4	
„ 24	3 39 „	5 40 „	0·25754	773·3	
„ 24	4 36 „	5 40 „	0·25696	771·6	
November 2	5 46 „	8 13 „	0·25678	771·2	0·25672
„ 11	12 22 „	11 15 a.m.	0·25658	772·4	
„ 19	10 44 a.m.	12 22 p.m.	0·25682	772·4	
„ 30	3 22 p.m.	3 50 „	0·25671	771·5	
December 2	5 20 „	4 12 „	0·25700	771·2	0·25699
„ 4	2 47 „	4 0 „	0·25710	772·0	
„ 17	3 26 „	4 49 „	0·25681	772·0	
„ 18	5 31 „	4 55 „	0·25693	772·0	
„ 30	11 20 a.m.	2 18 „	0·25704	771·9	
1904					
January 1	3 32 p.m.	4 59 „	0·25702	772·0	0·25697
„ 13	10 57 a.m.	12 12 „	0·25691	771·9	
„ 26	1 56 p.m.	12 14 „	0·25738	770·7	
„ 29	10 46 a.m.	12 13 „	0·25655	771·1	
February 6	7 7 p.m.	6 12 „	0·25668	772·0	0·25671
„ 12	3 51 „	3 2 „	0·25673	771·2	
				Mean of monthly means	0·25704

Table IV.—Hourly Readings of Declination (in Scale Divisions).

Day.	Forenoon.													Afternoon.												Range.		Time of maximum hourly reading.	Time of minimum hourly reading.
	Midnight, 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midnight.	Div.	Min.	p.m.	a.m.
1903 December 6 . . .	42·5	41·8	41·1	41·1	41·2	40·8	40·9	40·8	41·0	41·9	42·3	43·8	44·8	45·0	45·0	45·1	44·9	43·8	42·9	42·1	41·2	40·9	41·0	41·6	41·8	4·3	7·7	3	7
,, 7 . . .	41·8	41·7	41·1	40·0	39·6	39·2	38·9	39·0	39·2	40·1	41·1	42·9	43·8	45·2	45·1	44·0	43·4	42·9	42·0	42·3	42·2	42·1	42·0	41·9	41·7	6·3	11·3	1	6
,, 8 . . .	41·7	41·7	40·9	40·6	40·0	39·9	40·4	40·7	41·4	41·5	42·1	42·7	43·4	44·5	45·0	44·8	44·2	43·3	42·5	42·1	41·9	41·9	41·6	41·5	41·2	5·1	9·2	2	5
,, 9 . . .	41·2	41·3	41·1	40·9	40·2	39·8	40·0	40·3	40·9	41·0	41·8	42·3	43·1	43·8	44·1	44·4	43·7	43·0	42·5	42·2	42·1	41·9	41·8	41·9	41·7	4·6	8·3	3	5
,, 10 . . .	41·7	41·3	41·0	40·3	40·1	40·3	40·1	40 0	40·3	40·8	41·1	41·7	42·1	43·3	44·2	44·7	44·1	43·9	43·1	42·5	42·6	42·5	42·3	42·1	41·9	4·7	8·5	3	7
December 21 . . .	40·0	39·8	38·4	38·1	38·4	39·5	39·6	38·8	39·3	40·8	41·5	42·2	42·6	43·0	43·2	43·1	42·7	41·9	41·5	42·1	41·8	41·5	41·4	42·1	41·9	5·1	9·2	2	3
,, 22 . . .	41·9	41·8	41·6	41·1	40·9	40·2	40·4	40·9	41·7	42·3	42·8	43·2	43·9	44·2	45·1	45·2	44·0	43·2	42·5	42·9	42·7	42·7	42·8	42·5	41·8	5·0	9·0	3	5
,, 23 . . .	41·8	41·3	41·5	41·0	40·2	39·8	40·0	40·2	41·4	41·3	42·0	42·2	42·8	43·1	43·6	43·1	43·0	42·5	41·8	42·1	42·0	41·8	42·0	41·9	41·6	3·8	6·8	2	5
,, 24 . . .	41·6	41·7	41·6	41·8	41·0	40·9	40·2	40·1	40·4	41·0	41·6	42·8	43·4	43·9	43·8	43·2	42·8	42·6	42·3	42·3	42·2	42·1	42·0	41·9	41·9	3·8	6·8	1	7
,, 25 . . .	41·9	41·5	41·5	40·7	40·2	40·1	39·8	40·0	40·1	40·6	41·1	41·8	42·6	42·8	43·1	42·6	42·4	42·6	42·2	42·2	41·9	41·4	41·1	41·3	40·7	3·3	5·9	2	6
1904 January 4 . . .	39·8	39·9	39·9	39·5	39·9	39·5	39·2	39·3	40·1	40·3	40·5	41·8	43·3	44·8	44·1	43·8	41·9	40·5	40·1	40·2	40·5	40·1	40·0	40·0	40·0	5·6	10·1	1	6
,, 5 . . .	40·0	40·0	40·1	39·2	38·5	38·4	38·7	39·2	39·8	39·4	40·3	42·9	44·6	44·0	43·7	43·1	41·8	40·7	40·5	40·2	39·5	40·2	40·5	40·2	40·2	6·2	11·2	0	5
,, 6 . . .	40·2	40·1	40·0	39·6	39·0	39·2	39·5	40·0	40·1	40·0	39·8	40·9	42·1	43·6	44·3	43·1	42·0	41·9	41·2	40·5	40·0	40·1	40·0	39·9	40·0	5·3	9·5	2	4
,, 7 . . .	40·0	40·0	40·0	39·9	39·3	39·1	39·1	39·0	39·3	39·3	39·0	40·2	41·9	43·5	43·6	42·8	41·6	41·0	40·9	40·3	40·1	40·1	40·1	39·7	40·1	4·6	8·3	2	7
,, 8 . . .	40·1	40·4	39·9	39·9	39·3	39·3	39·8	39·2	39·0	38·5	38·4	39·3	41·1	42·7	43·0	42·5	41·9	41·3	41·5	41·2	40·8	41·0	40·6	40·8	40·7	4·6	8·3	2	10
January 19 . . .	40·0	39·5	39·6	39·4	39·3	39·0	39·1	39·1	38·6	37·9	38·0	38·9	40·3	41·8	42·0	41·7	41·2	40·6	39·9	39·9	40·0	39·9	40·0	39·8	39·6	4·1	7·4	2	9
,, 20 . . .	39·6	39·5	39·5	39·3	39·2	39·2	38·9	38·3	37·8	37·9	38·7	40·1	42·1	43·1	43·1	43·3	42·5	41·3	40·4	40·2	40·6	40·8	40·7	40·4	40·2	5·5	9·9	3	8
,, 21 . . .	40·2	40·0	39·7	38·9	37·8	38·0	38·0	38·2	38·9	38·9	39·7	40·9	42·9	44·0	43·7	42·8	42·3	42·2	41·5	41·0	41·3	41·0	40·9	40·1	40·4	6·2	11·2	1	4
,, 22 . . .	40·4	40·2	40·5	40·7	39·7	40·3	40·8	40·6	39·9	39·1	39·7	40·2	42·0	42·5	42·9	42·4	42·0	41·5	41·1	40·9	40·8	41·0	41·2	41·0	40·9	3·8	6·8	2	9
,, 23 . . .	40·9	40·7	40·8	40·5	40·1	39·9	39·4	39·1	39·3	38·6	38·8	39·7	41·2	42·2	42·7	42·8	42·4	41·7	40·9	40·2	39·9	40·3	40·3	40·8	40·8	4·2	7·6	3	9

Table V.—Diurnal Inequalities (in Minutes of Arc, + to East).

Period.	Forenoon.													Afternoon.												Range.	Time of maximum hourly reading.	Time of minimum hourly reading.
	Midnight, 0h.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Noon.	1h.	2h.	3h.	4h.	5h.	6h.	7h.	8h.	9h.	10h.	11h.	Midnight.			
	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	′	p.m.	a.m.
Inequality Uncorrected for Non-cyclic Change.																												
December 6 to 10	−0·40	−0·79	−1·73	−2·56	−3·20	−3·60	−3·49	−3·31	−2·59	−1·69	−0·58	+1·22	+2·59	+4·25	+4·82	+4·68	+3·71	+2·48	+1·08	+0·43	0·00	−0·25	−0·47	−0·36	−0·61	8·42	2	5
,, 21 ,, 25	−0·54	−0·94	−1·48	−2·16	−2·88	−2·95	−3·13	−3·13	−2·09	−0·97	+0·11	+1·26	+2·38	+2·99	+3·64	+3·06	+2·23	+1·48	+0·58	+1·04	+0·68	+0·29	+0·22	+0·36	−0·29	6·77	2	6
January 4 ,, 8	−1·06	−0·95	−1·13	−1·78	−2·54	−2·72	−2·43	−2·29	−1·71	−2·00	−1·82	+0·74	+3·58	+5·60	+5·63	+4·41	+2·21	+0·85	+0·41	−0·23	−0·77	−0·56	−0·67	−0·88	−0·74	8·35	2	5
,, 19 ,, 23	−0·36	−0·79	−0·72	−1·19	−2·16	−2·05	−2·12	−2·45	−2·74	−3·49	−2·59	−0·83	+2·30	+4·14	+4·43	+3·92	+2·99	+1·87	+0·61	+0·04	+0·18	+0·32	+0·36	0·00	−0·07	7·92	2	9
Inequality Corrected for Non-cyclic Change.																												
December	—	−0·85	−1·60	−2·35	−3·03	−3·27	−3·31	−3·22	−2·34	−1·33	−0·23	+1·24	+2·49	+3·62	+4·23	+3·87	+2·97	+1·98	+0·83	+0·73	+0·33	+0·01	−0·13	−0·01	−0·46	7·54	2	6
January	—	−0·73	−0·81	−1·38	−2·25	−2·30	−2·20	−2·31	−2·18	−2·70	−2·18	−0·04	+2·94	+4·86	+5·00	+4·12	+2·55	+1·30	+0·44	−0·18	−0·40	−0·23	−0·28	−0·58	−0·56	7·70	2	9
Midsummer . . .	—	−0·79	−1·21	−1·87	−2·65	−2·79	−2·75	−2·75	−2·27	−2·02	−1·21	+0·59	+2·72	+4·25	+4·61	+4·00	+2·77	+1·64	+0·63	+0·29	−0·04	−0·11	−0·20	−0·29	−0·50	7·40	2	5

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HARRISON AND SONS, PRINTERS IN ORDINARY TO HIS MAJESTY, ST. MARTIN'S LANE.

View of Copeland Observatory, Central Cairn, and Omond House, Scotia Bay.

Fig. 1. Taking of preliminary observations on the site of the future observatory on the beach, Scotia Bay.

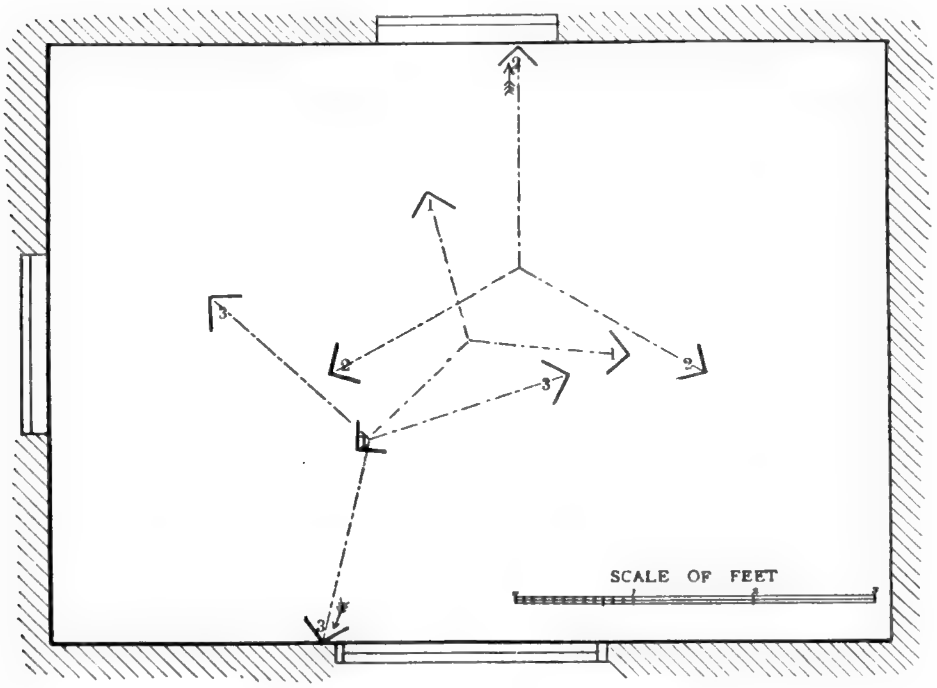
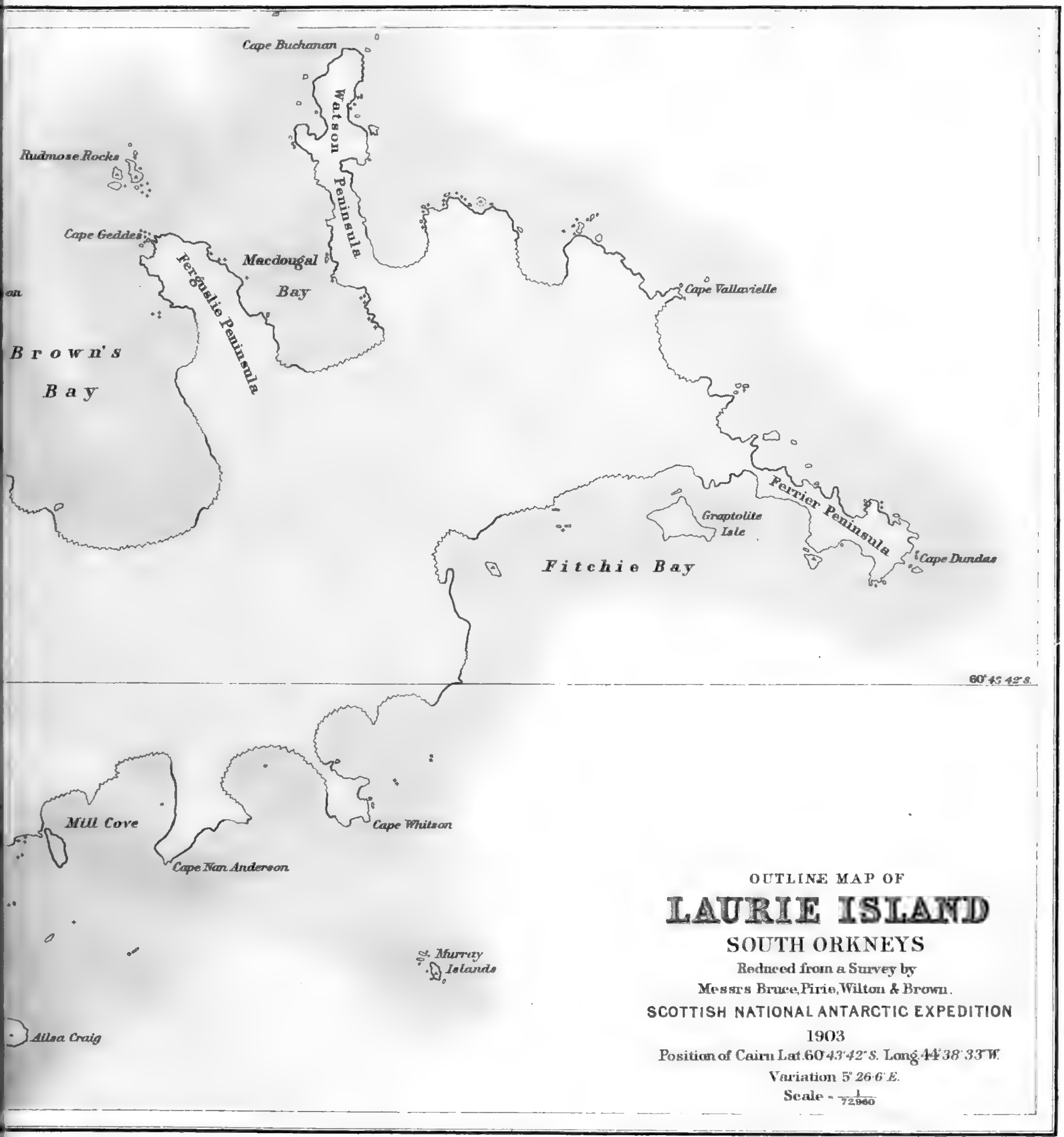


Fig. 2. Plan showing positions of magnetic instruments inside Copeland Observatory when in use.


44°38'33"W
N
Variation 5°26'6" E.
Magnetic
Cape Mabel
Pirie Peninsula
Eillium Isle
Nigg Rock
Jessie Bay
Cape Robertson
Route Point
Mackenzie Peninsula
Uruguay Cove
60°43'42"S
The Beach
Scotia Anchorage
Point Moreno
Cape Roca
Mossman Peninsula
Point Davis
SCOTIA BAY
Wilton Bay
Cape Davidson
Point Martin
Buchan Bay
Cape Burn Murdoch
Cape McVitie
44°38'33"W


Cape Buchanan
Watson Peninsula
Rudmose Rocks
Cape Geddes
Macdougal Bay
Ferguslie Peninsula
Brown's Bay
Cape Vallavielle
Ferrier Peninsula
Graptolite Isle
Fitchie Bay
Cape Dundas
60°43'42" S.
Mill Cove
Cape Whitson
Cape Nan Anderson
Murray Islands
Ailsa Craig
OUTLINE MAP OF
LAURIE ISLAND
SOUTH ORKNEYS
Reduced from a Survey by
Messrs Bruce, Pirie, Wilton & Brown.
SCOTTISH NATIONAL ANTARCTIC EXPEDITION
1903
Position of Cairn Lat. 60°43'42" S. Long. 44°38'33" W.
Variation 5° 26·6' E.
Scale - 1/72,960
J. G. Bartholomew