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A STUDY OF MAGNETIC BAYS AT MACQUARIE ISLAND

by

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PLATES.

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ABSTRACT.

Polar magnetic bays are the most striking feature of magnetic records from Macquarie Island. Negative bays are more numerous than positive bays and have greater amplitudes and durations. On the average negative bays occur around magnetic midnight whereas positive bays occur about five hours earlier. A daily reversal in direction of the bay-producing currents is indicated and the time at which this reversal takes place appears to vary with the seasons. During magnetically disturbed periods the ratios of H to Z bay amplitudes are observed to increase, indicating a northward movement of the bay-producing currents. At the same time aurorae are seen farther north than usual.

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MAGNETIC BAYS AT MACQUARIE ISLAND.

1. Macquarie Island is situated in the Southern Ocean about 900 miles south-east of Hobart, Tasmania. Its co-ordinates are:-

Geographic	-	latitude $54^{\circ}.5$ S. longitude $159^{\circ}.0$ E.
Geomagnetic	-	latitude $- 60^{\circ}.7$ longitude $243^{\circ}.1$

2. The Macquarie Island magnetic observatory continuously records the three components of the earth's magnetic field - horizontal intensity (H), vertical intensity (Z) and declination from the meridian (D). Together, these components define the total field. The character of the records obtained varies considerably from day to day. The first slide (plate 1) shows an undisturbed or "quiet" day. Apart from a period of an hour or two there is very little disturbance. The prominent disturbance beginning at midnight is termed a "magnetic bay" because of its resemblance to an indentation on a coastline. The second slide (plate 2) shows the record for a typical disturbed day. The declination trace is particularly disturbed, especially during the night hours. The most disturbed parts of the record show a number of overlapping bays.

3. On the next slide (plate 3) two or more bays can be seen. Considering the horizontal and vertical component traces, it is seen that in the first few hours a bay, or pair of bays, is formed by <u>increase</u>

of the H and Z components. Later in the day another bay is formed by decrease in H and Z components. In the following discussion the first type (increase) will be termed a positive bay and the second type (decrease) a negative bay. These bay-like features are very prominent on a large number of the records from Macquarie Island and are characteristic of records from magnetic observatories in the latitudes near the auroral zones.

4. The illustrations used in this paper are from records of the sunspot minimum year 1954. During that year some 435 negative bays and 172 positive bays were recorded. The histograms on the next slide (plate 4) illustrate the distribution of negative and positive bays throughout the year. In the case of negative bays especially, it is seen that bays are very much more common near the equinoxes. This is, of course, true of magnetic disturbances in general. There are many more negative bays than positive bays and it is found that, on the average, the amplitudes of negative bays are two or three times as great as those of positive bays.

5. The next slide (plate 5) shows the commencement times of all negative bays recorded in 1954. The horizontal line represents magnetic midnight, as defined by McNish (1936). It is seen that there is an obvious grouping of the commencement times around magnetic midnight. The following slide (plate 6) shows the commencement times of positive bays. Almost all positive bays occur before magnetic midnight and they are most common about five hours before magnetic midnight. Now although the commencement times of negative and positive bays appear to overlap somewhat on the last two diagrams, which show commencement times on a large number of days, it is found that on a particular day there is no overlapping. In other words all bays before a certain time on a particular day are positive, all bays after that time are negative. For example, on the next slide (plate 7) there is a sudden reversal of the direction of disturbances from positive to negative at the time marked "T". Not all 24-hour magnetograms show a sudden and definite transition from positive to negative as this one does, but on about a quarter of all days it is possible to pick such a transition time by inspection of the records.

6. The next slide (plate 8) illustrates the pattern of transition times observed throughout the year. The fact emerges that the transition times are generally earlier in the day near the equinoxes than they are near the solstices. However, at this stage it is not certain that this effect is purely a seasonal one. There is some evidence to suggest that the transition times are earlier on disturbed days than on relatively quieter days and of course there are many more disturbed days near the equinoxes. The subject requires further investigation in order to clarify the position.

7. So far this paper has been concerned with magnetic bays which are evident on the H and Z component traces. Such bays are invariably accompanied by D component disturbances, but these are generally oscillatory in character and not of simple bay shape. The next slide (plate 9) shows a different type of bay. It is evident that there is little disturbance on either H or Z but there is a pronounced negative bay in the declination component D. In 1954 about 80 of such bays were recorded. All of these were negative, that is they showed

an increase to the west, and all occurred in the intervening period between the times when positive H - Z bays and negative H - Z bays were most common.

8. The preceding part of this paper has presented a number of facts relating to magnetic bays as observed at Macquarie Island. Because of the limited time available it is not intended to enter into a detailed discussion of theories which may explain the facts. However, a number of fairly obvious conclusions may be drawn. It is clear from the changeover in bay sign that the bay-producing currents flowing near the southern auroral zone change direction from eastwards to westwards in the early evening of each day and that about this time currents, if present, tend to flow northwards over the recording station producing bays in declination only.

9. The bay current system is thus more or less stationary with respect to the sun as regards direction of current, but current flows intermittently with sudden large increases during the time bays are observed. These facts are explainable by a number of current theories which assume that the currents are due to an excess of ions of one sign carried along in some way by ionospheric winds. The winds are constant in direction relative to the sun but the bay-producing ionisation takes place in bursts. The normal diurnal variation is no doubt produced by less intense but more regular ionisation operating in conjunction with the same wind system. The large excess of negative bays over positive bays indicates a preponderance of bay-producing ionisation on the night side of the earth. The probability of seasonal variations in the changeover times from positive to negative bays suggests that magnetic bay studies may make useful contributions to the understanding of upper atmospheric wind systems.

10. It has long been recognised that the polar bay type of magnetic disturbance is often accompanied by visual aurora. Some aspects of the relationship between the two phenomena have been investigated at Macquarie Island. Chapman and Bartels (1.1940, p.471) have attempted to correlate auroral and magnetic activity on the basis of character figures which are a measure of the degree of daily magnetic and auroral activity. They found a good correlation between the two. At Macquarie Island, because of the large amount of cloud obscuring the aurora, it was not possible to attempt an exhaustive investigation of this kind. Instead an attempt was made to correlate the aurora and magnetic bays on the basis of time of occurrence. It was noticed that on quite a few days the first aurora observed for the evening corresponded closely in time to the beginning of the first magnetic bay activity. A number of such cases are illustrated on the next slide (plate 10).

11. The magnetic records and written records of auroral observations for the whole year were studied closely to determine whether simultaneous onset of magnetic bays and the aurora generally occurred. Of 77 nights on which the sky was clear and it was possible to decide whether the first bay activity coincided with the first auroral activity, good agreement was noted on 35 nights. On 16 more nights there was agreement in the

absence of both magnetic and auroral activity.

12. Absence of activity is comparatively rare in both phenomena, thus making the probability of coincidence low. Of the remaining 26 nights 14 would have showed agreement but for the recording of auroral glows, at a time when there was no magnetic bay activity. Since glows are the most indefinite type of aurorae and are frequently confused with twilight or moonlight on cloud, etc., these cases cannot be regarded as conclusive.

Summarising -

Number of Nights.	Correlation.
35	Good correlation.
16	Agreement in absence of activity.
14	Inconclusive.
12	No agreement.
77	Total

13. It is clear that in the majority of cases magnetic bays and aurorae do commence at about the same time. Once bays have begun, magnetic variations are usually so frequent that further correlation with the aurora is impossible. It seems likely that a burst of ionisation impinging on the ionosphere in the auroral zone produces the visible aurora and at the same time creates the condition in the ionosphere necessary for a bay, which commences simultaneously with or soon after the visible aurora. Arcs and bands are the auroral forms most consistently associated with the commencement of bays.

14. The fact that the bay-producing currents and the aurora are more or less coincident in space is also demonstrated by observations at Macquarie Island. On most days the vertical component of the earth's field Z produces a trace on the magnetogram which is very similar to that of horizontal intensity H. This is illustrated on slide 3 (plate 3). Such a position is consistent with bay-producing currents several degrees south of the recording station. However, on many magnetically disturbed days this situation is changed to a notable degree. As the amplitude of negative bays in H <u>increases</u> the amplitude of the corresponding bay in Z <u>decreases</u>, perhaps to zero, or the amplitude may even increase in the positive direction, as it does around midnight on slide 2 (plate 2). This situation is indicative that the bay currents move laterally northwards until they are over the recording station when Z is neutral, or north of the recording station when Z is positive.

15. Altogether, on 15 days of the year cases occurred in which the Z trace remained neutral or became positive during negative H bays. These days had two things in common. Firstly, all except one were very disturbed magnetically. Secondly, on all nights on which the sky was clear aurorae were observed overhead or to the north of the island rather than to the south as was usually the case. Moreover, the nights on which the most brilliant aurorae displays of the year were seen are included amongst

these cases.

16. Assuming that the bay-producing currents and the aurora both occur at about the same height, and it seems likely that they do, it is clear from observations at Macquarie Island that magnetic bays and the aurora are closely related in both time and space.

ACKNOWLEDGMENT.

The magnetic data used in this paper was obtained while the author was a member of the Australian National Antarctic Research Expedition at Macquarie Island in 1954. He wishes to thank other officers of that Expedition who collaborated with him and supplied auroral data.

REFERENCES.

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TABLE 1.

REGIONAL TRAVERSES, ICE THICKNESS MEASUREMENTS.

Station.	Latitude °S.	Longitude °E.	Ice Thickness Metres.	Method
SP3	67°53'.0	62°30'.0	528	Seismic
GG4	67°56'	62°22'	625	Gravity
GG5	68°00'	62°15'	739	"
GG6	68°03'	62°11'	1269	"
SP4	68°06'.7	62°07'.0	943	Seismic
GG7	68°10'	62°08'	1109	Gravity
GG8	68°14'	62°08'	1505	"
GG9	68°18'	62°09'	1476	"
GG10	68°21'	62°09'	1785	"
SP5	68°24'.7	62°09'.7	1607	Seismic
GG11	68°28'	62°08'	1409	Gravity
SP6	68°32'.7	62°06'.3	1668	Seismic
GG12	68°37'	62°07'	1516	Gravity
SP7	68°41'.3	62°08'.0	2403	Seismic
GG13	68°44'	62°07'	2181	Gravity
GG14	68°48'	62°07'	2055	"
GG15	68°52'	62°06'	1799	"
GG16	68°55'	62°05'	1633	"
SP8	68°59'.1	62°04'.6	1607	Seismic
GG17	69°03'	62°06'	1905	Gravity
GG18	69°08'	62°08'	1648	"
SP9	69°16'.3	62°10'.2	1387	Seismic
SP10	69°20'.8	62°10'.2	1284	"
GG19	69°25'	62°10'	1450	Gravity
GG20	69°29'	62°10'	1190	"
GG21	69°33'	62°10'	1202	"
SP11	69°37'.5	62°09'.8	1555	Seismic
GG22	69°42'	62°08'	1398	Gravity
GG23	69°46'	62°06'	974	"
GG24	69°51'	62°05'	362	"
SP12	69°55'	62°02'.9	256	Seismic
GG25	70°00'	62°05'	752	Gravity
GG26	70°04'	62°07'	779	"
SP13	70°13'4	62°08'6	2237	Seismic
GG27	70°18'	62°09'	2259	Gravity
GG28	70°22'	62°09'	2460	"
GG29	70°27'	62°09'	2425	"
SP14	70°31'	62°09'.2	2655	Seismic
GG30	70°36'	62°09'	2151	Gravity
GG31	70°40'	62°09'	1614	"
GG32	70°45'	62°08'	1942	"
SP25	70°49'.6	62°08'.0	2244	Seismic
GG33	70°54'	62°08'	2295	Gravity
GG34	70°59'	62°08'	2164	"
GG35	71°03'	62°07'	2372	"
SP15	71°08'.1	62°06'.9	2401	Seismic
GG36	71°13'	62°07'	2400	Gravity
GG37	71°17'	62°07'	2145	"
SP16	71°21'.6	62°07'.0	2095	Seismic
GG38	71°26'	62°07'	2063	Gravity
GG39	71°30'	62°07'	2091	"
GG40	71°34'	62°07'.2	1916	"
GG41	71°38'	62°07'.3	2134	"
GG42	71°42'	62°07'.4	2184	"

Station.	Latitude °S.	Longitude °E.	Ice Thickness Metres.	Method
SP17	71°45'.8	62°07'.5	2190	Seismic
GG43	71°50'	62°07'.5	1926	Gravity
GG44	71°55'	62°07'.6	2237	"
SP24	71°59'.2	62°07'.6	2495	Seismic
GG45	72°04'	62°08'	2441	Gravity
GG46	72°08'	62°08'	2275	"
SP18	72°12'.6	62°07'.8	2045	Seismic
GG47	72°17'	62°08'	1935	Gravity
SP19	72°21'.6	62°07'.8	1983	Seismic
GG48	72°26'	62°08'	1417	Gravity
GG49	72°31'	62°08'	1798	"
SP20	72°35'.6	62°08'.3	1757	Seismic
GG50	72°37'	61°54'	1099	Gravity
GG51	72°39'	61°40'	1007	"
GG52	72°40'	61°26'	1477	"
SP21	72°41'.8	61°12'.2	1991	Seismic
GG53	72°44'	61°01'	1870	Gravity
GG54	72°47'	60°49'	2137	"
GG55	72°49'	60°38'	1834	"
SP22	72°52'.0	60°26'.0	1475	"
GG56	72°48'	61°17'	1899	"
SP23	72°51'.1	61°21'.0	1297	Seismic
G43	72°51'	62°00'	2436	Gravity
G44	72°51'	61°51'	2699	"
SP34	72°51'.1	61°43'.0	2732	Seismic
G48	72°51'	61°35'	2778	Gravity
G49	72°37'	61°35'	2565	"
G50	72°24'	61°35'	2414	"
G51	72°08'	61°35'	2322	"
G53	71°53'	61°35'	2287	"
SP35	71°38'.8	61°34'.7	2267	Seismic
G54	71°24'	61°35'	2315	Gravity
G55	71°10'	61°35'	2468	"
G56	70°55'	61°35'	2535	"
G57	70°41'	61°35'	2423	"
G58	70°26'	61°35'	2321	"
G59	70°26'	61°27'	2395	"
G60	70°26'	61°20'	2512	"
G61	70°26'	61°12'	2557	"
G62	70°26'	61°05'	2514	"
G63	70°26'	60°58'	2527	"
SP36	70°26'.5	60°50'.3	2572	Seismic
G64	70°24'	60°50'	2694	Gravity
G65	70°21'	60°50'	2712	"
G66	70°19'	60°50'	2718	"
G67	70°16'	60°50'	2775	"
G68	70°14'	60°50'	2793	"
G69	70°11'	60°50'	2759	"
G70	70°08'	60°50'	2721	"
G71	70°06'	60°50'	2539	"
G72	70°03'	60°50'	2196	"
G73	70°01'	60°50'	2135	"
G74	69°58'	60°50'	2240	"
SP37	69°55'.5	60°50'.3	2323	Seismic
G76	69°53'	60°50'	2365	Gravity
G77	69°50'	60°50'	2062	"
G78	69°48'	60°50'	1966	"
G79	69°45'	60°50'	2063	"
G80	69°42'	60°50'	2133	"
G81	69°40'	60°50'	2213	"

Station	Latitude	Longitude	Ice Thickness Metres.	Method
G82	69°37'	60°50'	2253	Gravity
G83	69°35'	60°50'	1860	"
G84	69°32'	60°50'	1941	"
G85	69°30'	60°50'	1988	"
G86	69°27'	60°50'	1994	"
G87	69°24'	60°50'	1572	"
G88	69°22'	60°50'	1592	"
G89	69°19'	60°50'	1679	"
SP38	69°16'.7	60°50'.3	1463	Seismic
G91	69°14'	60°50'	1769	Gravity
G92	69°12'	60°50'	1878	"
G93	69°09'	60°50'	1718	"
G94	69°06'	60°50'	1296	"
G95	69°04'	60°50'	1186	"
G96	69°01'	60°50'	1441	"
SP39	68°58'.6	60°50'.3	1591	Seismic
G98	68°57'	60°56'	1632	Gravity
G99	68°56'	61°02'	1955	"
G100	68°54'	61°08'	1902	"
G101	68°53'	61°14'	1909	"
G102	68°52'	61°20'	1888	"
G103	68°50'	61°26'	1916	"
G104	68°49'	61°32'	2003	"
G105	68°47'	61°38'	2179	"
G106	68°46'	61°44'	2179	"
G107	68°44'	61°50'	2253	"
G108	68°43'	61°56'	2273	"
G109	68°42'	62°02'	2171	"
G110	68°40'	62°08'	2265	"
G111	68°41'	62°15'	2405	"
G112	68°38'	62°15'	2204	"
G113	68°36'	62°14'	1919	"
G114	68°33'	62°14'	1769	"
G115	68°30'	62°13'	1486	"
G116	68°28'	62°12'	1425	"
G117	68°26'	62°11'	1575	"
G118	68°23'	62°16'	1624	"
G119	68°22'	62°22'	1191	"
G120	68°21'	62°28'	1168	"
G121	68°20'	62°34'	1351	"
G122	68°18'	62°40'	1109	"
G123	68°17'.1	62°46'.4	1118	"
SP40	68°14'.5	62°42'.5	1098	Seismic
G124	68°12'	62°39'	985	Gravity
G125	68°10'	62°36'	1019	"
G126	68°08'	62°33'	898	"
G127	68°06'	62°30'	793	"
G129	68°04'.2	62°27'.3	824	"
G130	68°02'	62°26'	886	"
G131	67°59'	62°24'	897	"
G132	67°56'	62°22'	873	"
G133	67°53'.6	62°20'.3	741	"

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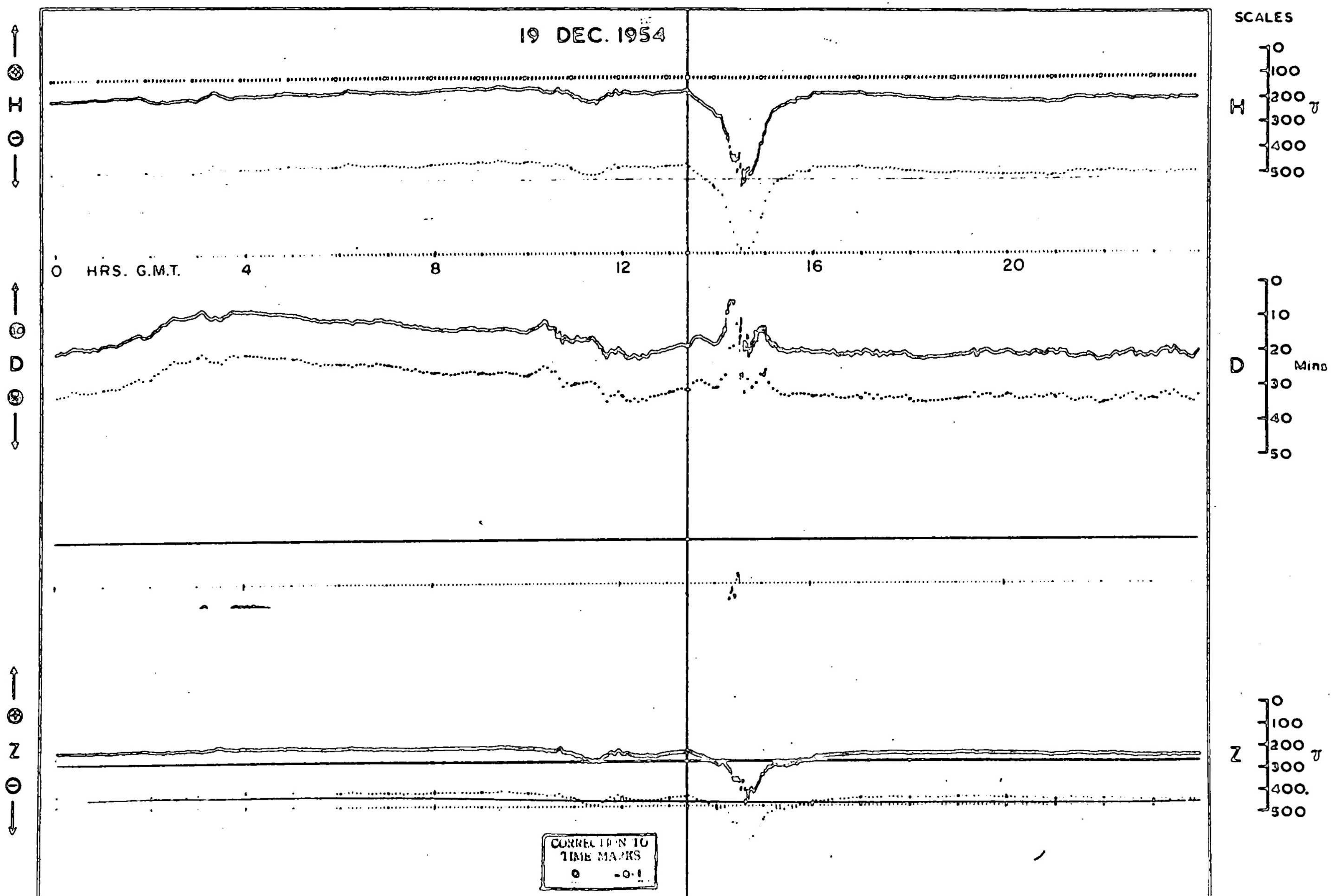
MACQUARIE ISLAND 24 HOUR MAGNETOGRAM

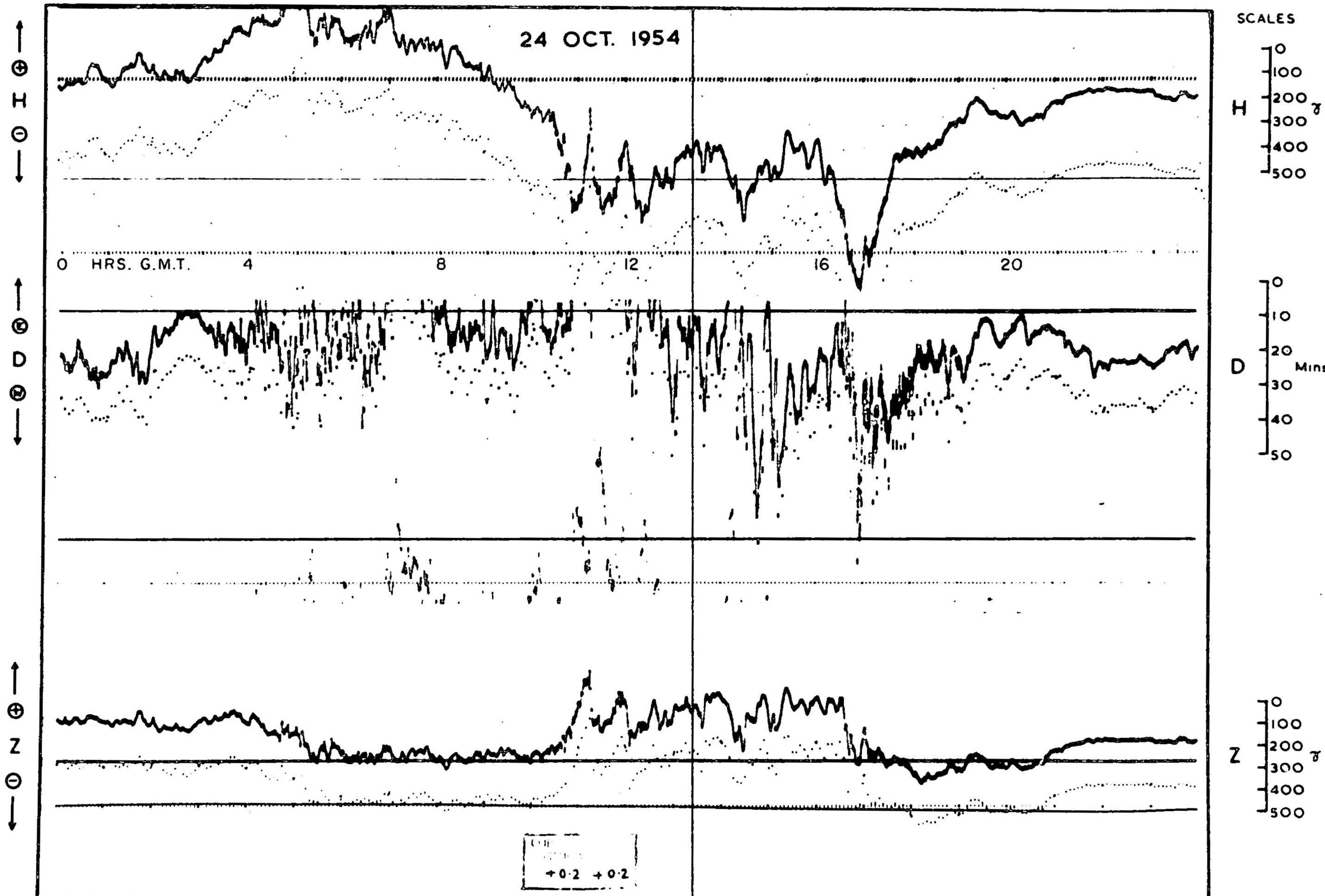


Local midnight (13·4 hr G.M.T.) indicated by vertical line.

PLATE I

G54-37

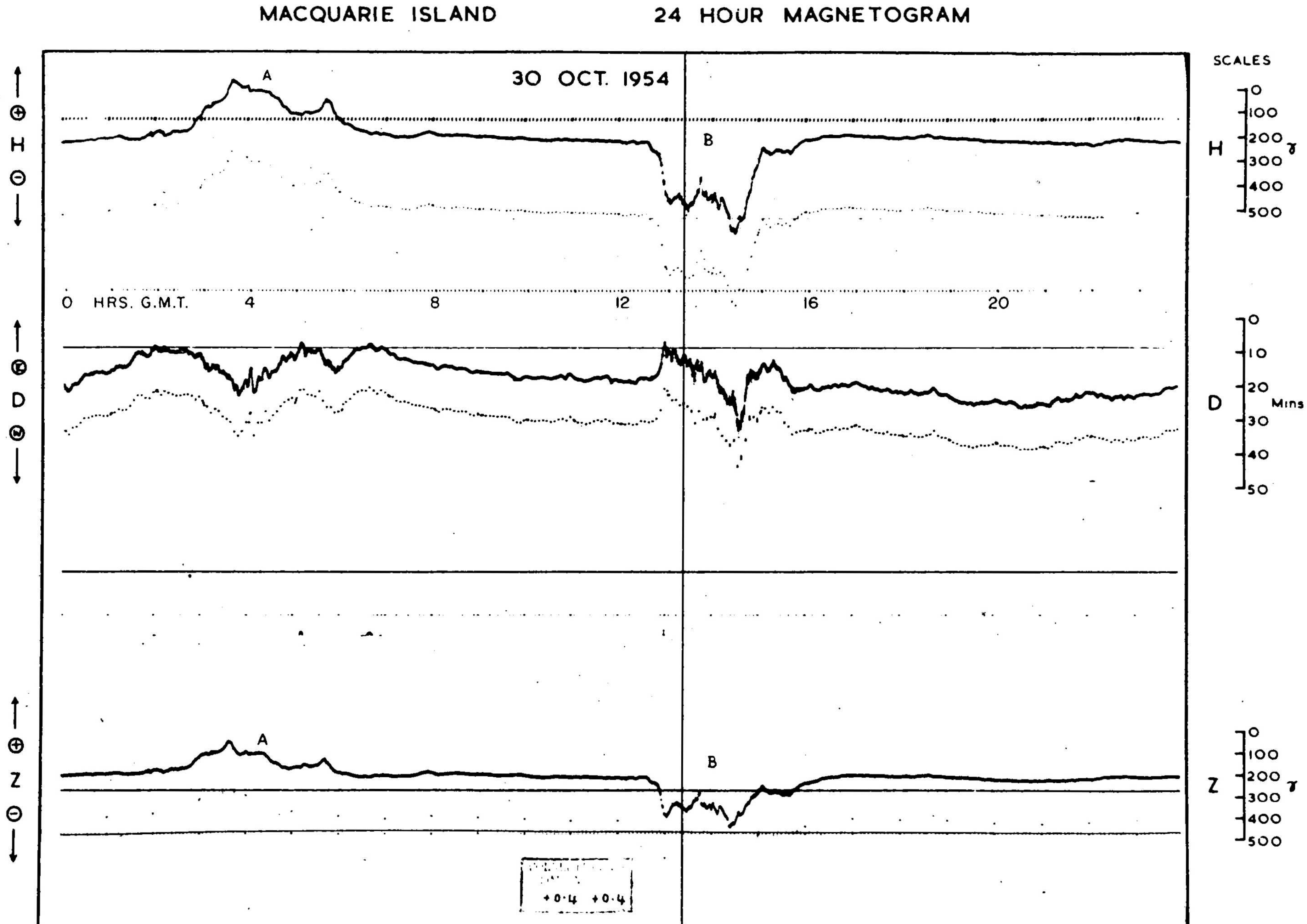
MACQUARIE ISLAND 24 HOUR MAGNETOGRAM



Local midnight (13·4 hr G.M.T.) indicated by vertical line.

PLATE 2

G54-38

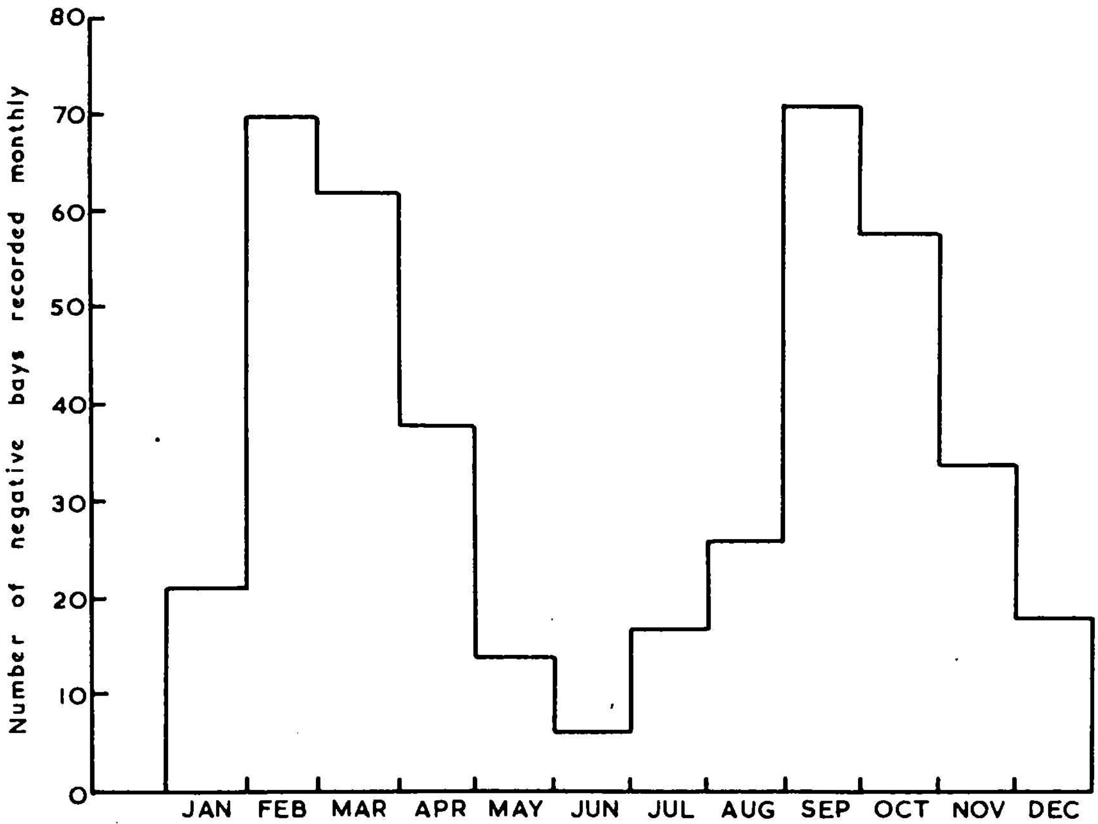


Local midnight (13·4 hr G.M.T.) indicated by vertical line.

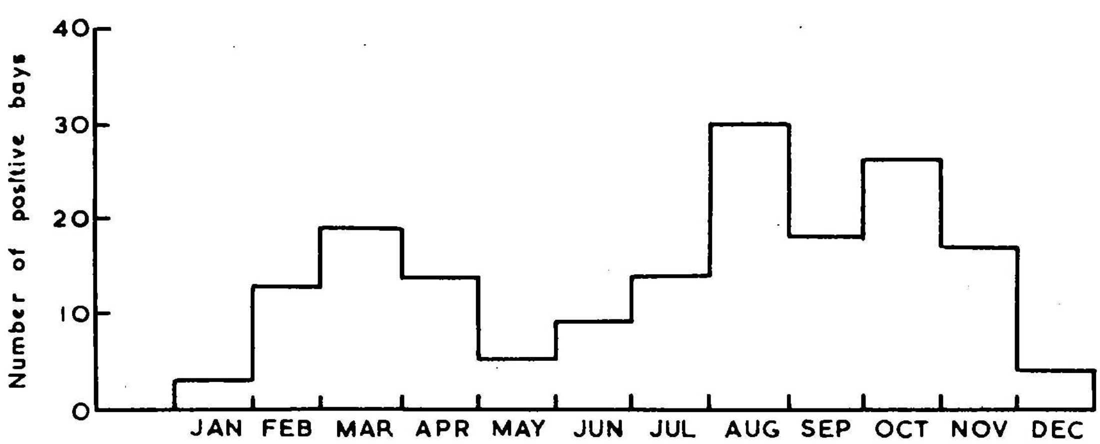
PLATE 3

G54-39

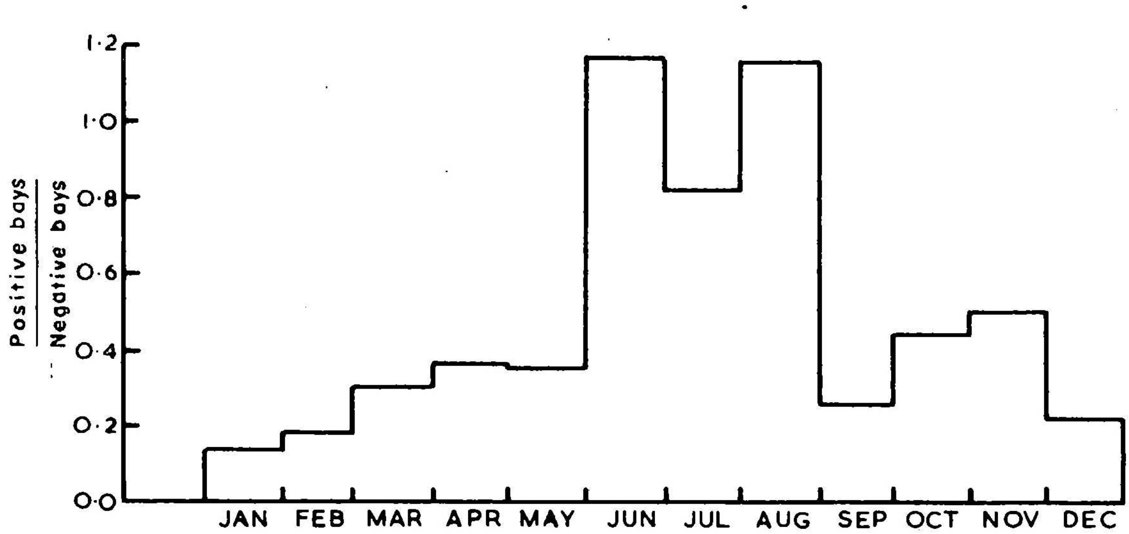
MAGNETIC BAYS MACQUARIE ISLAND 1954



Distribution of negative bays.



Distribution of positive bays.

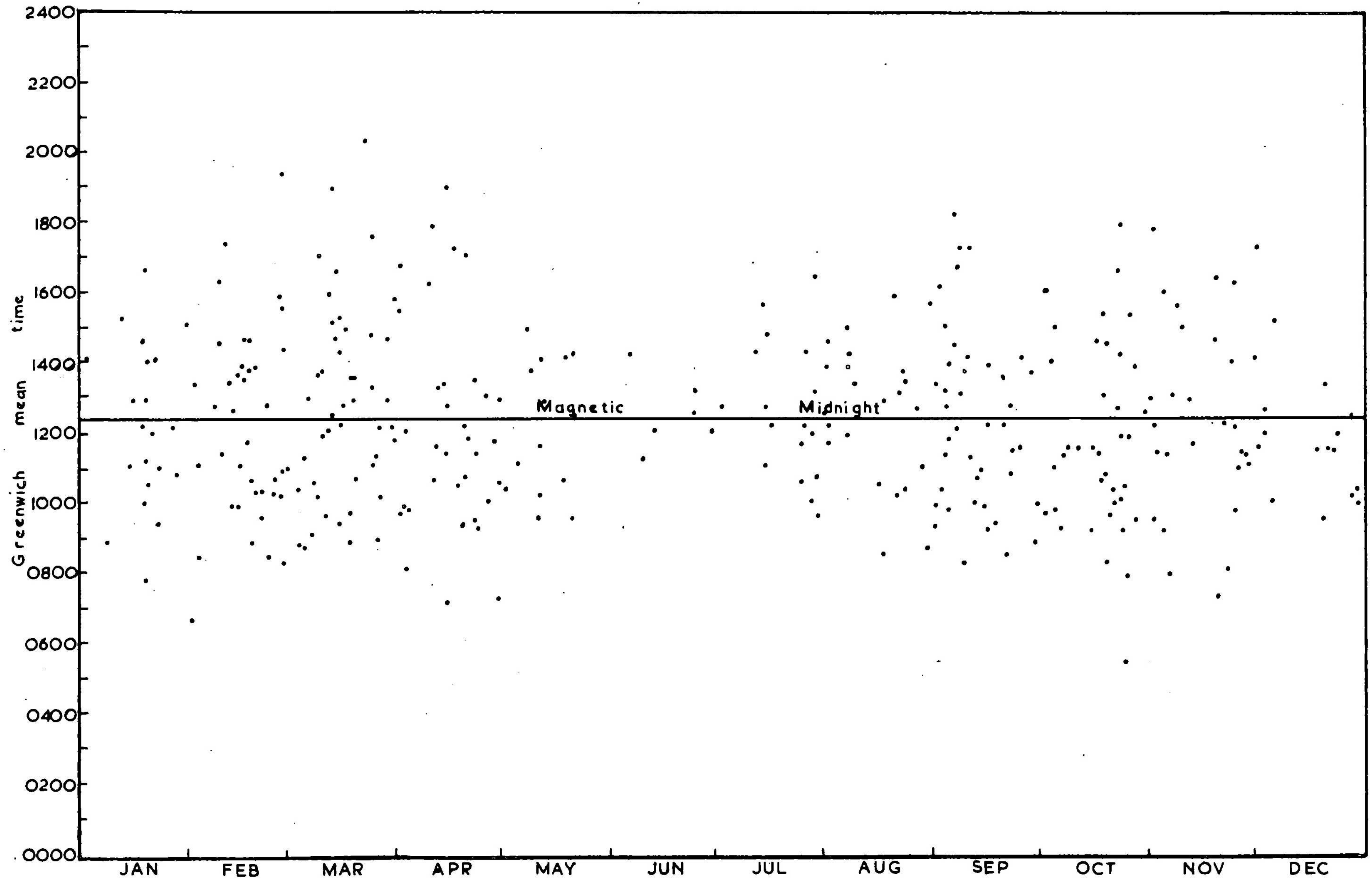


Relative numbers of positive and negative bays.

G54-40

COMMENCEMENT TIMES OF NEGATIVE BAYS

MACQUARIE ISLAND, 1954.



G54-41

PLATE 5

COMMENCEMENT TIMES OF POSITIVE BAYS
MACQUARIE ISLAND, 1954.

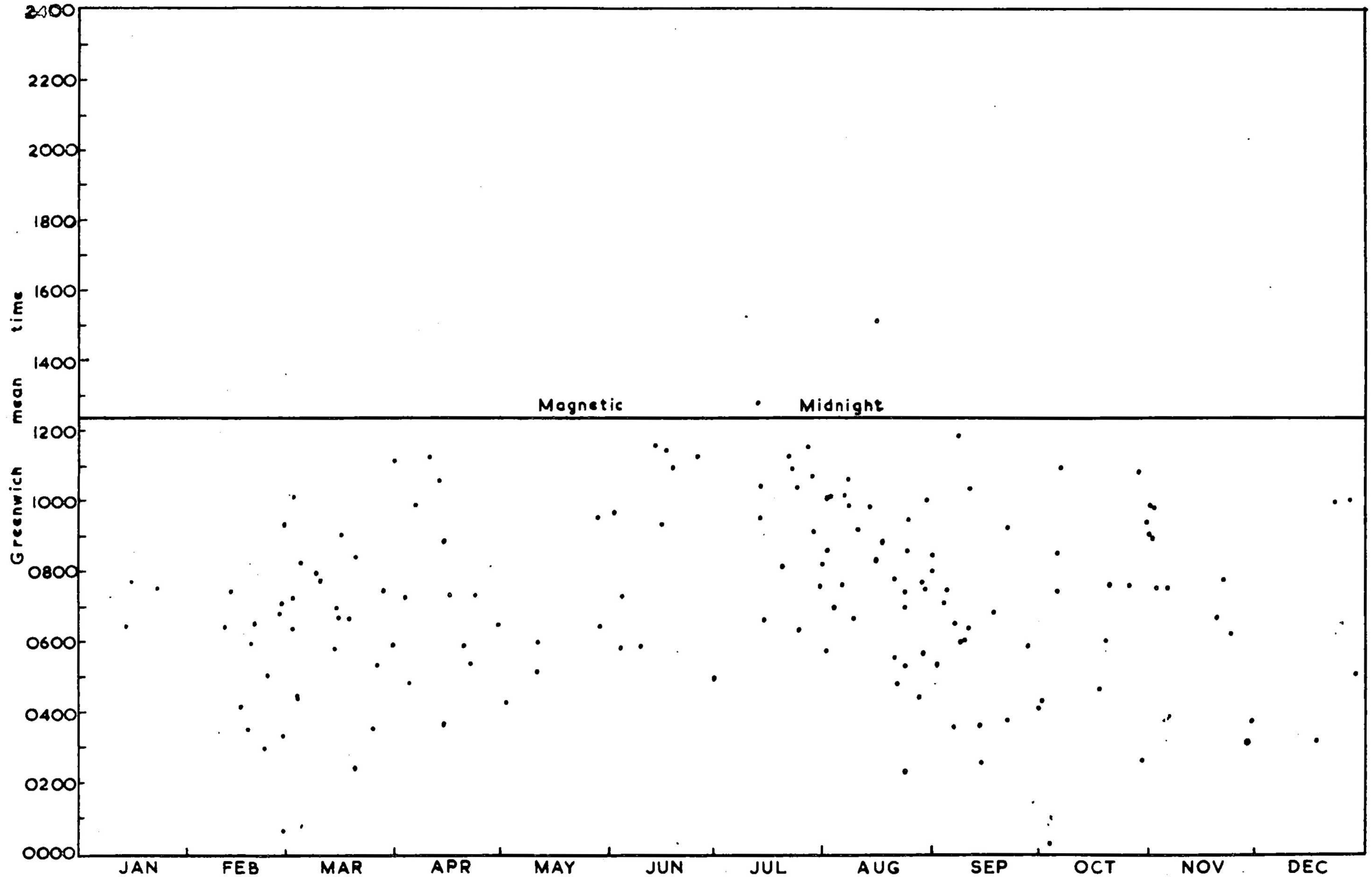
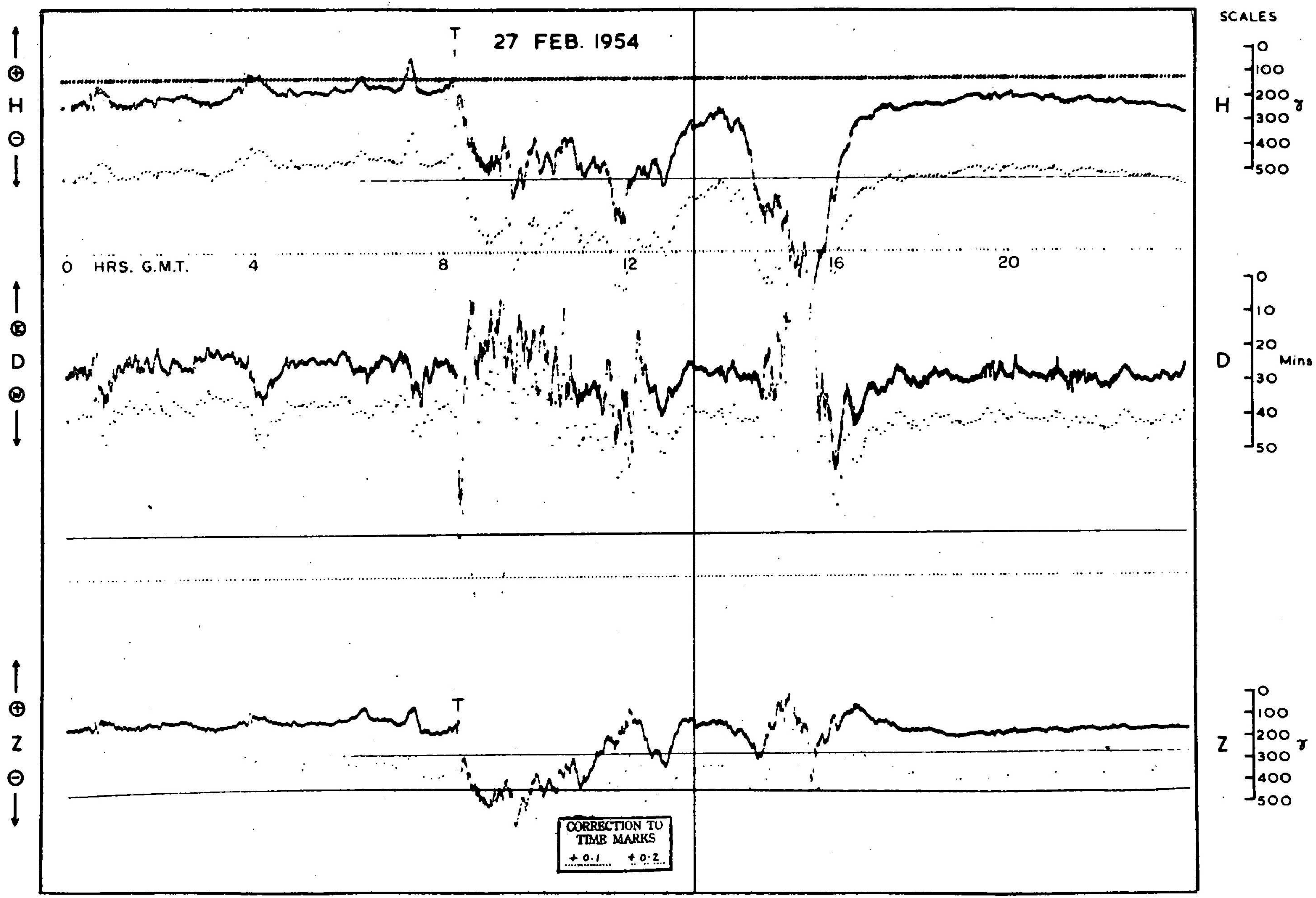


PLATE 6

G54-42

MACQUARIE ISLAND 24 HOUR MAGNETOGRAM

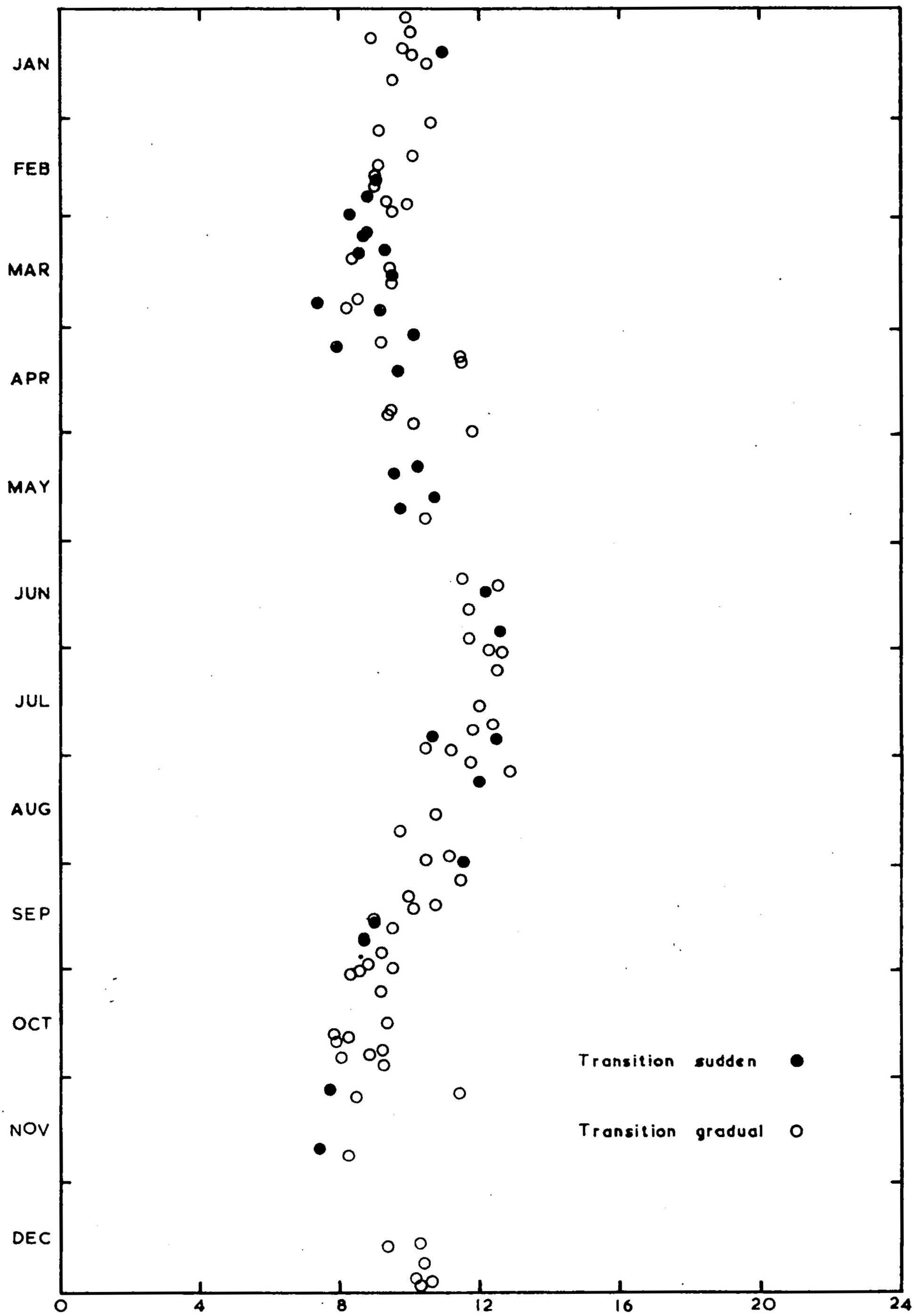


Local midnight (13·4 hr G.M.T.) indicated by vertical line.

PLATE 7

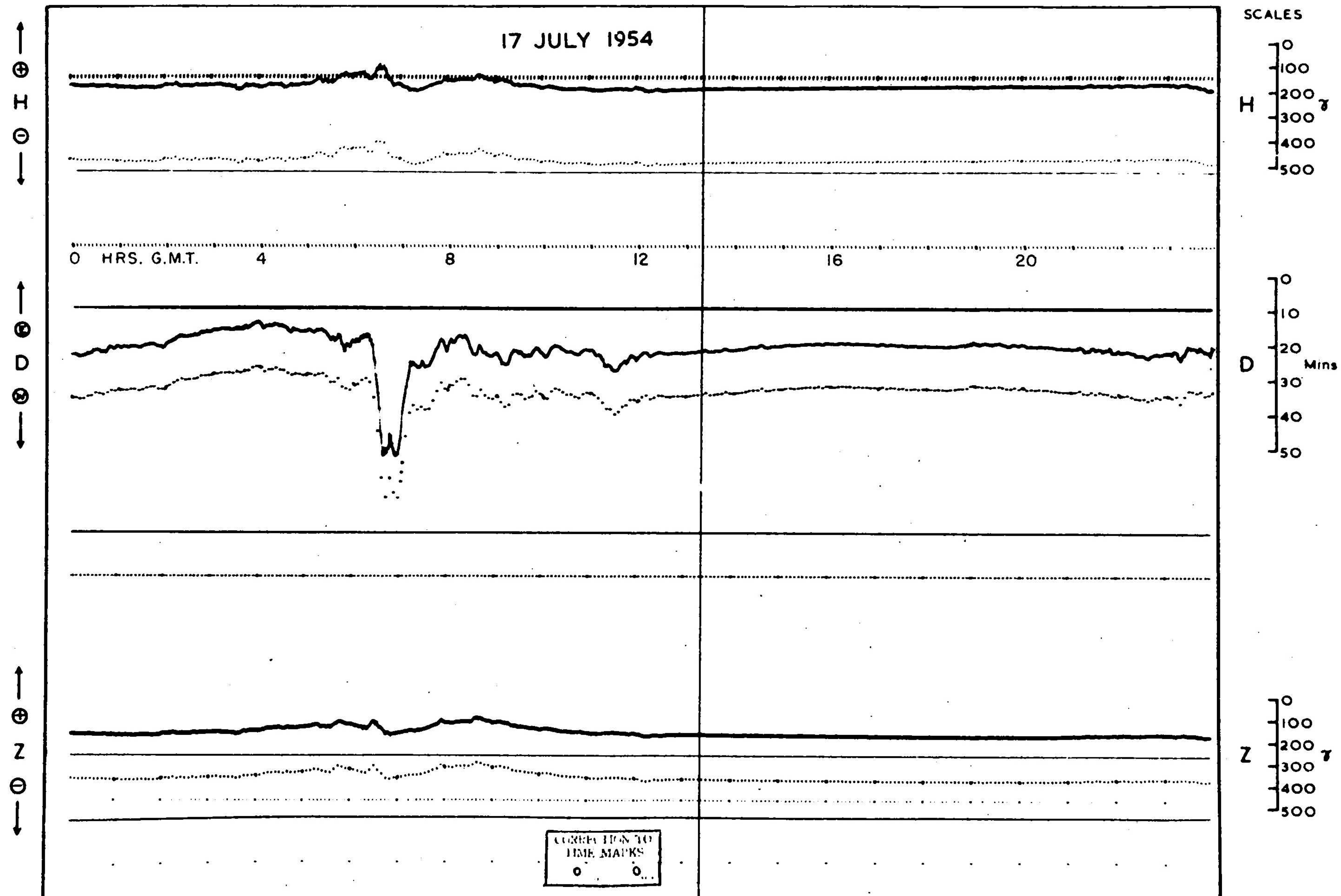
G54-43

SEASONAL VARIATION OF TRANSITION TIMES
MACQUARIE ISLAND, 1954.



(Midnight local mean time is at 13·4 hr G.M.T.)

MACQUARIE ISLAND 24 HOUR MAGNETOGRAM



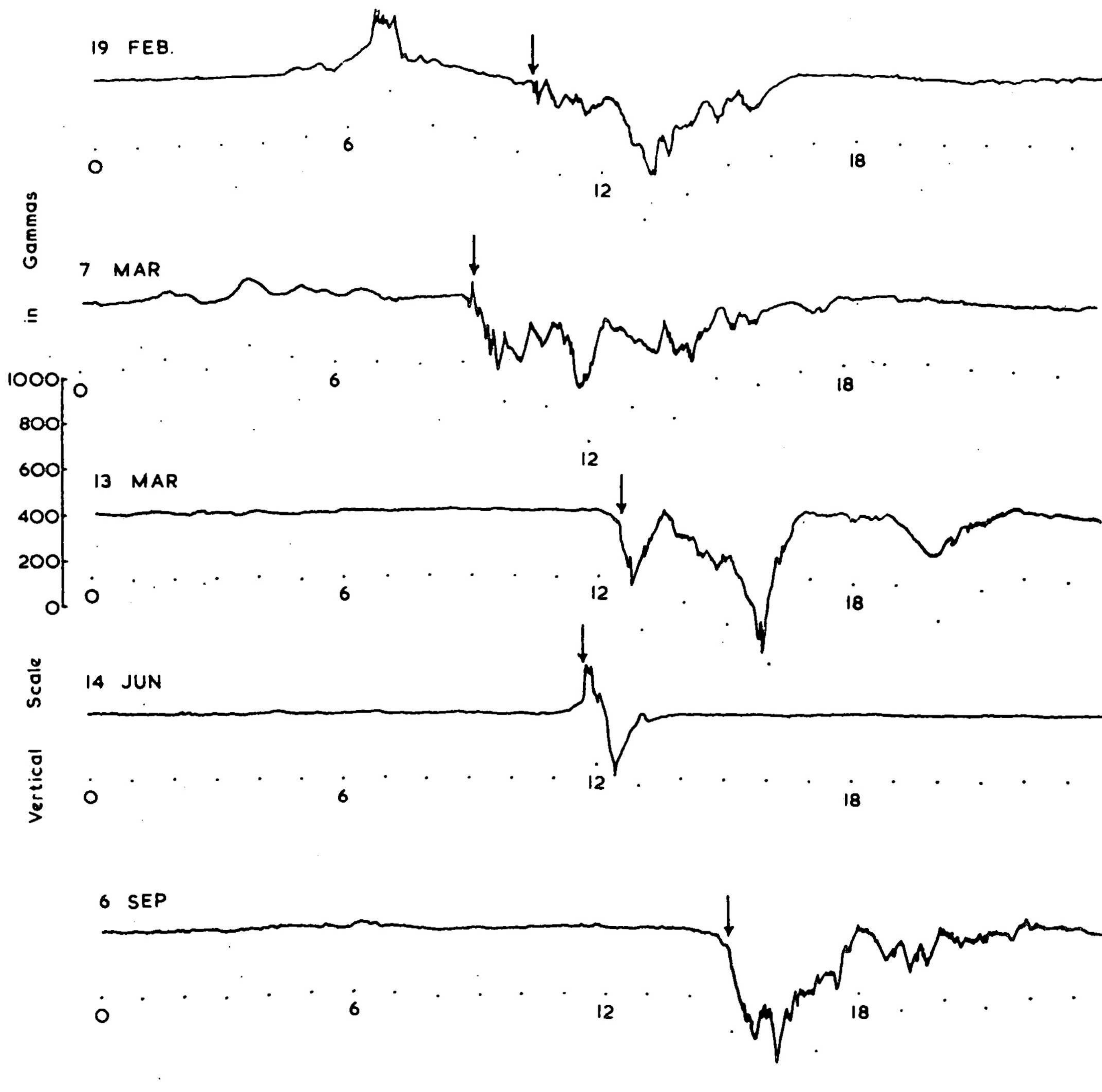
Local midnight (13·4 hr G.M.T.) indicated by vertical line.

PLATE 9

G54-45

SIMULTANEOUS ONSET OF THE AURORA

AND MAGNETIC BAYS AT MACQUARIE ISLAND



Tracings of the horizontal intensity component record for 5 days in 1954. The arrows indicate the times at which the first aurora of each evening was observed. Times shown are G.M.T. Midnight local mean time is at 13·4 hr G.M.T.