Subject: A Note on the Geomagnetic Variations Following the Solar Flare and Cosmic Ray Effects of 23 February 1956

By: S. Matsushita

Earlier this year Dr. Roberts called my attention to geomagnetic fluctuations on certain records from dark-hemisphere, high latitude stations that seemed to indicate effect within the polar cap occurring very soon after the now-historic flare and cosmic ray effects of 23 February 1956. The magnetograms were kindly furnished to Dr. Roberts by Dr. R. G. Medill of the National Research Council of Canada. It has been my pleasure to follow up in detail this interesting possibility.

Magnetograms made at Resolute Bay (74.7°N, 265.1°E; gm 63°N), Baker Lake (64.3°N, 261.0°E; gm 74°N), College (64.9°N, 212.2°E; gm 64°N), Meanook (54.6°N, 216.7°E; gm 62°N), Sitka (57.1°N, 224.7°E; gm 60°N), Agincourt (43.8°N, 280.7°E; gm 55°N) and Cheltenham (38.7°N, 283.2°E; gm 50°N) were used in this study. For these magnetograms, the horizontal component (X-component at Resolute Bay) and the declination (Y-component at Resolute Bay) were scaled every 15 minutes during the period from 02:00 to 10:45 U.T. on 23 February 1956. The variations of these two components are shown in Figures 1 and 2. The values plotted at each time are the departures of the value of two components from the values at 03:30 U.T. (The solar flare occurred at 03:31 U.T.)

After about 30 minutes following the start of the flare, magnetic disturbances similar in shape to magnetic bays seem to occur at Resolute Bay and Baker Lake, as will be seen in the figures, although large variations did not occur at lower latitudes. Magnetic bays occur most frequently and with greatest intensity in the auroral zone. The present bay-shaped variation on 23 February occurred only at the polar cap. Accordingly, we could suppose that this phenomenon might be associated with the solar flare.

A question may arise as to how this disturbance could occur even though the stations involved were in the dark hemisphere of the earth, and also why it took place only at the polar cap. As A. H. Shapley and W. O. Roberts(2) have reported, ionograms of vertical incidence sounding show that a radio blackout occurred on the dark hemisphere at latitudes higher than about gm 60°N. This means an absorption layer was formed even in the dark hemisphere by the solar flare. The ionograms also showed that

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the radio blackout occurred earlier at the higher geomagnetic latitudes. At Thule (gm 88°N), Narsarsuuk (gm 71°N) and Reykjavik (gm 70°N), the radio blackout occurred within an hour from the flare beginning; this shows an absorption layer was formed at the polar cap shortly after the flare took place. It is interesting that the above mentioned geomagnetic variation at the polar cap started about 30 minutes after the flare beginning. We may suppose that something like shock waves or very high-speed particles or X-ray radiation from particles might arrive at the ionospheric E-D level in latitudes higher than gm 70°N, at about 30 minutes following the onset of flare. We may speculated that this produced ionization at that level, which in turn caused the bay-shaped magnetic disturbance and the radio blackout. From the range of the magnetic disturbance and theoretical calculation of electric current and absorption of radio waves, the ion production rate may be of order 10^2 per c.c., assuming the effective recombination coefficient at that level at night is 10^{-9} c.c./sec and the collisional frequency is of order 10^5 per sec. For this calculated value and the circumstances involved, X-rays seem the most probable source of ionization although many other observations and theoretical studies are necessary to confirm it.

In the zone gm 60°N - 70°N, the radio blackout occurred 3 or 4 hours after the flare beginning; however, no significant geomagnetic variations occurred in that zone. The reason may be that the absorption layer in that zone was formed at a lower height than that responsible for the magnetic variation. If the level is about 50 or 60 km, the effective recombination coefficient is about 10^{-6} c.c./sec and the collisional frequency is of order 10^7 per sec. Accordingly, the ion production rate in this case is also of order 10^2 per c.c. in 10 km thickness.

A large magnetic bay occurred in the usual way(1), at 13:00 - 21:00 U.T. (about 10 hours after the flare) on 23 February at all stations studied. The ranges of bay disturbances were as follows:

Resolute Bay, +35°; Baker Lake, +405°; College, -235°; Meancock, -31°;
Sitka, -42°; Agincourt, -30°; Cheltenham, -60°. (Horizontal component)

It is quite natural, as I have suggested(1), that a positive bay occurred at Baker Lake. A magnetic storm with sudden commencement occurred at 03:08 U.T., on the 25th of February, as has already been established.

A search has also been made for night-side geomagnetic variations following other solar flares, in magnetograms made at Point Barrow (gm 68°N) and College. All flares of importance 2 or greater since January 1950 were studied. Out of 30 flares investigated, three show magnetic disturbances shortly following the flare. These are tabulated below:

<table>
<thead>
<tr>
<th>Flare Date</th>
<th>Time (G.M.T.)</th>
<th>Flare Importance</th>
<th>Time Lag at College (minutes)</th>
<th>Range (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Mar, 1950</td>
<td>09:14</td>
<td>2</td>
<td>30</td>
<td>124</td>
</tr>
<tr>
<td>22 May, 1951</td>
<td>13:13</td>
<td>2</td>
<td>0</td>
<td>221</td>
</tr>
<tr>
<td>14 Aug, 1951</td>
<td>00:26</td>
<td>2</td>
<td>0</td>
<td>301</td>
</tr>
</tbody>
</table>
In each of these cases, however, the disturbance is of the typical bay type. Because of the range of disturbance and the time at which the bay occurred, these cases are doubtful examples of the relationship of night-side geomagnetic variations and flares found for 23 February 1956. Even for the large flare at 10:29 U.T., 19 November 1949 (3), no great geomagnetic variation occurred at Point Barrow and College. We should study again, after the collection of magnetograms made in the polar cap, Point Barrow and College are not high enough in geomagnetic latitude for that kind of relationship.

In conclusion, the author wishes to express his sincere gratitude not only to Dr. Madill but also to Mr. J. W. Wright for his kind help and to the Boulder Laboratories, National Bureau of Standards for use of magnetograms and the solar flare table made by Mr. V. L. Petersen.

References:

(1) S. Matsushita, in preparation.


Figures 1 and 2 attached.

End of Memo
Figure 1. Horizontal component
February 23, 1956

Figure 2. Declination