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Discussion

McCracken, K. G.: Dr. Gold has suggested that the radiation may be trapped in a magnetic configuration above the flare on the east limb, and then gradually diffusing across to the foot of the line of force connecting the earth. We can exclude this possibility, since it predicts an anisotropic flux of cosmic radiation at the earth, but this was not observed.

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 INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-3B-21. A Survey of Polar Cap Absorption Events (Solar Proton Events) in the Period 1952 through 1960

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From a detailed survey of signal-strength recordings from several high-latitude VHF ionospheric scatter paths it has been possible to detect and classify some 44 PCA's in the uninterrupted period from 1952 through 1960. It has also been possible to estimate the onset time and duration of each event. Some eight of these events have been accompanied by ground-level increases in cosmic-ray intensity and are thus describable as solar cosmic-ray events. Most of the 44 events have been followed by significant magnetic storms some 15 to 30 hours after the onset of the ionospheric absorption over the polar cap. Of these, seven have exhibited the phenomenon of breakdown of Störmer cutoffs shortly after the onset of the magnetic storm, by the admission to lower magnetic latitudes, typically 60°N, of solar protons of normally excluded energies.

Strong solar-cycle dependence in the occurrence of PCA's is found. Furthermore it is suggested that particle storage, apparently always present during times of high solar activity, is not well developed in sunspot minimum years, with the result that the few PCA's then are of relatively short duration and localized in the polar cap.

The first clearly recognized polar cap absorption (PCA) event occurred on 23 February 1956. It produced marked effects on the signal intensities of the VHF ionospheric "forward" scatter radio communication links operating, at that time, between points in Labrador, Greenland, and Iceland. This par-

ticular event has been intensively studied by one of us and accounts of the observational material, positions of the path midpoints, operating frequencies and path lengths are available¹.

Beginning with the event of 23 February 1956 the continuous signal intensity record-

ings have been carefully examined and many later PCA's have been found. The earlier records have also been studied, but less thoroughly, back through 1954. For the years 1952 and 1953 recordings made by the National Bureau of Standards have been used in the search for earlier unrecognized PCA's. Only one was found²⁾.

In 1958 an arbitrary size classification was adopted for PCA's; it is defined in terms of the behavior of the VHF "forward" scatter signal intensities observed in the Greenland region of the polar cap. All events discovered in the records were classified into one of the five following categories:

VS—very small S—small
M—medium L—large
VL—very large.

The recordings prior to 1956 have not yet been searched for very small events, some of the more recent ones of which are only barely detectable.

The statistics of the occurrence of PCA's are summarized in Table 1. The letter "U" in the VS column stands for "unknown."

Table I. Statistics of occurrence

Year	VS	S	M	L	VL	Totals	Totals
1952	U	0	0	0	0	0	≥ 0
1953	U	1	0	0	0	0	≥ 1
1954	U	0	0	0	0	0	≥ 0
1955	U	0	0	0	0	0	≥ 0
1956	0	1	1	1	0	2	3
1957	1	4	6	0	0	6	11
1958	3	1	2	2	2	6	10
1959	1	0	0	1	3	4	5
1960	5	6	3	0	0	3	14
						21	≥ 44

Table II. Ground level solar cosmic ray events

Date	Pca Size
23 February 1956	L
31 August 1956	S
17 July 1959	L
4 May 1960	VS
3 September 1960	S
12 November 1960	M
15 November 1960	S
20 November 1960	S

Evidence for solar-cycle dependence of the occurrence of PCA's is particularly marked in the totals given in the next to the last column.

It is worth remarking that the event of 23 February 1956 is only of class "L," although it was preceded and accompanied by the most intense outburst of solar cosmic rays yet observed. Table 2 lists the few events in the period covered by Table 1 that are known to have been accompanied by solar cosmic rays observed at ground level. The absence of any direct and obvious relationship between the size of the PCA and the magnitude of the solar cosmic ray effect observed at ground level is an important indication of the variability from event to event of the form of the energy spectrum of the arriving solar protons. In a number of the more recent PCA's, beginning with that of 22 August 1958, protons have been observed directly at balloon altitudes in high latitudes³⁾.

The terminal links of the VHF ionospheric "forward" scatter system connect Massachusetts with Labrador and Iceland with England. The midpoints of these links are at about geomagnetic latitude 60°N; thus the signal intensities observed over them do not ordinarily exhibit evidence of polar cap absorption which may be very intense in latitudes from 70° upward. On a few occasions, however, these paths have experienced marked absorption effects characteristic of that produced by protons normally capable of arriving only over the polar cap. The onset of the absorption appears to follow the onset of a magnetic storm and often at the time of a strong Forbush decrease in the intensity of cosmic rays, usually many hours after the onset of the polar cap absorption farther north. During these comparatively rare occurrences it has been shown by direct balloon observation of abnormally soft protons that the usually operating low-energy cutoffs at these latitudes are greatly reduced⁴⁾. Unmistakable absorption events of this kind were observed on the dates given in Table 3. The earlier onset time is given when differences occurred between the two terminal links.

A detailed account dealing with the PCA events referred to in this survey is in preparation.

Table III. Occurrence of solar proton produced absorption outside the polar cap.

Onset		Onset of the Preceding PAC		
Date	Time, UT	Date	Time, UT	size
1957 September 22	1600	September 21	1630	M
1958 July 8	1000	July 7	0600	VL
1959 May 12	0400	May 11	0100	VL
1959 July 11	1700	July 10	1100	VL
1959 July 15	0700	July 14	0800	VL
1959 July 17	1800	July 17	0300	L
1960 November 13	0500	November 12	1400	M
1960 November 15	1300	November 15	1000	S

“The list of events and their details described statistically in the above paper has been inserted in the discussion of paper I-2-11.”

References

1) D. K. Bailey, Proc. I. R. E. **47**, (1959) 255.

2) D. K. Bailey, R. Bateman, R. C. Kirby, Proc. I. R. E. **43**, (155) 1181, (See Figure 31 on p. 1207).
3) K. A. Anderson, Phys. Rev. Lett. **1**, (1958) 335.
4) E. P. Ney, J. R. Winckler, P. S. Freier, Phys. Rev. Lett. **3**, (1959) 183.

Discussion

Waddington, C. J.: Do the cut-off removals that you observe at your terminal stations always occur with the same time sequence, or at least with the removal occurring first at the same station.

Bailey, D. K.: The cut-off reduction phenomenon as observed in the east and west North Atlantic does not systematically occur earlier on one side. The statistical sample is small however, and local time influence may be present.

Gold, T.: The results are in many ways superior to those that can be obtained by other means, as they are independent of effects other than those due to fast particle. Is it proposed to operate a network of this kind purely for such investigations?

Bailey: The operation of the present North Atlantic VHF scatter communication system is coming to sea level. There is a proposal for further operation at low power with great frequency stability and narrow band. It is thus hoped to continue the observing program.