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EVIDENCE OF HYDROMAGNETIC WAVES IN THE EARTH'S MAGNETOSPHERE AND OF THEIR PROPAGATION TO THE EARTH'S SURFACE*

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After the theoretical discovery of hydromagnetic waves by Alfvén,[1] the existence of such waves was demonstrated in the laboratory by Lundquist,[2] and others.[3] The importance of these waves in astrophysical and geohpysical problems was soon realized.[4] Dungey[5] and several other authors suggested that oscillations of the earth's magnetic field in the magnetosphere at a distance of several earth radii would be propagated as hydromagnetic waves. They would manifest themselves on the earth's surface as regular variations in the continuous record of the earth's field. As shown by Piddington[6] these waves should be circularly polarized, due to anisotropic conductivity of the plasma in the presence of the magnetic field, and would propagate along the lines of force as transverse perturbations. The waves would be elliptically polarized if the propagation were oblique.

First evidence of elliptically polarized hydromagnetic waves in the ground records of the earth's magnetic field at College, Alaska, was communicated by Sugiura.[7] Waves with periods of a few minutes were assumed to originate in the earth's magnetosphere at a distance of several earth radii. Later, Judge and Coleman[8] interpreted Explorer-VI magnetic field observations as indicating that circularly polarized hydromagnetic waves of 200-sec period exist near 6.3 earth radii. The effects of such waves on the ground magnetic record were not demonstrated, however.

It is the purpose of this Letter to present more conclusive evidence of such waves in the magnetosphere from the total vector magnetic field measurement by the Explorer-XII magnetometer and from simultaneous ground magnetic records from College, Alaska.

We have selected magnetic field observations when Explorer XII was close to the longitude of College, Alaska, on 14 September 1961. The satellite observations were averaged over 15 sec. These observations were obtained in a satellite-oriented coordinate system B, α, ψ.[9] A transformation was made to obtain three orthogonal components B_r, B_θ, B_φ in a geocentric spherical coordinate system, where B_r is outward from the earth, B_θ in the direction of increasing north latitude, and B_φ in the direction of increasing east longitude. On 14 September 1961 from 2050 to 2125 UT the satellite was close to the geomagnetic equator (geomagnetic latitude 8°N) so that B_r and B_φ were approximately perpendicular to the main field line along B_θ. Therefore, we need to study variations in only B_r and B_φ to observe transverse hydromagnetic waves. To bring out the variations clearly, these components were smoothed by taking sliding averages over a period of a minute. Results are shown for two periods of data in Fig. 1 that exhibit peri-

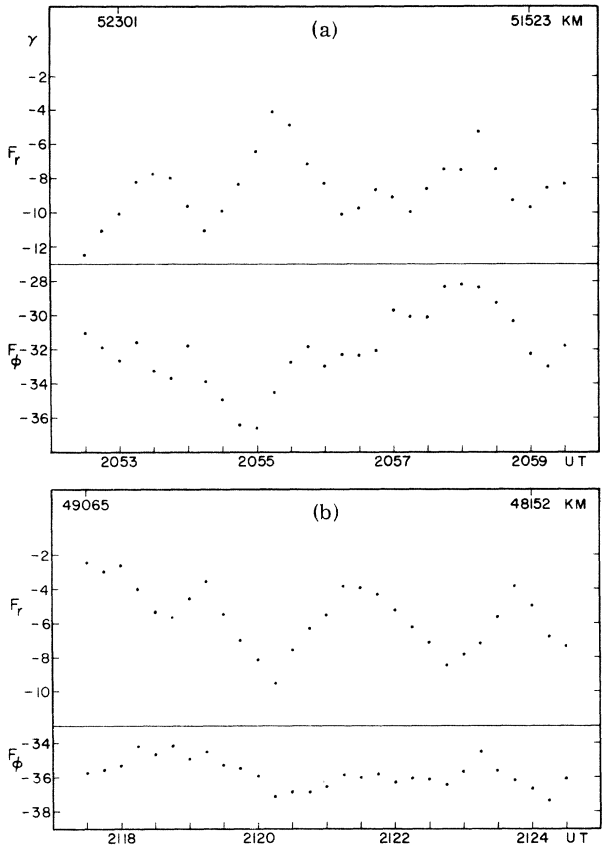

FIG. 1. Explorer-XII data on 14 September 1961.

odic variations of 6 to 8 gammas in B_γ and B_φ.

In order to demonstrate the polarization of these waves, vector diagrams are formed indicating the rotation of the disturbance vector. Figures 2(a) and 2(c) correspond to the waves in Figs. 1(a) and 1(b), respectively. In both cases the waves are eliptically polarized with period approximately 120 and 180 sec. The direction of the polarization is clockwise for an observer looking along the magnetic field line. This sense of rotation of the polarization was found in many other cases during one and one-half hours of data examined but not shown here. These waves in the magnetosphere should propagate along the lines of force and generate similar effects on the magnetic field records on the surface of the earth. We have examined the magnetic records at College, Alaska. The results are shown in Figs. 2(b) and 2(d). They correspond to the waves in the simultaneous satellite records in Figs. 2(a) and 2(c), respectively. The rotation of the polarization is clockwise on the ground since the observer is looking along the field. These observations are made between 1053 and 1125 local time. They are in agreement with the studies of Wilson and Sugiura,[10] Judge and Coleman,[8] and Nagata, Kokubun, and Iijima.[11] They found that during the local time interval between 1000 and 2200 hours, polarization in the northern hemisphere is clockwise. Our results show that the transverse hydromagnetic waves seen on the ground at College, Alaska, originated close to the geomagnetic field boundary which was at 55 000 km on this day.

It should be noted that these waves had a travel time of approximately one and one-half minutes and that their amplitudes were attenuated slightly. Detailed work on these waves is continuing and a complete study will be published later.

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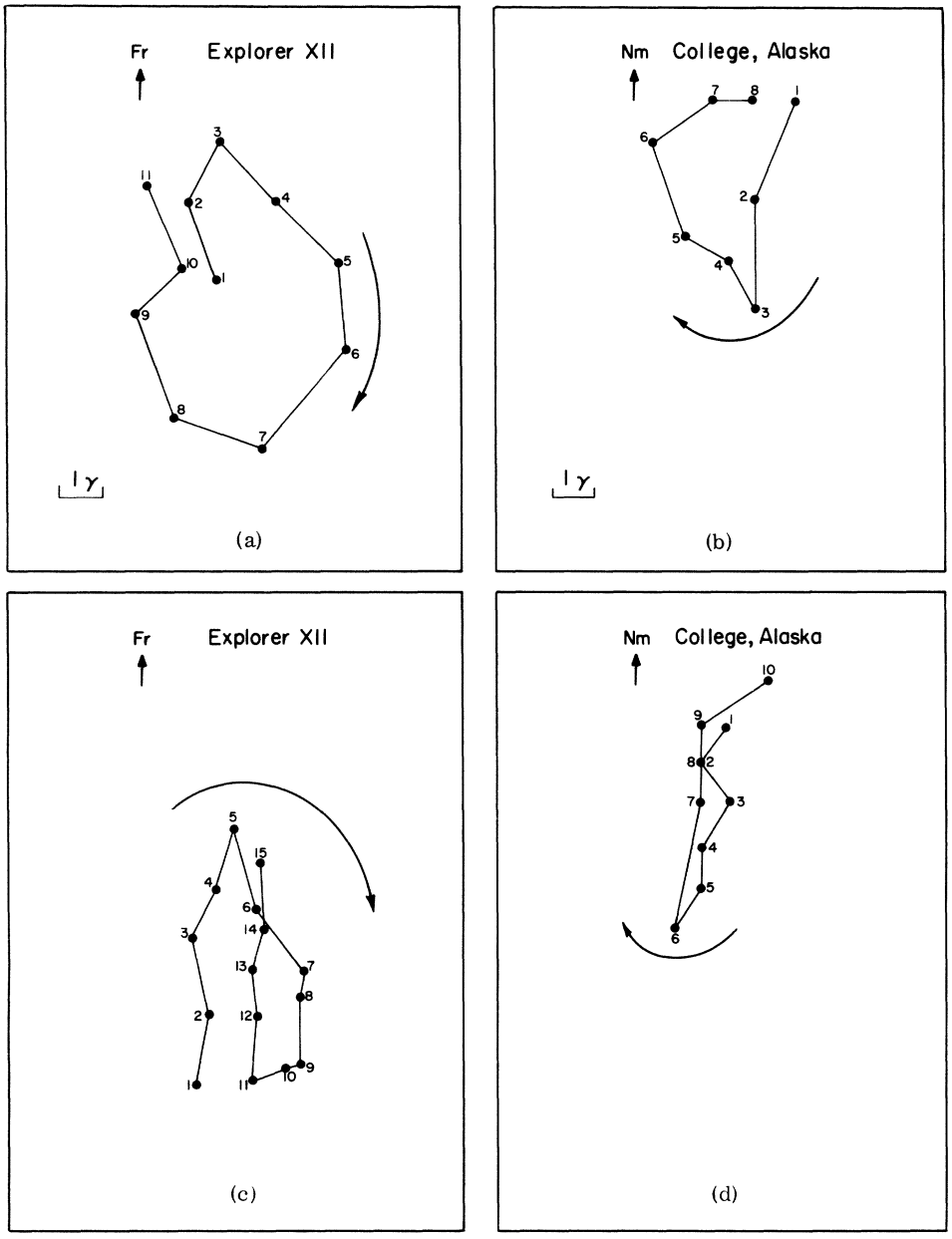

FIG. 2. The starting time (a) is 2053 h, 30 sec; (b) 2056 h, 30 sec; (c) 2118 h, 45 sec; and (d) 2121 h UT on 14 September 1961. In all four parts the scale is same. The points are at interval of 15 sec.