GEOMAGNETIC ACTIVITY AFTER THE ALASKAN EARTHQUAKE

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Winch et al. [1963] have reported that periodic magnetic variations having the same frequency as the first two torsional modes of the free oscillations of the earth appeared on the surface of the earth following the great Chilean earthquake. The purpose of this note is to report on a search for similar magnetic activity after the 1964 Alaskan earthquake.

In their calculations of the expected frequencies of the free oscillations of the earth, MacDonald and Ness [1961] have found that it is necessary to take into account the interaction between the main geomagnetic field and the motion of the earth at the core-mantle boundary. This interaction, in addition to changing the frequencies of vibration, will cause a perturbation of the magnetic field. If the disturbance of the field can rise through the mantle it may appear, in spite of attenuation, on the surface magnetograms as a variation with the frequency of the vibrational modes. The most strongly interacting modes will be torsional, since then the motion of the earth is at large angles to the magnetic field at the core-mantle boundary. Little theoretical work has been reported on the possibility of surface observation of this interaction and the results of the calculations are inconclusive [McDonald, 1957]. Experimentally, Winch et al. [1963] examined the regular-run magnetograms after the Chilean earthquake and calculated the power spectrum for the 18 hours after the earthquake. The spectra show peaks at the frequencies of the first two torsional

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modes. While their results are very interesting, the evidence is not clear enough to establish a casual relationship between the magnetic activity and the earthquake.

The Chilean and Alaskan earthquakes were of the same magnitude on the Richter scale. However, only surface waves are used in the determination of the Richter intensity and the Chilean earthquake was much more effective in exciting the free oscillations of the earth as a whole. It was necessary in fact, to use a Fourier analysis of the Lamont strain seismograph of the Alaskan earthquake period to show that the free oscillations had been excited (L. Alsop, personal communication). Since the oscillations were less intense than after the Chilean earthquake, the magnetic variations would also be much less intense. Fortunately, the magnetic field was exceptionally quiet and conditions were ideal for observation of small, long period variations, particularly on the nighttime side of the earth.

Two Varian Associates rubidium vapor magnetometers were recording the total magnetic field intensity, one at Lamont magnetic station in Lebanon, New Jersey, and the other at the Varian Associates facility near Palo Alto, California. They were recording on a continuous basis with a sensitivity capable of detecting a change of 0.2 gamma. The variations of the surface field caused by the torsional modes should start within the first few hours after the earthquake. At least part of the lag is due to the fact that the magnetic disturbance takes time to rise through the mantle.

The rise time is estimated [McDonald, 1957] at about 2 hours for a disturbance of 1-hour period using a particular model of conductivity of the mantle. Using this estimate strictly as an order of magnitude, we examined the magnetic activity appearing during the first 6 or 7 hours after the earthquake. No power spectrum was calculated since the variations on magnetic records, in contrast to those on seismic records, represent highly nonstationary functions. There are typically frequent, sudden, nonperiodic variations that make the results of a power spectrum calculation uninterpretable. It is true that magnetic variations caused by oscillations of the earth would form a pseudo-stationary part of the record but they do not constitute a dominant part of the magnetograms. In the case of the Alaskan earthquake, the magnetic field was so quiet for many hours after the earthquake that the actual records can be examined for earthquake-associated activity.

The periods of the first three torsional modes as calculated are approximately 43, 28, and 22 minutes [MacDonald and Ness, 1961]. In order to display these periods most clearly, the records from the two magnetometers were digitized at 1-minute intervals for a period beginning before the earthquake and continuing for many hours after. The resulting series was smoothed with a 5-point running average to eliminate high frequencies. Figure 1 shows the results drawn to a scale that accentuates the activity. Note that the night was so quiet that typical changes are of the order of a gamma over a half hour. There is no evidence of anything that could be due to the earthquake until 0650 UT. Then, 3 hours and 13 minutes after the start of the Alaskan earthquake, a long period variation appears at New Jersey. A sine wave of 43-minute period is shown in Figure 1 for comparison with the New Jersey variations. The average peak-to-trough time difference of the magnetic variations is 20.4 minutes so that a 40.8-minute period sine wave might be a somewhat better fit; but the difference between 41 and 43 minutes is smaller than the accuracy of the determination of the periods. The amplitude from the first maximum to the first minimum was 1.7 gamma, the largest variation since several hours before the earthquake. The time lag from the beginning of the earthquake is consistent with McDonald's [1957] model using a mantle conductivity at the core-mantle boundary of 10^{-9} emu and an attenuation on transmission through the mantle on the order of 10^{-5} to 10^{-6}.

Any activity due to free oscillations of the earth should be world-wide and simultaneous. Figure 2 compares New Jersey and California at the onset of the activity. The agreement is remarkable. The two curves show no measurable time lag between stations. This simultaneity is in marked contrast to the time difference in the activity that occurs around 0430. Figure 1 shows that the local magnetic variations in California were large enough so that they could have masked a continuation of the 43-minute activity.

The agreement and simultaneity between the two stations is the most persuasive argument in favor of assigning the activity to the earthquake. However, we need to know if this type of agreement occurs often between the two stations. About 100 days of the California and New Jersey records have been compared with one another. On quiet days the two stations agree about 10 per cent of the time. This estimate is made without regard to the type of activity (i.e., micropulsations, irregular changes, etc.). Little work has been done on the long period periodic variations of the earth's field [Horton and Hoffman, 1962], so we do not know if low amplitude, long period, simultaneous activity is rare or common.

Activity due to the free oscillations of the earth should be continuous, although damped. Figure 1 shows that only the first three or four maxima are seen in New Jersey. This is a serious difficulty. If the measured damping of the first few cycles of of the earth's free vibrations was small after the Alaskan earthquake, then the magnetic activity discussed here is fortuitous. However, when a complex body is struck and set into oscillation, modes can be selectively excited. Which modes these will be depends on just how the body is excited. In any real body, for example, the earth, the concept of eigen oscillations is only an approximate one and the modes will, in actuality, be coupled. This coupling will allow the excitation energy in the initially excited mode to pass into other modes until equilibrium is reached. This coupling can cause rapid pseudo-damping of the initially excited mode. After equilibrium is reached, normal damping mechanisms come into play and the oscillations gradually die out. In this regard, it is interesting to note that the seismic records after the Kamchatka earthquake showed just four cycles of long period variations starting about 3-1/2 hours after the earthquake. It was originally suggested [Benioff, 1954] that these were due to the free oscillations of the earth. This hypothesis is often rejected on the grounds that the variations damped too quickly.

As a further check on the possible continuous nature of the magnetic variations, periods long after the earthquake were examined. No 43-minute activity was observed 24 hours after the earthquake on the California record. The magnetic field at that time was so quiet that the intensity of any unobserved oscillations of periods shorter than 1 hour was less than 0.3γ from maximum to minimum.

In conclusion, the possibility remains that magnetic activity appearing 3-1/2 hours after the Alaskan earthquake was induced by the free oscillations of the earth. This result must be considered along with the results shown by Winch et al. [1963] for the Chilean earthquake. Before it can be finally determined if the torsional modes of the earth's oscillation interacts with the main magnetic field to cause surface variations, magnetic records from other severe earthquakes must be studied. One of the main values of the data discussed here will be to compare with data from future earthquakes.

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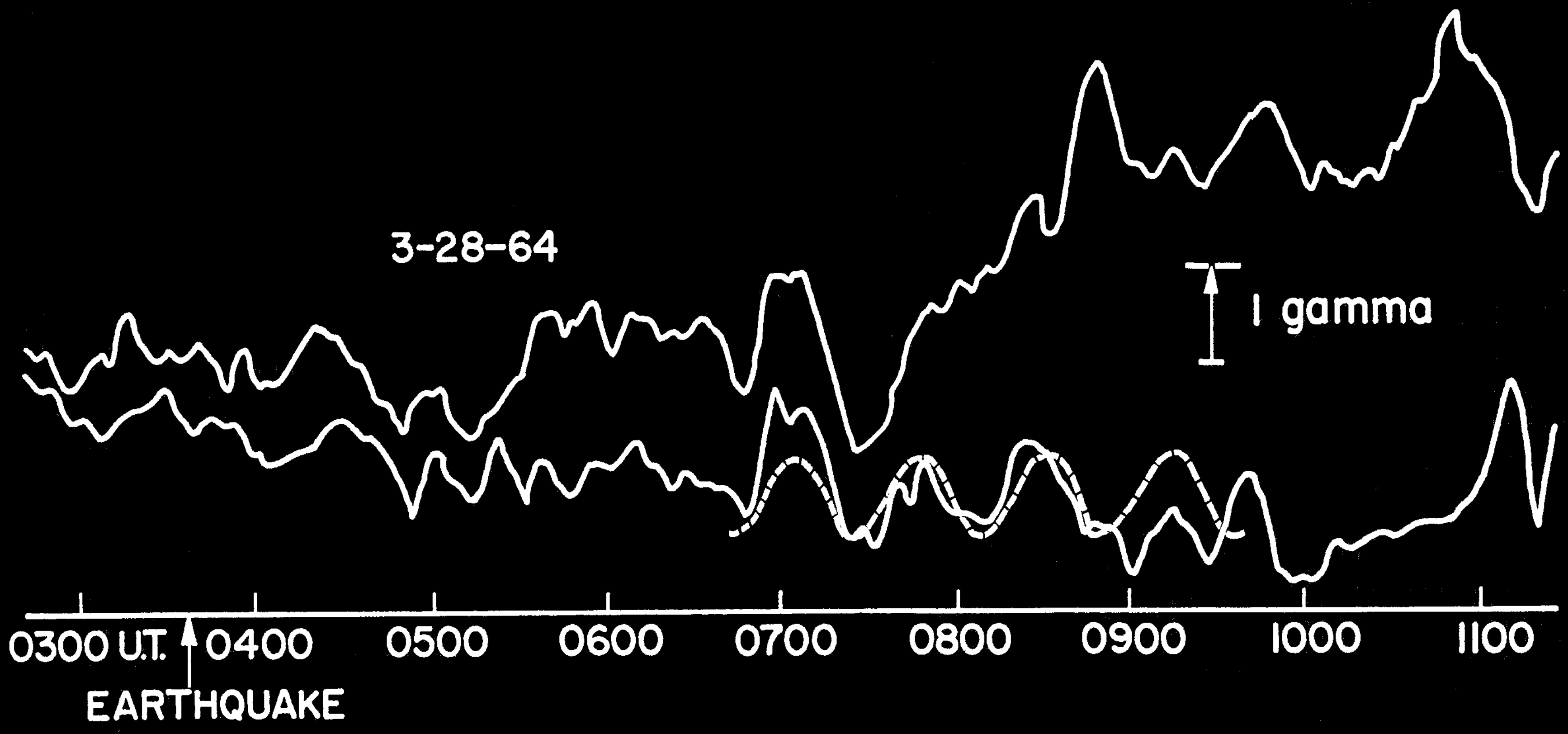
FIGURE LEGENDS

Figure 1.- Magnetic variations following the Alaskan earthquake of 1964. The upper curve is from Palo Alto, California. The lower curve is from Lebanon, New Jersey. The time of the earthquake is indicated by the arrow.

Figure 2.- A comparison of the magnetic activity at Palo Alto, California, and Lebanon, New Jersey, during the onset of the activity. The traces are offset from one another to facilitate comparison. Note the simultaneity.



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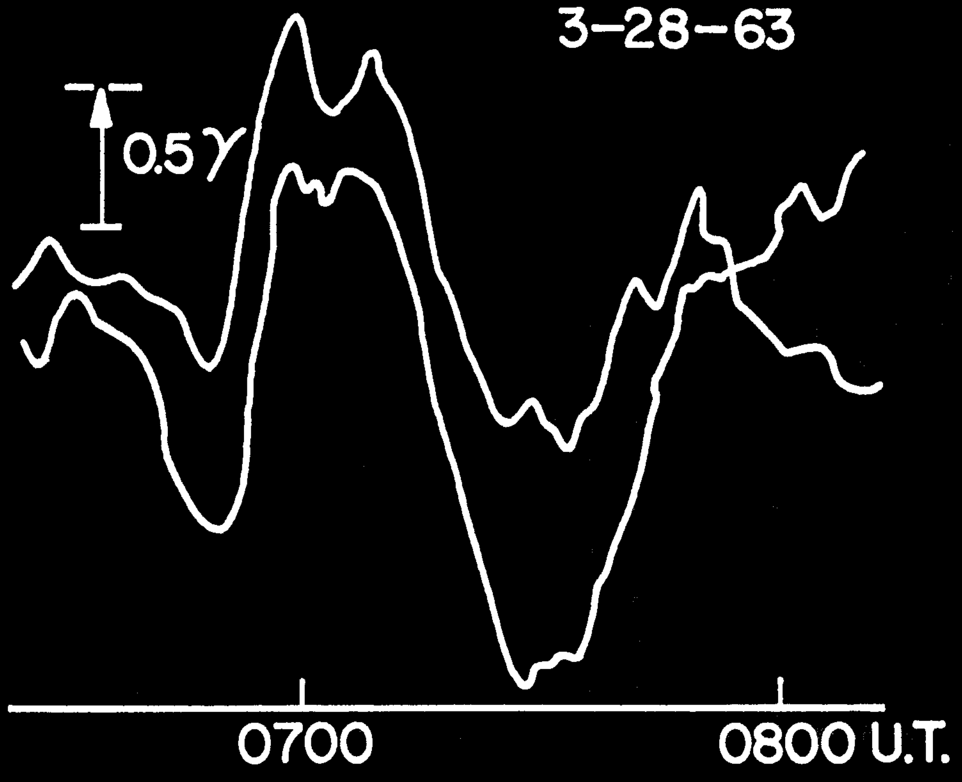

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