DIFFERENCES IN DIURNAL VARIATION OF VERTICAL MAGNETIC INTENSITY IN SOUTHERN CALIFORNIA

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Introduction

This paper sets forth the results of an experimental investigation of the diurnal variation in the intensity of the vertical component of the Earth's magnetic field in the northern half of Southern California. It also presents a discussion of the effect which the diurnal variation may have on the results of magnetic investigations of geologic features in this region. Attention was directed primarily to determining to what degree the diurnal variation is or is not constant over the various areas of the region regardless of the local weather prevailing at the different localities.

Southern California is divided into local topographic areas characterized by diverse atmospheric conditions. Areas open to oceanic breezes are frequently covered with fog and are consequently cool in summer; other districts closed to the sea by ridges may receive simultaneously extreme amounts of solar energy directly from the Sun, or may become heated by foehn or valley winds from adjacent regions. These variable local conditions of energy-absorption and radiation may influence earth-currents if they are considered as induced currents circulating in conductive paths in the Earth's crust. Any change in earth-currents would influence magnetic intensities by the amount of change in magnetic flux produced by the disturbed earth-currents.

It would appear from theoretical considerations that varying atmospheric potential-gradients may also influence magnetic diurnal measurements, but observational evidence on this point is not sufficiently abundant to be conclusive. In accordance with the theory assumed by J. G. Brown[1] in his recent discussion of diurnal variation of atmospheric potential-gradient at Palo Alto, California, it would seem reasonable to expect differences in diurnal variation of the potential gradient, if it were measured over the whole region under discussion. In the main, Brown assumes that the diurnal variation in the potential gradient is produced primarily by variations in the distribution of space-charge, brought about by temperature-changes resulting from expansions and contractions of the air, together with convection-currents which arise. Thus the problem which is presented by the above suppositions consists of many factors but the investigation discussed in this paper will treat these factors collectively rather than individually.

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[1]Potential gradient, Palo Alto, California, Terr. Mag., 35, 1-15 (1930).

Importance of a knowledge of the diurnal variation

In the location and outlining of geologic features associated with large magnetic anomalies, satisfactory results can be obtained with rather crude instruments and methods. But where the anomalies to be expected are small, due to great depth of disturbing matter or the scarcity of magnetic materials in the geologic formations, more sensitive instruments and methods are necessary. There many precautions must be taken to secure results of sufficient accuracy for a logical interpretation in terms of geological conditions.

As it is well known that the elements composing terrestrial magnetism are subject to periodic and aperiodic fluctuations, known as diurnal or daily variations and magnetic storms of various types, it is important that the investigator using magnetic methods should know the magnitude and the time of occurrence of these variations in the area being surveyed, so that he may make the proper corrections.

The diurnal variation is greatest during the daylight hours; at night it is less pronounced and also generally less regular. The amplitude of the diurnal variation differs from month to month, in fact in a small way it varies from day to day. The extent and precise progress of the daily cycle at any given place depend largely upon the geographic latitude. The amplitude increases toward the magnetic poles, and the course of the variations becomes generally more irregular; near the equator, on the contrary, the variations are very steady and regular in their occurrence. The amplitude of the diurnal variations in vertical or horizontal intensity may amount to as much as seventy gammas ($1\gamma = 0.00001$ c.g.s. unit).

This clearly shows the need for a continuous record of the variations, both aperiodic and periodic, so that the visual readings taken in the field with the magnetic field balance can be adjusted to show only the geologic anomaly. Otherwise the diurnal and aperiodic variations may entirely obscure the presence of small anomalies. This necessary information may be secured from records made at magnetic observatories maintained by the United States Coast and Geodetic Survey or from temporary recording-stations maintained in the area under magnetic survey. If one uses the records from distant observatories two difficulties arise, first the data usually are received too late by the field man to be of immediate use and, second, where the distance between the nearest observatory and the area under survey is considerable, the information does not serve the purpose because of reasons which will be discussed later.

The solution of the problem would seem to lie in the establishing of a temporary terrestrial magnetic observing-station in the area where the magnetic measurements are in progress, so that the variations in intensity would be recorded uninterruptedly while the visual field observations are being made.

It has been suggested by men in search for oil-bearing structure that in regions like Southern California one such temporary recording-station would not suffice for the whole territory because there seems to be some evidence that the diurnal variation is not the same for the whole region. The suspected difference in the diurnal variation was attributed to the diverse atmospheric conditions of the local topographic units.

In order to investigate this problem it was only necessary to establish diurnal-variation recording-stations in the various topographic units of the region and then compare the diurnal curves of these stations with respect to amplitude and phase.

Apparatus and procedure

Only one complete set of automatic recording-equipment was available; it was set up and operated at one station for the whole period of the investigation. This necessitated visual recording at all of the other stations.

The recording-set is of the photographic type designed by the Askania Corporation for field use. It consists of a recording-drum driven by a clock and a vertical-intensity variometer in which the telescope has been replaced by a mirror-attachment.

The precision of the magnetograms obtained by the automatic recording-device is much the same as of those prepared from the visual readings. The time-element of the charts was controlled by a precise lever-clock and the time could be determined with an accuracy of three minutes, this being represented by one millimeter distance on the charts. The vertical intensity of the charts was estimated to one-quarter of a millimeter, which represents very nearly one tenth of a scale-division as read on the visual field-balance. The temperature-change was easily estimated to one-tenth of a degree Centigrade as a deviation of 7.2 millimeters was recorded for every change of one degree.

The problem in operating the equipment was, first, to secure a location free from all magnetic disturbances caused by culture, such as electric railways, power-plants, and passing automobiles. Second, there must be provision for keeping the recording-instruments in darkness and, third, for maintaining a constant or very slowly changing temperature. All of these requirements were met in an adit driven 125 feet into the granite of a canyon-wall about two and one-half miles north of Tujunga, a town 15 miles west of Pasadena. The adit is on the Fitzgerald Ranch and furnishes a portion of the water-supply. It is about one-half mile from the private road leading to the main buildings of the ranch and the location was thus ideal, being undisturbed by magnetic disturbances caused by traffic or wandering visitors.

The adit is parallel to the magnetic meridian, facilitating the setting up of the apparatus. Installing three blankets as curtains at the portal afforded the required darkness.

The wrapping of the sensitized paper on the drum was done in the late evening when the outside temperature of the air most nearly approximated that of the adit, so that entering did not cause a perceptible change in the temperature of the recording-instruments. In this way the magnetograms did not show a change of more than one or two degrees Centigrade during 24 hours of recording.

The constants of the recording-apparatus were all determined before taking it into the field and again after it was placed in the adit. Each determination gave 8.4 gammas per millimeter deviation of the vertical-intensity line and one-degree change in temperature gave 7.3 millimeters deviation of the temperature-line, which compares with 7.2 millimeters in the laboratory. The influence of temperature was determined by a heating-and-cooling arrangement which was operated through several ranges of temperature, together with several rates of warming and cooling, and in this way it was found that the influence was practically a linear one for both the recording-instrument and the visual-reading instrument. In the case of the recording-instrument the influence amounted to 1.8 gammas which was to be added to the reading for each degree Centigrade increase in temperature and in the visual-reading instrument the temperature was determined to be 2.1 gammas per degree change in temperature.

As above indicated the constants of the visual-reading balance were determined at the same time as those of the self-recording instrument. The scale-value was adjusted to the value of 21.3 gammas per scale-division. The artificial fields used in the determinations were measured by galvanic methods.

It is to be noted that estimating the deviations of the intensity-variation curve of the megnetograms to one quarter of a millimeter, the variation can be read to the nearest two gammas, but if one allows for a lag of one degree Centigrade in the temperature between that of the thermometer and the effective temperature of the magnetic system, a possible error of three or four gammas may result. But due to the very slow temperature-changes in the adit, it is very unlikely that a lag of one degree in temperature ever existed during the recording-time. The accuracy of the visual balance was of the same order of magnitude as that of the recorder. The readings were estimated to the nearest tenth of a scale-division which is equivalent to two gammas and if we allow for one-degree lag in temperature, we have the same possible error as before. It is, therefore, evident that the instruments gave approximately the same accuracy and the results should be comparable.

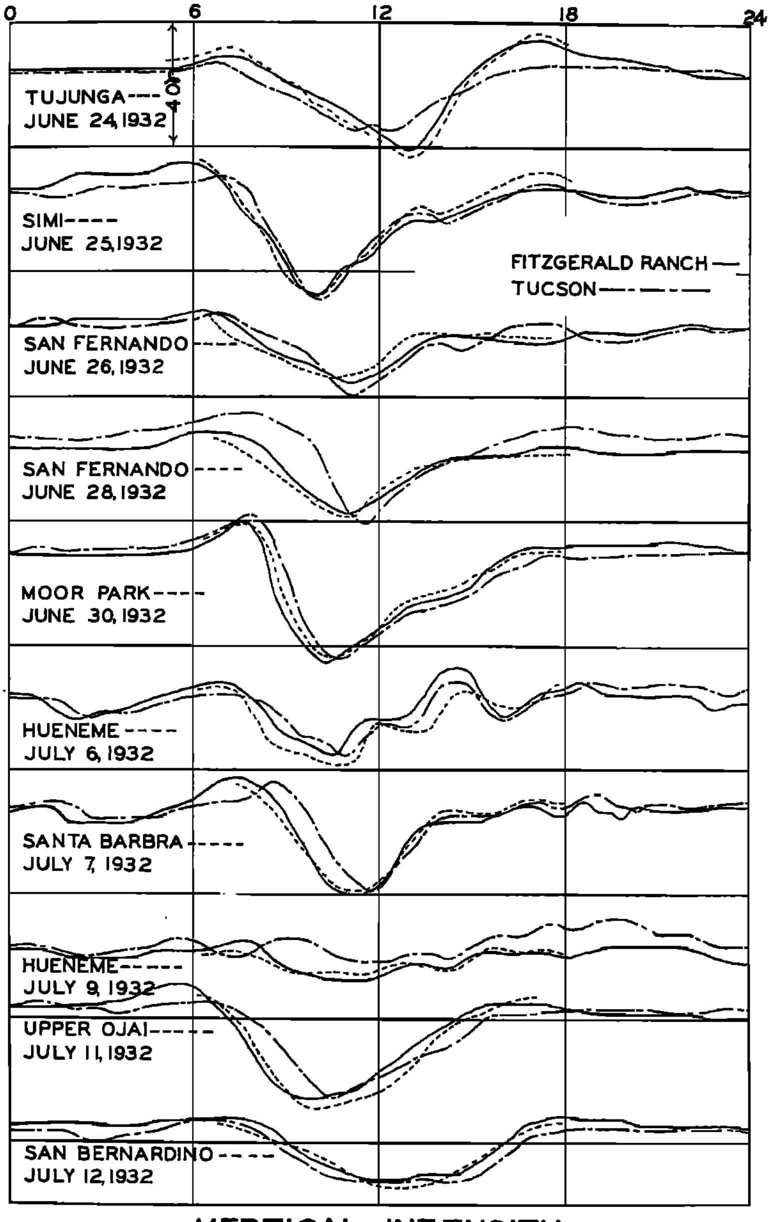
The next step after establishing the recording-station was to locate stations for visual observations at points where different local conditions prevailed and where also no magnetic disturbances from culture would affect the readings. At each selected station a non-magnetic shelter was erected. This shelter consisted of canvas attached to a wood frame with brass screws. A favorable place for the stations was in clumps of trees. The purpose of the shelter was to avoid exceedingly rapid changes of temperature which might be caused by air-currents coming directly in contact with the instruments. The vertical-intensity visual balance was set up in the usual way but the magnetic system was released and remained released throughout the day. Meanwhile the visual readings were taken at time-intervals of 15 or 30 minutes. These readings were converted into gammas and the temperature-correction was applied; a graph was then prepared showing the time and variation at a glance. A graph of similar scale was prepared from the magnetograms so that a close comparison of the two independent results could be made.

Since the diurnal variation is small during the hours of darkness and most magnetic methods of investigating geological problems are carried on during the daylight hours, visual readings were not taken during the nights.

Discussion of data

Through the kindness of Dr. Albert K. Ludy of the United States Coast and Geodetic Survey, blue-print copies of the magnetograms recorded at Tucson, Arizona, were secured so that diurnal curves from a more distant observatory could be compared with those obtained in this region.

Ten of the most typical curves (Fig. 1) were selected and plotted



VERTICAL INTENSITY

FIG. 1

together with corresponding Tucson curves, to show the various degrees of disturbance as well as the relationships of the curves.

The first impression given by the diurnal curves is that the irregular change is the predominant feature, but if the records of the less disturbed days are studied more closely, one finds that they show general features which repeat themselves with considerable regularity; maxima and minima of rather definite values occur at quite definite times of day.

The curves representing the diurnal variation for the days June 24, 25, and 28, 1932, were obtained under similar atmospheric conditions, except that for those from Tucson the weather data are not known. The latter four curves show a general agreement with those from Southern California as to form and amounts of variation except that the Tucson record of June 28 shows in the forenoon a greater degree of deviation from the two California curves. The general agreement is within the limit of errors in the obtaining of the independent results.

It is also interesting to note that the visual readings at Simi were taken in an area of Basalt flows and the vertical-intensity anomalies in this area are very large—700 to 3,000γ are not unusual. And since the curves correspond very closely one might infer that a change of terrestrial-magnetic flux, caused by the diurnal variation, does not induce a change of intensity sufficient to cause a marked difference between the real and apparent diurnal variation in spite of the presence of highly magnetic formations. Two other curves not reproduced herewith, were read in this magnetically disturbed area, but no particular differences could be noted.

The visual curves taken on June 30, July 6, 7, 9, 11, and 12, 1932, were obtained under very different temperature and weather conditions from those existing in the vicinity of the self-recording station. At Hueneme, July 6, 1932, the temperature ranged from 18 to 26 degrees Centigrade and was accompanied by intermittently, faintly shining Sun, while at the self-recording station the temperature ranged from 25 to 35 degrees with a very brilliant Sun. A mild sea breeze was quite noticeable at Hueneme station but wind was not noted in the area near the automatic recording-station. Very similar conditions existed on July 7 while visual readings were in progress at Santa Barbara station. At the Upper Ojai visual recording-station on July 11 the temperature ranged from 26 to 38 degrees Centigrade while at the self-recording station temperatures of 24 to 32 degrees were recorded by a maximum and minimum thermometer near the portal of the adit; both places had a brilliant Sun. Very similar conditions prevailed on July 12 while the visual station was located at San Bernardino.

Although there were certain disturbances which affected the curves somewhat there is no indication that the diurnal variation for any day was different at the two recording-stations by an amount sufficient to impair the use of any one record for a corresponding day anywhere in the entire region. The curves for Southern California also show a rather close relationship to the curves recorded at Tucson, though there are some differences which must not be overlooked.

In most cases the difference in diurnal variation between the California and Tucson curves is insignificant, but where the curves show aperiodic magnetic disturbances there is usually a difference in phase between the two curves. This difference is apparent because the variation is plotted against local mean time but if the variation is plotted against Greenwich mean time there is a very close agreement in phase of the aperiodic variations and a corresponding difference in the phase of the periodic variation.

Conclusions

The evidence obtained in this research indicates that the diurnal variation is nearly constant over the whole region investigated, and there is no indication that the same would not be true of even larger areas. This, however, does not eliminate the hypothesis that local diurnal variation is not to a very small degree a function of the local weather-conditions but it does demonstrate that the effects of local weather upon diurnal variation of vertical intensity are not of any consequence in magnetic methods of geophysical investigation. That is to say, the effects of local weather upon diurnal variation are probably less in magnitude than the errors of our present instruments.

The comparison of the diurnal vertical-intensity variation curves from Tucson with those from Southern California demonstrates the possibility of developing errors by attempting to use records made at distant observatories for the correction of field magnetic readings taken for the purpose of detecting very small geologic anomalies. The diurnal variations, it is true, strongly indicate that they are related in some way to the position of the Sun above the horizon and thus an allowance for differences in local mean time must be made if records of distant observatories are used to correct for diurnal variations. But it often occurs that other variations, notably the short aperiodic ones lasting an hour or two, are superimposed on the periodic diurnal variations in the record and then the apparent variation as shown by the record is only partly governed by local mean time. Therefore it would be inaccurate to cover them by using the records of a very distant observatory with an allowance for the difference in local mean time. Any attempt to differentiate between variations which depend upon mean time and those which do not would probably prove unsuccessful.

The solution of the problem is in the establishing of a temporary terrestrial-magnetic station in the area where the magnetic methods are in progress, so that the variations in vertical intensity may be recorded uninterruptedly while the field-observations are being made. A second solution which is often practiced, is to use the field-instrument as a combined recording- and field-instrument; this merely requires repeating observations at a base-station as often as the accuracy of the work demands in order to obtain the hourly progress of the diurnal variation. With these repeated observations a diurnal-variation curve can be drawn which will yield the approximate back-ground readings needed for correcting the field-station values for the magnetic variations occuring during the progress of the day. A third method for the correction of magnetic values for diurnal and aperiodic variations is suggested by interpolating values of the variations for areas which lie in between two terrestrial-magnetic observatories. In general this method would be limited because of the lack of well distributed observatories.

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