Examination of geomagnetic data as precursors of the September 5, 2018 (MW = 6.6) and August 20, 2016 (MW = 6.0) earthquakes in Japan

Hamideh TAHERINIA[1], Shahrokh POURBEYRANVAND[2]
[1]M.S. student, International Institute of Earthquake Engineering and Seismology, Tehran, Iran, hesar.t.n266@gmail.com
[2]Assistant Prof., International Institute of Earthquake Engineering and Seismology, Tehran, Iran, beyranvand@iiees.ac.ir

SUMMARY

Magnetic anomalies have been discussed long ago as an earthquake precursor. In this study, the characteristic curves are obtained by frequent overplotting of magnetic data per 24-hour time frames on each other for three geomagnetic stations in Japan (MMB, KAK, KNY). All three components (Z, Y, X) or (Z, D, H) were processed in one year. In order to increase the intensity and distinction of the anomalies observed before the earthquake compared to the original data, we tried to eliminate the effect of daily variation of the magnetic field on the geomagnetic records by this method.

Keywords: anomaly, characteristic curve, Earthquake, Japan, magnetic field

INTRODUCTION

Earthquakes are one of the most devastating natural disasters, and their impact on human society, in terms of casualties and economic damage, has been significant throughout history. Earthquake prediction can aid in preparing for this major event, and its purpose is to identify earthquake-prone areas and reduce their financial and human losses. Any parameter that changes before the earthquake in a way that one can predict the earthquake with a careful study of its variations is called a precursor. Recently, more attention has been paid to geophysical, geomagnetic, geoelectrical, and electromagnetic precursors. The term Tectonomagnetism has been used in this context which involves changes in the magnetic field associated with an earthquake. The effect of magnetic seismicity was investigated by Ricky Taki (1976) (Meloni et al., 1998). The effect of magnetic seismicity is quite evident from comparing simultaneous data of a geomagnetic network (Liu et al., 2006). In the present study, the geomagnetic data of three stations, obtained through INTERMAGNET, with a distance of less than 500 km to the September 5. 2018 and August 20, 2016, Japan earthquakes are investigated.

Then the method of characteristic curves is used to remove the effect of diurnal variation of the geomagnetic field. After that, by examining the more distinct anomalies after implementing the method, the cases are matched with the seismic activities of the region. The pure anomaly can be observed by separating the noise from the desired signal. Among the various magnetic components, the horizontal components are more suitable than the others for the proposed process because of more variations in the geomagnetic field in the vertical direction due to f the geomagnetic gradient. Each component behaves differently as a function of the geological and geomagnetic conditions of the station site. In the present study, one year of magnetic data, including three stations and for X, Y, and Z components in addition to seismic data for Japan, are used to implement this method. The method is based on plotting different magnetic field components in specific time intervals in the same 24 hours frame. This will lead to a plot that shows the geomagnetic nature of each component of the geomagnetic field for each station. After averaging the values for every point at the horizontal axis of the plot, which is a unit of time depending on the sampling (hourly mean, minute mean, etc.), a curve will be obtained called the characteristic curve. Then we reduce the characteristic curve values from geomagnetic data to reveal the anomalies free of diurnal variation noise so that the possible anomalies related to earthquakes will be shown more distinctly. After drawing the components of the magnetic field and removing the daily changes from each of the components, we can observe the anomalies related to the earthquakes to justify the observed anomalies better and considering the standard deviation for each component, pre-seismic anomalies have a more significant distinction than the original data for being studied as a seismic precursor.

One of the problems with using this indicator is the ambiguity in separating seismic anomalies from the data (Hayakawa et al. 2007) because the number of factors affecting the earth's magnetic field is large and how some of them affect it is not completely clear. There is ample practical evidence for specific magnetic and electrical oscillations before an earthquake occurs. Previous studies have used discrete wavelet transform to process geomagnetic data to automatically detect the sudden occurrence of magnetic storms (Gamri et al., 2013).

The study of changes in the earth's magnetic field before, at the same time, and after an earthquake has continued from the middle of the last century to the present day, and its related scientific formulations have evolved. Existing theories for interpreting magnetic anomalies related to seismic activity can be classified into three theories: magnetohydrodynamic, electro-synthetic and piezomagnetic. For more information on these theories, refer to the relevant references (Edwin and Roberts 1983).

Methods

According to the research in this field in the present study, this research has been done for Japan using geomagnetic data from three stations with a distance of less than 500 km. The geomagnetic stations used in this study are three stations, MMB, KAK and KNY and this information has been received from the INTERMAGNET site. Based on the Dobrowolski relationship $P = 10^{0.43M}$ (Dobrowolski et al. 1979), it is expected that the prediction phenomena will be observed in a radius of about 700 km. However, due to the lack of data and geomagnetic stations in the region, one of the stations in a radius of about 950 km was inevitably used for this purpose.

Figure (1) shows the location map of the studied stations, as well as the epicenter of the earthquake and seismicity of the region from 1900 to 2014.

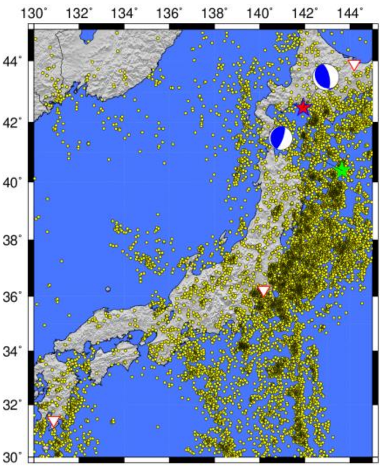

Figure 1. Location map of the studied stations (white triangle), as well as the epicenter of two earthquakes (red star position of the first earthquake and green star position of the second earthquake) and seismicity of the region from 1900 to 2014 (yellow circles).

In this research, the method of characteristic curves has been used to eliminate the effect of factors affecting the earth's magnetic field at the location of magnetometric stations. Relevant is removed from the data.

Then, by examining the abnormalities that have become clearer after the above steps and eliminating the noise due to daily changes, these cases are matched with the seismic activities of the region. Then, by isolating the noise from the desired signal and finally the observed abnormality, it is amplified as much as possible to make more use of the data in question as a precursor to the earthquake.

Among the various magnetic components, the X component is more suitable for the proposed process than the Y and Z components. Of course, other components can also be used depending on the geological and geomagnetic conditions of the station. In the present study, to show examples of the application of this method, the magnetic and seismic data available on the Japan Indicator Database website have been used. To display the data, you must first delete the values that have been registered as unsuitable data, which in the program written in PYTHON, these values have been replaced with their previous values. After selecting the appropriate time period using the available data from each station, the diagram of repeating the observed values over 2 hours on different days shows the desired station's geomagnetic nature; thus, the characteristic curve for a period of one year in the station in question. Comments were made on the magnetic components X, Y and Z in question. Figure (2) shows the characteristic curve at one of the stations for the Y component of the magnetic field of two earthquakes.

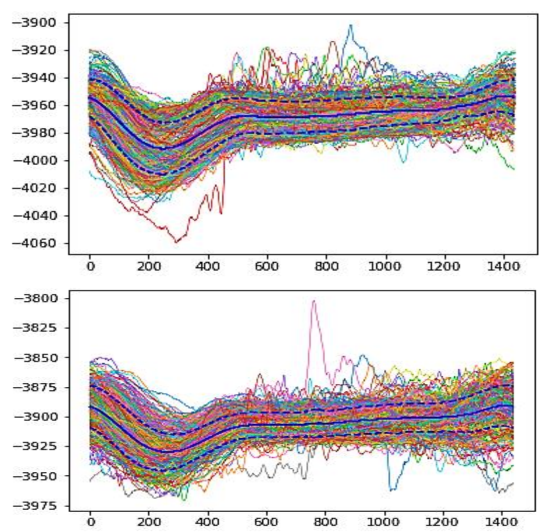

Figure 2. The characteristic curve (continuous line) is drawn at one of the stations for component Y of the magnetic field of two earthquakes (the first figure for the earthquake of 05/09/2018 and the second figure for the earthquake of 20/08/2016). The standard deviation dashes are based on 1s calculations. The horizontal axis represents time (minutes) and the vertical axis represents the amplitude of the magnetic field (nanotesla).

After drawing the magnetic field components and removing the daily changes from each component, one can observe the anomalies related to earthquakes better; to justify the observed anomalies and consider the standard deviation for each component, which is the definition of each component. It is shown in Figure (3) for the first earthquake and in Figure (4) for the second earthquake.

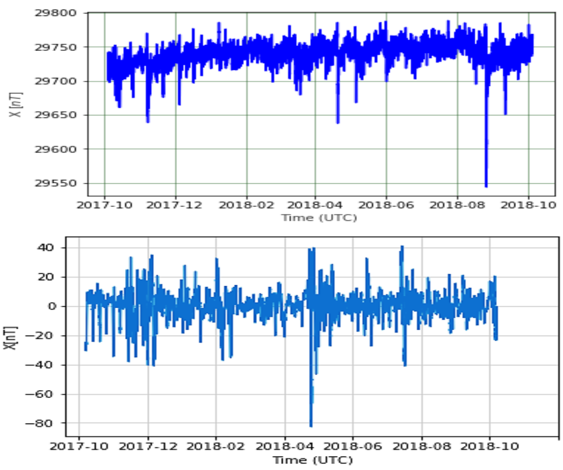

Figure 3. The Characteristic curve for one year of raw data at one station (Figure above) and data processing at the same station (Figure below) for the magnetic component (X).

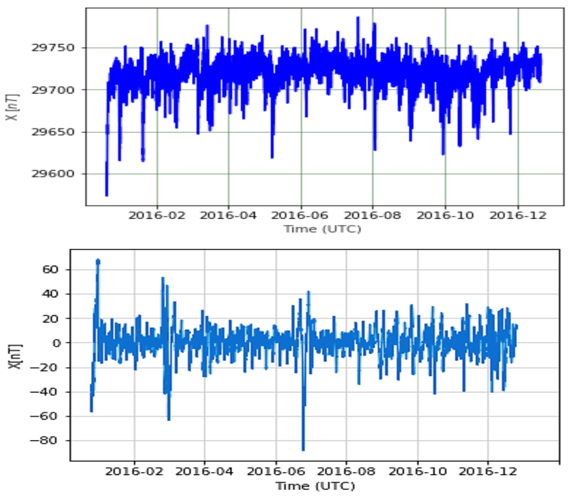

Figure 4. The Characteristic curve for one year of raw data at one station (Figure above) and data processing at the same station (Figure below) for the magnetic component (X).

Due to the fact that an earthquake occurs between 5-15 days after the geomagnetic anomaly, an anomaly is observed in the first earthquake on 26/08/2018, which can be used as an indicator of an earthquake with a magnitude of 6.6 on 05/09/2018. In the second earthquake, the anomaly of 05/08/2016 can be considered as a precursor to the earthquake with a magnitude of 0.6 on 20/08/2016 in Japan. Component X is more suitable for detecting this anomaly and shows a better anomaly. Component X of the magnetic field is compared for raw and processed data and related anomalies to observe the changes made by the characteristic curve method and its application in geomagnetic prediction studies. The first earthquake is shown in Figure (4) and the second earthquake in Figure (5).

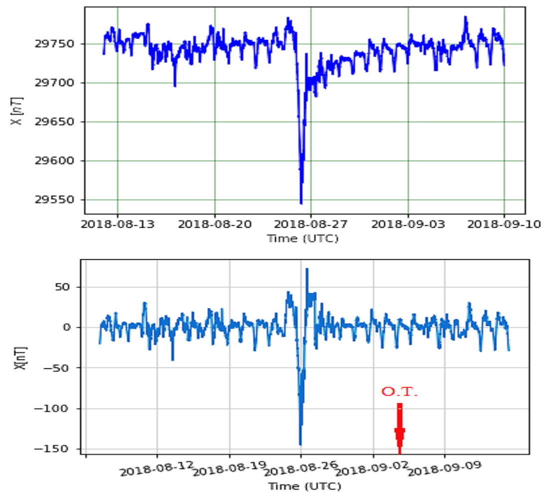

Figure 5. Curves of nature related to raw data (unprocessed, figure above) and data processing along with the time of the first earthquake for the magnetic component (X) (figure below).

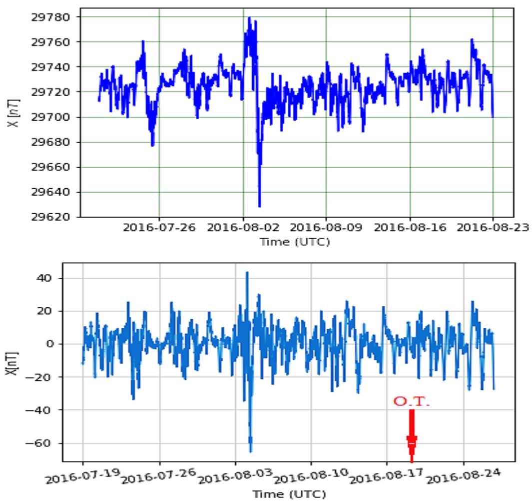

Figure 6. Curves of nature related to raw data (unprocessed, figure above) and data processing along with the time of the second earthquake for

the magnetic component (X) (figure below).

By comparing these two earthquakes, which are related to close geographical points and have approximately equal magnitudes (6.6 and 0.6), it was found that the earthquake of 05/09/2018 occurred at a depth of 35 km and the earthquake on 20/08/2016 Occurred at a depth of 10 km. As shown in Figure (7), the focal mechanism of earthquakes is inverse.

Figure 7. Focal mechanism of earthquake 05/09/2018 (left) and earthquake 20/08/2016 (right).

As shown in the diagrams, between these two earthquakes, the earthquake that occurred at a greater depth has a higher CLVD and has a more non-tectonic component and has a more specific anomaly.

CONCLUSIONS

Based on the obtained results and the processing performed on the magnetic records of three geomagnetic stations in Japan, abnormalities related to the change in the magnetic field have been identified. Finally, by comparing these two identified earthquakes, an earthquake that occurred at a greater depth has a higher CLVD and a more specific anomaly.

ACKNOWLEDGEMENTS

The Intermagnet is appreciated for providing access to the digital geomagnetic data used in this study.

REFERENCES

Dobrovolsky, I.P., Zubkov, S.I. & Miachkin, V.I., 1979. PAGEOPH (1979) 117: 1025. doi:10.1007/BF00876083

Edwin, P. and Roberts, B., 1983. Wave propagation in a magnetic cylinder, Sol. Phys., 88, 179.

Ghamry, E., Yumoto, K. and Yayama, H., 2013. Effect of SC on frequency content of geomagnetic data using DWT application: SC automatic detection. Earth Planets Space, 65, 1007-1015.

Hayakawa, M., Httori, K., and Ohta, K., 2007. Monitoring of ULF (Ultra-Low-Frequency) Geomagnetic variations associated with earthquakes. Sensors, 7, 1108-1122.

INTERMAGNET (hosted by Natural Resources Canada, G. O. (2018, June 18). INTERMAGNET. Retrieved from http://intermagnet.org/index-eng.php.

Meloni A., Mele G. and Palangio P., 1995, Tectonomagnetic field observations in central Italy 1989-1995, Physics of Earth and Planetary Interiors, vol 105, pp 145-152.

Liu J.Y, Chen C.H, Chen Y.I. and Yen H.Y., (2006, Seismo-magnetic anomalies and M ⩾ 5.0 earthquakes observed in Taiwan during 1998-2001, Physics and Chemistry of the Earth, 2006, vol. 31, pp 215-222.

Rikitake, T., 1976. Earthquake Prediction, Elsevier Scientific Publishing Company.