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**Research Article**

# Geomagnetic anomalies observed during earthquakes: A review of Scopus database papers published in English between 1975 and 2024.

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**ABSTRACT**

This bibliometric analysis aims to examine published articles on anomalies observed in the magnetic field due to earthquakes in fourteen seismically active countries between 1975 and 2024. The data used in this analysis are obtained from the online version of the Scopus database and correspond to 290 publications according to the selection criteria. The bibliometric analysis showed that most of the articles were published in English, with the largest number of publications coming from Japan, China, Türkiye, Indonesia, Mexico, the Philippines, Italy, the Russian Federation, and Chile. Out of the 290 articles reviewed, 28 earthquakes showed changes in 6 parameters. The anomaly of the BH component of the magnetic field accounted for 28% of the total. The change in BZ is 20%, D 18%, ΔF 18%, BX 14%, BY 2%.

***Keywords:*** geomagnetic field; variations; earthquakes; anomalies

## 1. Introduction

The relationship between geomagnetic anomalies and seismic activity has generated great interest in the scientific community, particularly as researchers seek to improve earthquake prediction methods. Since the mid-20th century, numerous studies have examined the potential correlation between changes in the Earth's magnetic field and seismic events, and that these anomalies may serve as precursors to earthquakes. This review focuses on articles published in English between 1975 and 2024, with the aim of synthesizing results from the Scopus database to provide a comprehensive overview of the current understanding of earthquake-related geomagnetic anomalies.

The Earth's magnetic field is a natural field that is generated by various geophysical processes, including tectonic movements and interactions in the Earth's core. The geomagnetic field changes due to physical, chemical, and cosmic processes on the earth. These geomagnetic changes can manifest themselves as localized anomalies that can be detected before strong seismic events. Currently, the problem of earthquake prediction is of national, economic, and social importance, and has been the subject of research by many leading scientists in Japan, China, Türkiye, Indonesia, Mexico, the Philippines, Italy, the Russian

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Federation, Chile, Uzbekistan, Kyrgyzstan, and other countries[1-9]. Researchers have used a variety of methodologies to study these phenomena, from satellite observations to ground-based magnetic studies, resulting in a rich but complex collection of literature. Currently, many researchers are trying to advance the relationship between earthquakes and changes in the properties of the Earth's magnetic field during earthquakes in different ways through field studies and scientific research[10-16]. Extensive research has been conducted in this direction using various methods including seismological, geophysical, astrophysical, biophysical and others. The authors note that an electromagnetic precursor is associated with many strong earthquakes. Random and planned observations covered a wide range of electric and magnetic field measurements[17-20]. Merzer and Klemperer[21] proposed a quasi-static model in which the conductivity fault zone acts as an antenna to communicate with the external geomagnetic field to create the observed geomagnetic anomalies. It has been proposed as an effective way to monitor crustal activity. Geomagnetic disturbances detected before fault rupture have been proposed as an effective method for monitoring crustal activity[22-24]. There are many reports of geomagnetic changes associated with earthquakes, and polarization analysis[25-28], principal component analysis (PCA)[29-31] several methodologies have been proposed such as. Fractal analysis[32-33] and low-point displacement analysis[34-36]. Feng et al.[37-39] proposed a method called geomagnetic harmonic wave amplitude ratio analysis (which we will briefly call geomagnetic amplitude ratio analysis in this paper) to obtain the electromagnetic radiation as an earthquake precursor, and numerous studies have been reported.[40-43] The authors also used this method to analyze strong geomagnetic changes, which they believed may be related to earthquakes in the Yunnan area.

The objective of this study is to analyze current work and key regions of research on the impact of earthquakes on the geomagnetic field in a seismically active region, and to use historical scientific data to gain new insights into the trends and directions of research on the impact of strong earthquakes on the geomagnetic field.

## 2. Materials and methods

In this review, we focused on collecting regional knowledge from existing studies. The study was conducted using Scopus database, the most frequently used online bibliographic database, covering the period from 1975 to 2024. We used "geomagnetic field", "earthquakes", "geomagnetic anomaly" and "variation" as keywords, including specific countries such as China, Russian Federation, Japan, Türkiye, Indonesia and Uzbekistan. The analysis was conducted in August 2024. For the analysis, we used CSV file, Microsoft Excel 2021, RIS, vos Viewer and map Chart, each of which performs a specific function during data processing and visualization.

### 2.1. Criteria for selection and review of articles:

For the search process, relevant information such as the keyword "geomagnetic anomaly" and all articles in English were added to the spreadsheet. Article = ("geomagnetic anomaly"), document type = "Article", time range = "1975-2024", science field = Earth and planetary sciences, countries = Japan, China, Indonesia, Philippines, Italy, Türkiye, Mexico, Chile, Russian Federation, Uzbekistan and Tajikistan. Shows the flow chart of the selected research methodology (**Figure 1**). The following exclusion criteria were used during the study.

1. only the title and abstract of the article in English, and everything else in another language
2. articles from other areas of research
3. lack of definition of search queries (stability, responsiveness, sustainability).

4. many articles do not have DOI and have limited article search capabilities. In general, these articles could not be excluded using the filter options in Scopus.

### 2.2. Bibliometric analysis

The data obtained in CSV format were loaded into Excel for bibliometric analysis. Before starting the analysis, the data were carefully checked for errors. The peer-reviewed articles were analyzed and the most relevant ones were identified, their corresponding authors – those who authored the most articles. The articles retrieved from the search were evaluated and classified according to various aspects: number of articles per year, top list of articles, top journals, top authors, distribution by subject categories and journals, and affiliation by countries and institutions. Finally, co-authors and co-occurrence of keywords were analyzed to study the cognitive components and structure of the research field by identifying clusters of authors of the literature and the most common keywords in the literature.

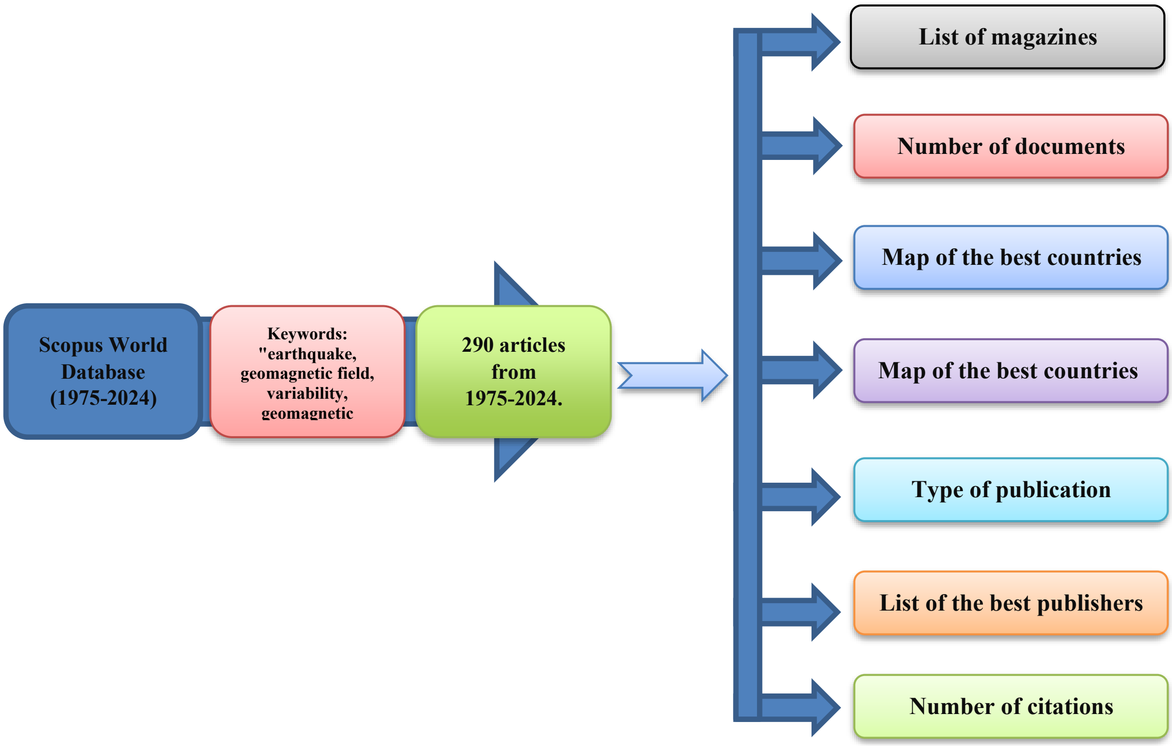


**Figure 1.** Scheme of the research methodology.

## 3. Results and discussions

### 3.1. Trends of magnetic anomalies observed in the geomagnetic field due to earthquakes

A total of 290 published articles on the problem of geomagnetic anomalies worldwide were studied during 1975-2024 (**Figure 2). The number of publications increased by 1-34 during the period from 1982 to 2024. Figure 2 s**hows that 30 more articles were published in 1975-76 than in 1982, and the least number of articles were published during the period from 1982 to 2009. It has the most publications in 1978, 2020, 2024. These published articles contain information on more than 100 general and detailed 28 earthquakes for example (**Table 1**). Of these, from 1992 to 2018, 10 earthquakes with a magnitude of M = 6.2-9 were observed in Japan, in which anomalies of D, H, Z, $B_X$ were observed in 4 parameters. In 2023, 2 earthquakes with a magnitude of M = 4.9-6.8 were recorded in Morocco, and an anomaly was observed in $B_X$. In 2018, an earthquake with a magnitude of M = 7.1 occurred in New Caledonia, in which an anomaly of $B_X$, $B_Y$, $B_Z$ was observed. In 2014, 2 earthquakes with a magnitude of M = 6.4-6.9 occurred in the Aegean Sea, in which an anomaly in $B_H$ was observed. In 2016, an earthquake with a magnitude of M = 5 occurred in the North Caucasus, in which an anomaly in $B_H$ was also observed. In 2021-2022, 7 earthquakes with magnitude M=3.1-5.5 were observed in China, and various anomalies were observed in ΔF and other earthquakes.

According to the obtained results, changes in only 6 parameters were observed in 28 earthquakes. The anomaly of the $B_H$ component of the magnetic field was 28% of the total. The change in $B_Z$ is 20%, D 18%, ΔF 18%, $B_X$ 14%, $B_Y$ 2%. (**Figure 3**)

**Table 1.** An example of conducting geomagnetic surveys in seismically active regions of the world.

| № | Name of countries | Station | Year | Magnitude (M) | Parameters |
|---|---|---|---|---|---|
| 1 | **Japan's East Sea Region** | **PXT** Chengdu | 11.03.2011 | M=9.0 | ΔD≈26S, ΔH≈28S, ΔZ≈95S and the total field strength ΔF≈31S, (S represents the standard deviation of the local geomagnetic field at normal times;) |
| 2 | | | 11.04.2011 | M=7.3 | |
| 3 | **Japan** (Yunnan) | **TCH** Tengchong<br>**THJ** Tonghai<br>**CHX** Chuxiong<br>**YOS** Yongsheng | 23.04.1992 | M= 6.9 | D/H/Z |
| 4 | | | 27.01.1993 | M=6.3 | D/H/Z |
| 5 | | | 12.07.1995 | M=7.3 | D/H/Z |
| 6 | | | 24.10.1995 | M=6.5 | D/H/Z |
| 7 | | | 03.02.1996 | M=7.0 | D/H/Z |
| 8 | | | 20.11.1998 | M=6.2 | D/H/Z |
| 9 | | | 15.01.2000 | M=6.5 | D/H/Z |
| 10 | **Japan** | **KHB** Xabarovsk | 24.01.2018 | M=6.3 | Earthquake time: UTC 10:50<br>Maximum amplitude change :<br>UTC 10:37; $B_X$= 4.2 nTl<br>UTC 10:54; $B_X$= 3.6 nTl<br>UTC 11:07; $B_X$= 4.7 nTl |
| | | **IRT** Irkutsk | | | Maximum amplitude change UTC 10:37; $B_X$= 5 nTl<br>UTC 10:54; $B_X$= 4.3 nTl<br>UTC 11:07; $B_X$= 5.4 nTl |
| | | **NVS** Novosibirsk (Klyuchi) | | | Maximum amplitude change :<br>UTC 10:37; $B_X$= 3.8 nTl<br>UTC 10:54; $B_X$= 3.3 nTl<br>UTC 11:07; $B_X$= 3.3 nTl |
| | | **SPG** S. Peterburg | | | Maximum amplitude change :<br>UTC 10:32; $B_X$= 4 nTl<br>UTC 11:11; $B_X$= 6.1 nTl |
| | | **MHV** Mixnevo | | | Maximum amplitude change :<br>UTC 10:32; $B_X$= 5 nTl<br>UTC 11:11; $B_X$= 6.2 nTl |
| | | **KIV** Kiev | | | Maximum amplitude change :<br>UTC 10:32; $B_X$= 3.7 nTl |

| № | Name of countries | Station | Year | Magnitude (M) | Parameters |
|---|---|---|---|---|---|
| | | | | | UTC 11:11; $B_X$= 4.3 nTl |
| 11 | **Morocco** | | 08.09.2023 | M=6.8 | Maximum amplitude:<br>$B_X$ ~1 to ~10 nTl;<br>duration ~ 50 ~80 min; |
| 12 | | | 08.09.2023 | M=4.9 | |
| 13 | **New Caledonia** | **MHV**<br>Mixnevo | 29.08.2018 | M= 7.1 | Anomalies were observed in the $B_X$, $B_Y$, $B_Z$ components;<br>Estimated time of the earthquake: UTC 03:51; 2 minutes after the earthquake, a short-term change was observed for 3 minutes from UTC 03:53 to UTC 03:56, with a maximum amplitude of 4 nTl;<br>7 minutes after the earthquake, a long-term change was observed for 5 minutes from UTC 03:59 to UTC 04:04, with a maximum amplitude of 5.5 nTl |
| 14 | **Aegean Sea** | **MHV**<br>Mixnevo | 24.05.2014 | M= 6.4 | Anomaly observed in the $B_H$ component;<br>Estimated time of the earthquake: UTC 09:30;<br>Maximum amplitude of change:<br>UTC 09:23; $B_H$ =1.4 nTl;<br>UTC 09:30; $B_H$ =1.8 nTl;<br>(short-term changes)<br>A short-term change was observed for 3 min from UTC 09:35 to 09:38, 5 min after the earthquake, with a maximum amplitude of 1.5 nTl |
| 15 | | | 24.05.2014 | M= 6.9 | |
| 16 | **North Caucasus** | **MHV**<br>Mixnevo | 07.08.2016 | M= 5.0 | Earthquake time: UTC 08:15<br>$B_H$ value changed from 15814nTl to 15824nTl; between UTC 08:03 and 08:33; |
| 17 | **Honduras** | **MHV**<br>Mixnevo | 10.01.2018 | M= 7.5 | Earthquake time: UTC 02:51<br>$B_H$ value changed from 15580nTl to 15584nTl; between UTC 02:50 and 03:20; |
| 18 | **Ecuador** | **MHV**<br>Mixnevo | 07.09.2018 | M= 6.2 | Earthquake time: UTC 02:51<br>$B_H$ value changed from 15834nTl to 15849nTl; between 01:00 and 03:00 UTC; |
| 19 | **China**<br>(Xingwen County, Yibin City,<br>Sichuan Province) | | 17.11.2021 | M=3.1 | Gradients of geomagnetic anomalies: ΔF before the earthquake was from -100nTl to -200nTl, after the earthquake a negative anomaly was observed from -180nTl to -210nTl; |
| 20 | **China**<br>(Changning District, Yibin City, Sichuan Province) | | 21.11.2021 | M=4.6 | ΔF was 100nTl before the earthquake, and a positive anomaly of 300; 380; 250nTl was observed during and after the earthquake; |
| 21 | **China**<br>(Weiyuan County, Neijiang<br>City, Sichuan Province) | | 26.11.2021 | M=3.3 | ΔF before the earthquake was -50nTl, no anomaly was observed; |
| 22 | **China**<br>(Changning District, Yibin City,<br>Sichuan Province) | | 01.12.2021 | M=4.2 | After the earthquake on 2021.12.01, the gradient value of the geomagnetic anomaly ΔF drops to -390nTl; |

| № | Name of countries | Station | Year | Magnitude (M) | Parameters |
|---|---|---|---|---|---|
| | | | | | -300nTl on 2021.12.05; |
| 23 | **China**<br>( Yanyuan County, Liangshan Prefecture, Sichuan P.) | | 12.12.2021 | M=3.0 | ΔF before the earthquake is 220nTl, after the earthquake is 200nTl; |
| 24 | **China**<br>(Ningnan County, Liangshan Prefecture, Sichuan P.) | | 21.12.2021 | M=3.3 | Between 2021.12.12 and 2021.12.21, ΔF (>400)nTl and (> -400)nTl<br>Positive and negative anomalies were observed; |
| 25 | **China**<br>(Ninglang District, Lijiang City, Yunnan Province) | | 02.01.2022 | M=5.5 | Between 2021.12.21 and 2022.01.02, (>400)nTl and (>-400)nTl positive and negative anomalies were observed; before the earthquake, ΔF -250; 260nTl and 270nTl during the earthquake; after the earthquake, an anomaly of -380nTl was observed; |
| 26 | **New Guinea** | **IRT**<br>Irkutsk | 29.03.2018 | M=6.9 | Earthquake time: UTC 21:25<br>Maximum amplitude change:<br>UTC 21:17; $B_X$= 5 nTl<br>UTC 21:51; $B_X$= 7 nTl<br>UTC 22:25; $B_X$= 9.2 nTl |
| | | **NVS**<br>Novosibirsk (Klyuchi) | | | Maximum amplitude change:<br>UTC 21:17; $B_X$= 5.4 nTl<br>UTC 21:51; $B_X$= 7.3 nTl<br>UTC 22:25; $B_X$= 7.7 nTl |
| | | **BOX** | | | Maximum amplitude change:<br>UTC 21:17; $B_X$= 10.2 nTl<br>UTC 21:51; $B_X$= 14.8 nTl<br>UTC 22:25; $B_X$= 13.2 nTl |
| | | **MHV**<br>Mixnevo | | | Maximum amplitude change:<br>UTC 21:17; $B_X$= 7.8 nTl<br>UTC 21:51; $B_X$=11.1 nTl<br>UTC 22:25; $B_X$= 8.7 nTl |
| | | **SPG**<br>S. Peterburg | | | Maximum amplitude change:<br>UTC 21:18; $B_X$= 8.2 nTl<br>UTC 21:53; $B_X$= 12.1 nTl<br>UTC 22:26; $B_X$= 11 nTl |
| | | **KIV**<br>Kiev | | | Maximum amplitude change:<br>UTC 21:18; $B_X$= 6 nTl<br>UTC 21:53; $B_X$= 8.4 nTl<br>UTC 22:26; $B_X$= 8.1 nTl |
| | | **BEL**<br>Belsk | | | Maximum amplitude change:<br>UTC 21:18; $B_X$= 7.5 nTl<br>UTC 21:53; $B_X$= 11.3 nTl<br>UTC 22:26; $B_X$= 9.6 nTl |
| 27 | **Indonesia** | **KHB**<br>Xabarovsk | 15.04.2018 | M=6.0 | Earthquake time: UTC 19:30<br>Maximum amplitude change:<br>UTC 18:13; $B_X$= 2.6 nTl<br>UTC 19:22; $B_X$= 1.9 nTl<br>UTC 20:00; $B_X$= 2.4 nTl |
| | | **IRT**<br>Irkutsk | | | Maximum amplitude change:<br>UTC 18:13; $B_X$= 5.5 nTl<br>UTC 19:22; $B_X$= 3.6 nTl<br>UTC 20:00; $B_X$= 4.2 nTl |
| | | **NVS**<br>Novosibirsk (Klyuchi) | | | Maximum amplitude change:<br>UTC 18:13; $B_X$= 5.7 nTl<br>UTC 19:22; $B_X$= 3.8 nTl<br>UTC 20:00; $B_X$= 3.8 nTl |

| № | Name of countries | Station | Year | Magnitude (M) | Parameters |
|---|---|---|---|---|---|
| | | **MHV**<br>Mixnevo | | | Maximum amplitude change:<br>UTC 18:13; $B_X$= 7.8 nTl<br>UTC 19:22; $B_X$= 7 nTl<br>UTC 20:00; $B_X$= 6.1 nTl |
| | | **QUTI**<br>Borok | | | Maximum amplitude change:<br>UTC 18:15; $B_X$= 8.7 nTl<br>UTC 19:21; $B_X$= 8.9 nTl<br>UTC 20:05; $B_X$= 10.6 nTl |
| | | **KIV**<br>Kiev | | | Maximum amplitude change:<br>UTC 18:15; $B_X$= 5.8 nTl<br>UTC 19:21; $B_X$= 5.7 nTl<br>UTC 20:05; $B_X$= 6.1 nTl |
| | | **SPG**<br>S. Peterburg | | | Maximum amplitude change:<br>UTC 18:15; $B_X$= 7.8 nTl<br>UTC 19:21; $B_X$= 8.6 nTl<br>UTC 20:05; $B_X$= 8.8 nTl |
| | | **BEL**<br>Belsk | | | Maximum amplitude change:<br>UTC 18:15; $B_X$= 6.7 nTl<br>UTC 19:21; $B_X$= 7.5 nTl<br>UTC 20:05; $B_X$= 8.8 nTl |
| 28 | **Tajikistan** | **NVS**<br>Novosibirsk<br>(Klyuchi) | 09.05.2018 | M=6.2 | Earthquake time: UTC 10:41<br>Maximum amplitude change:<br>UTC 10:43; $B_X$= 11.3 nTl<br>UTC 11:16; $B_X$= 13.3 nTl |
| | | **IRT**<br>Irkutsk | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 15.6 nTl<br>UTC 11:16; $B_X$= 12.9 nTl |
| | | **MHV**<br>Mixnevo | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 16.6 nTl<br>UTC 11:16; $B_X$= 15.6 nTl |
| | | **QUTI**<br>Borok | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 28.4 nTl<br>UTC 11:16; $B_X$= 31.7 nTl |
| | | **KIV**<br>Kiev | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 12.9 nTl<br>UTC 11:13; $B_X$= 12.3 nTl |
| | | **BEL**<br>Belsk | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 12.6 nTl<br>UTC 11:13; $B_X$= 14.6 nTl |
| | | **KHB**<br>Xabarovsk | | | Maximum amplitude change:<br>UTC 10:43; $B_X$= 10.6 nTl<br>UTC 11:18; $B_X$= 10.1 nTl |

**Table 1.** (*Continued*)

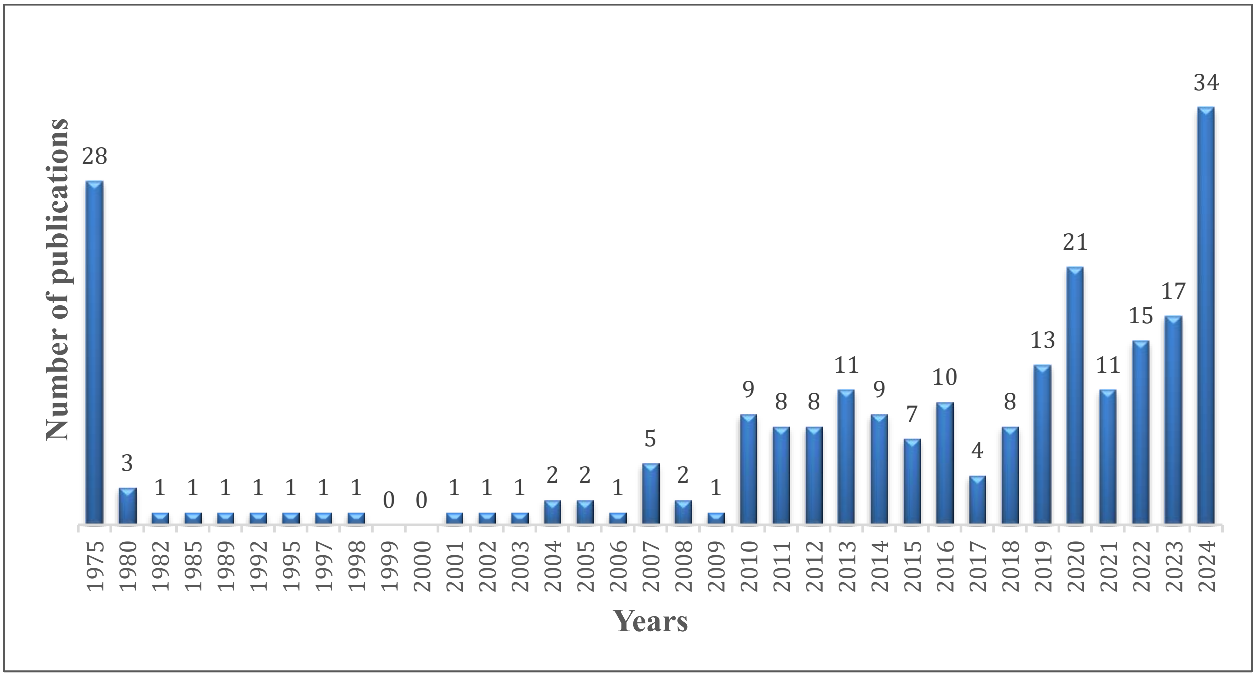


**Figure 2.** Number of articles on geomagnetic anomalies worldwide from 1975 to 2024.

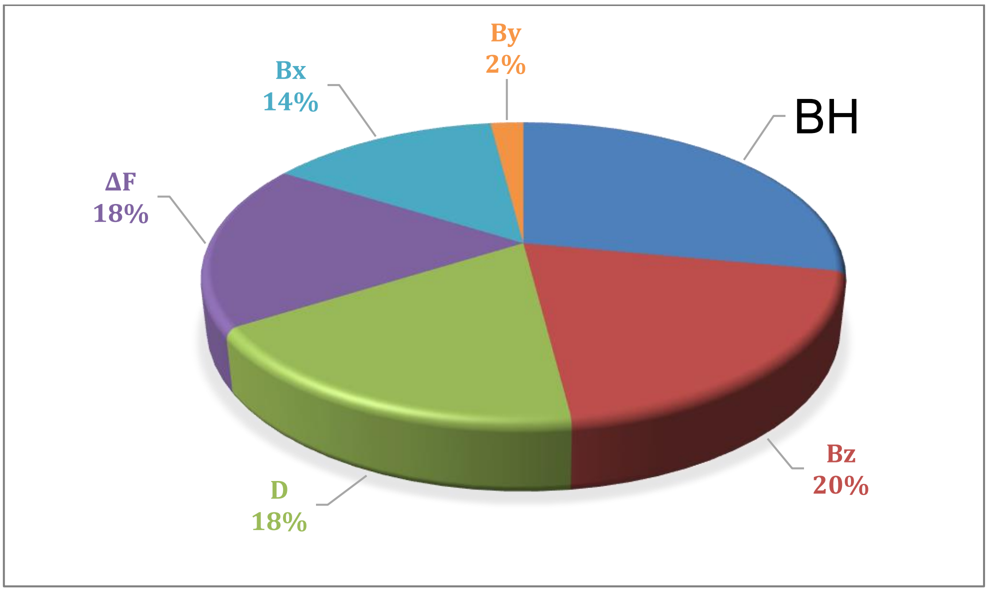


**Figure 3.** Quantitative expression of geomagnetic anomalies during earthquakes observed from 1975 to 2024.

### 3.2. Journals on geomagnetic anomalies during earthquakes

Scientists from all over the world publish their research in various journals. Based on the models of scientific communication, a general distribution of publications was made across 65 journals published in many countries. Of these 290 articles, 100 (54.9%) were published in 10 journals, and the remaining 45.1% were published in other journals (**Figure 4**). The titles of 38 journals are given, in which at least 2 or more articles were published during the specified period (**Table 2**).

**Table 2.** List of journals published on earthquake-induced geomagnetic anomalies.

| Scopus source title | Quantity | Scopus source title | Quantity |
|---|---|---|---|
| Journal of Geophysical Research | 17 | Contributions to Geophysics and Geodesy | 3 |
| Natural Hazards and Earth System Sciences | 13 | Earth and Planetary Physics | 3 |
| Researchgate International Journal of Geosciences | 13 | Natural Hazards | 3 |
| Annals of Geophysics | 10 | Sensors | 3 |
| Geophysical Journal International | 9 | SpaceWeather | 3 |
| Entropy | 8 | Tectonophysics | 3 |
| Open Journal of Earthquake Research | 8 | Acta Geophysica | 2 |
| Physics of the Solid Earth | 8 | Advances in Space Research | 2 |
| Remote sensing | 8 | Contents lists available at ScienceDirect Tectonophysics | 2 |
| New Concepts in Global Tectonics Journal | 6 | Earth sciences | 2 |
| Aplied science | 5 | Frontiers in Earth science | 2 |
| Geosciences | 5 | Geomatics, Natural Hazards and Risk | 2 |
| GIAB. Mining Informational and Analytical Bulletin | 5 | International journal of earth science | 2 |
| Doklady Earth Sciences | 4 | Journal of geomagnetism and geoelectric | 2 |
| Geofisica internacional | 4 | Journal of Geophysical Research Atmospheres | 2 |
| Geophysical research | 4 | Journal of Volcanology and Seismology | 2 |
| Geophysics | 4 | Pure and Applied Geophysics | 2 |
| J. Geomag. Geoelectr., | 4 | Solnechno-zemnaya fizika | 2 |
| Atmosphere | 3 | Universe | 2 |

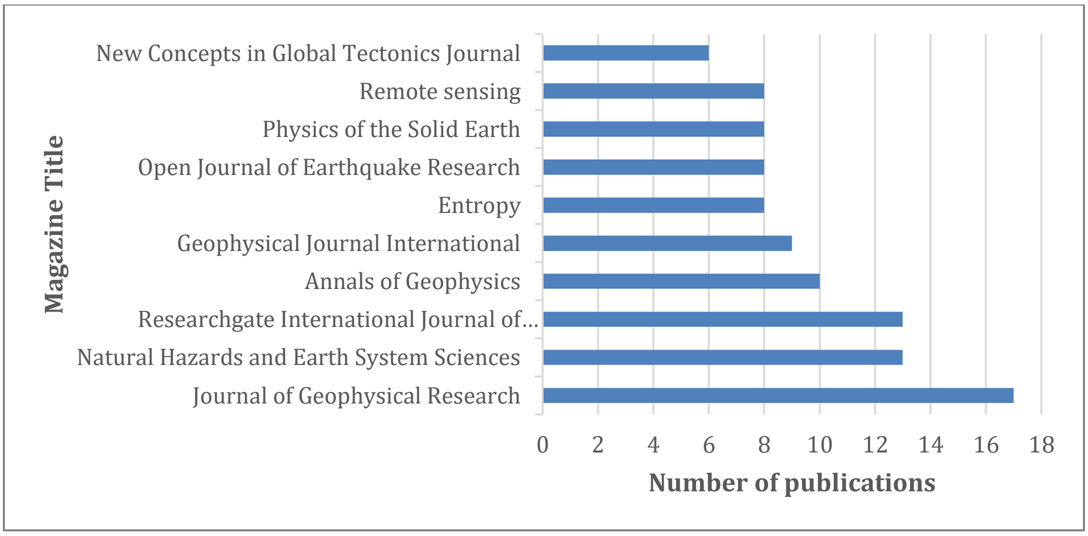


**Figure 4.** List of the most frequently published journals on geomagnetic anomalies during earthquakes from 1975 to 2024.

## 3.3. Authors and their associated countries

Our study showed that 607 authors from more than 14 countries conducted research on earthquake-induced geomagnetic anomalies during the period from 1975 to 2024. There are 10 authors who published seven or more articles (**Figure 5**). Among them, Katsumi Hattori published 18, followed by Suaidi. Ahad 10,

M. Hayakawa 10, A. Kotsarenko 8, K.N. Abdullabekov, David Lanose, Khairul Adib Yusuf, Nurul Shazana Abdul Hamid, Mardina Abdulla, Peng Han published 7 scientific articles each.

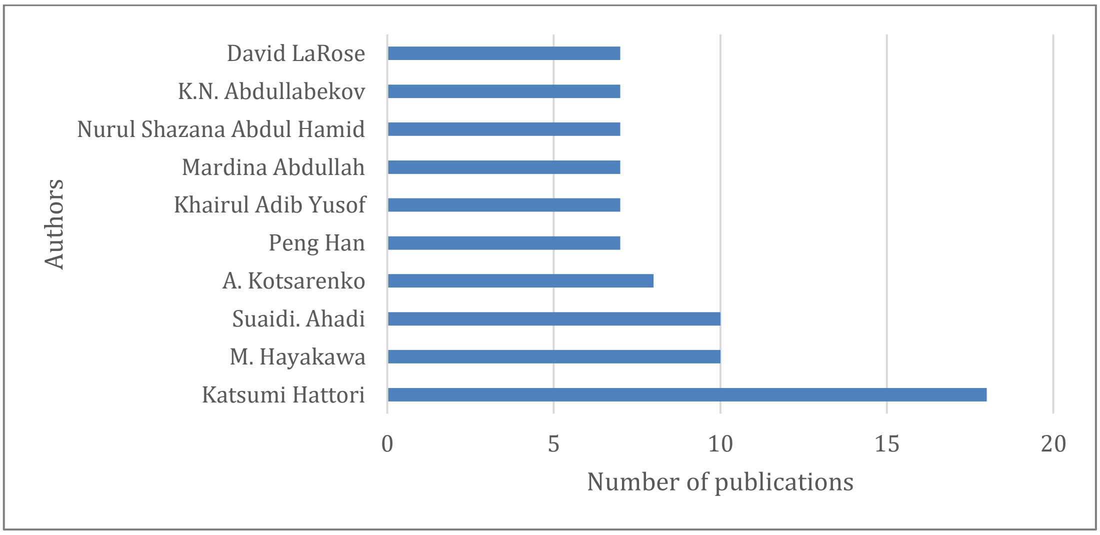


**Figure 5.** List of the most published authors on geomagnetic anomalies during earthquakes from 1975 to 2024.

### 3.4. List of leading countries in published geomagnetic anomalies

The top eight countries that most frequently observed geomagnetic anomalies during earthquakes from 1975 to 2024 are shown. The leaders among them are Japan (45; 15.5%), China (38; 13.1%), Chile (31; 10.7%), Türkiye (23; 7.9%), Mexico (23; 7.9%), Indonesia (21; 7.2%), Italy (14; 4.8%), the Philippines (13; 4.5%), Uzbekistan (7; 2.4%) and other countries (75; 25.8%) (**Figure 6**).

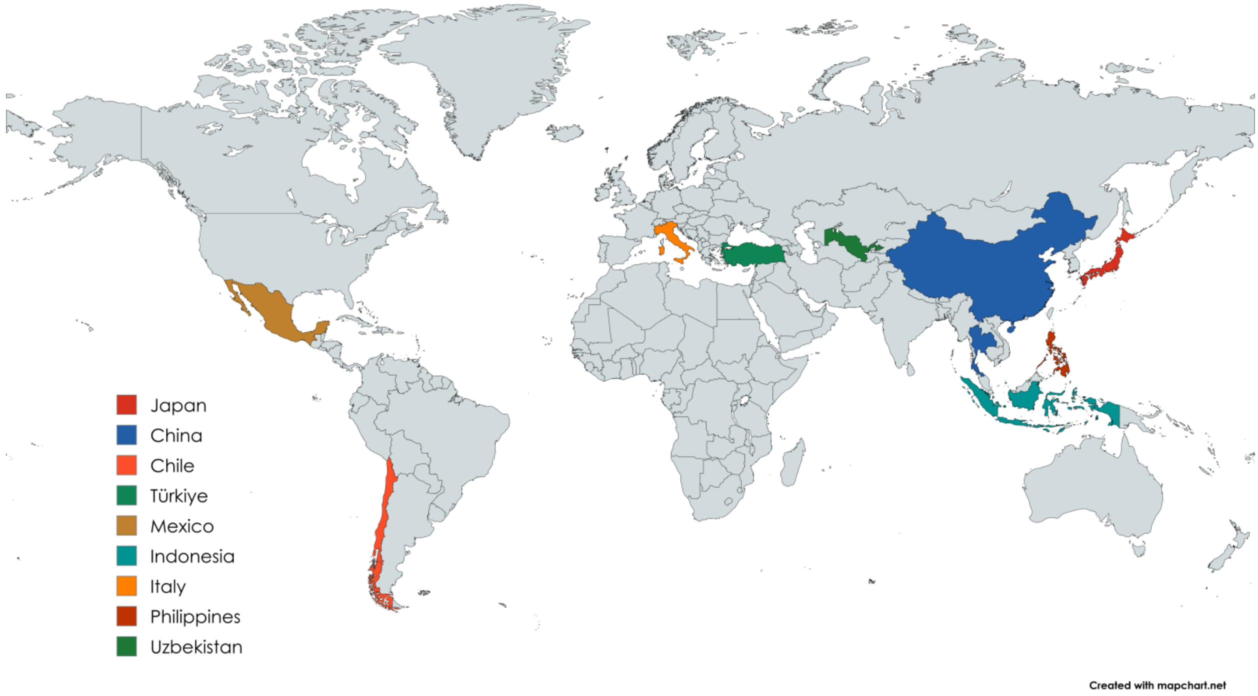


**Figure 6.** List of countries leading in the registration of geomagnetic anomalies.

### 3.5. Co-authors and keywords about geomagnetic anomalies

Using VOSviewer software, co-authorship, keyword co-occurrence, citation, bibliographic combination and co-citation maps can be created from bibliographic information. The supported file formats include .txt, ris and .csv from databases such as Scopus (Samir Kumar Jalal, 2019). The file was imported into vosviewer and the software generated a co-author and keyword co-occurrence map (shown in **Figures 7, 8**). The co-authorship analysis resulted in a network of 600 authors.

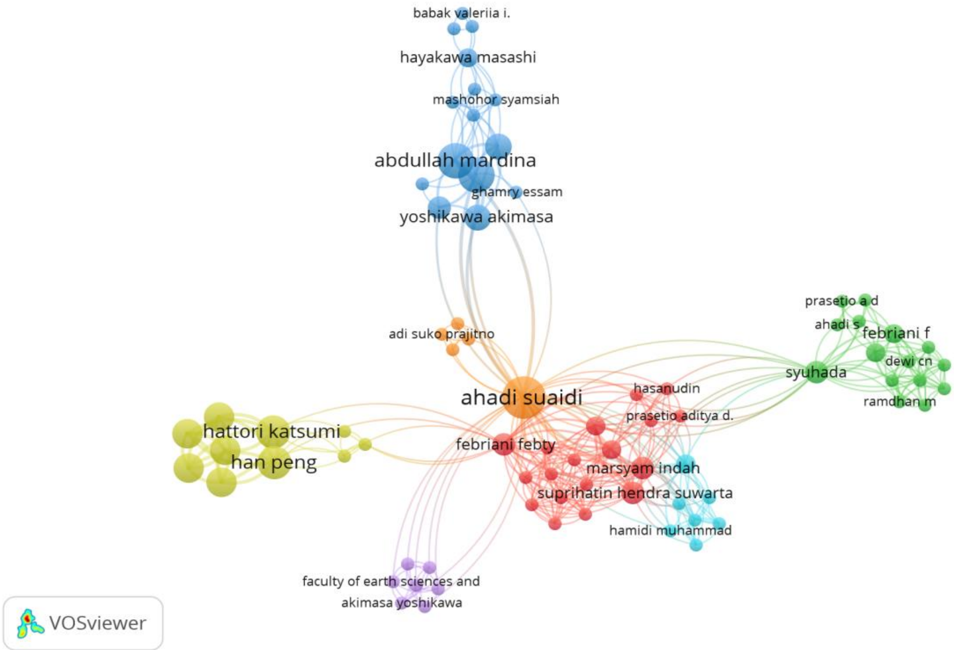


**Figure 7.** Network map of top collaborators based on overall connection strength.

The analysis identified 530 keywords. After eliminating less relevant and rare keywords (by default, at least five keyword iterations are selected to strengthen results that occur together), 20 items were identified. Based on the total link strength, each resulting keyword is compared to a node and a network map of all keywords is created. **Figure 8** shows the network map of the top 20 authors by keyword. The size of the node reflects the importance of the keyword.

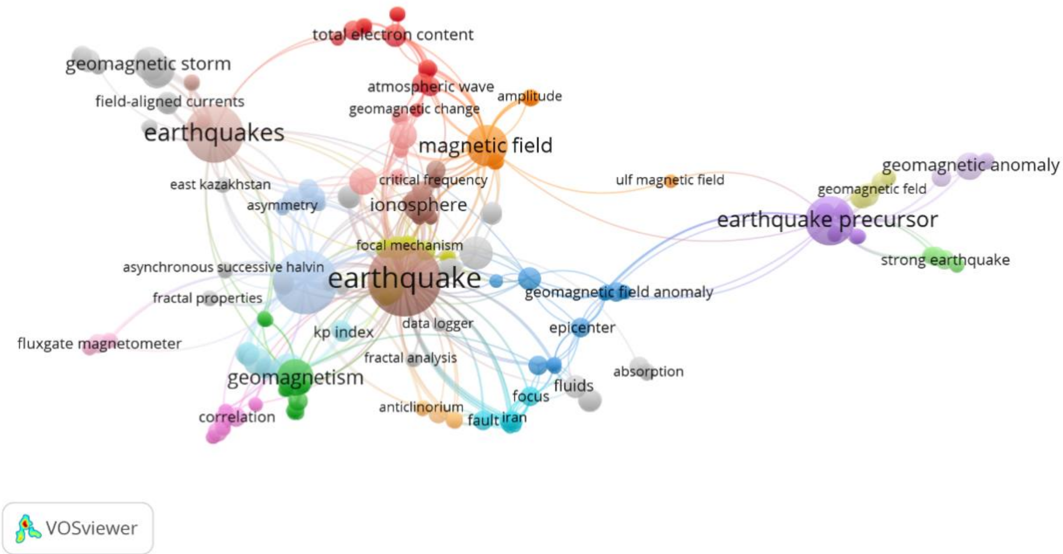


**Figure 8.** Network map of top keywords based on overall link strength

## 4. Discussion

Thirty-one articles were published in 1975-1976. From 1982 to 2006, the publication of articles decreased significantly. In 2007-2009, the average number of articles was 8. In 2010-2012, this figure will reach 25. In the period from 2013 to 2016, 37 articles were published respectively. The publication of articles increased significantly in the period from 2017 to 2024, and 123 articles were published during these years. According to the results obtained, changes in only 6 parameters were observed in 28 earthquakes. The anomaly of the $B_H$ component of the magnetic field accounted for 28% of the total. The change in $B_Z$ is 20%, D 18%, ΔF 18%, $B_X$ 14%, $B_Y$ 2%.

## 5. Conclusion

Possible formulations: Bibliometric and statistical analysis of scientific literature on geomagnetic anomalies Comprehensive bibliometric analysis of publications on geomagnetic anomalies Statistical review and bibliometric analysis of geomagnetic anomaly studies Bibliometric and statistical study of publication activity on geomagnetic anomalies In more detail: Bibliometric analysis — involves the study of quantitative characteristics of publications: the number of articles, authors, journals, publication dynamics, geography, etc. Statistical analysis — allows you to identify patterns in the data (for example, the types of anomalies and their distribution over time, regions, magnetic field components, etc.)

This study provides a comprehensive bibliometric statistical analysis of the literature on geomagnetic anomalies observed in the magnetic field from earthquakes during 1975-2024 worldwide. According to the results, changes in only 6 parameters were observed in 28 earthquakes. The anomaly of the $B_H$ component of the magnetic field accounted for 28% of the total. The change in $B_Z$ is 20%, D 18%, ΔF 18%, $B_X$ 14%, $B_Y$ 2%. The results showed that the number of publications has increased significantly over the past 14 years. Scientists mainly preferred to publish their findings in academic journals (91%). The largest number of geomagnetic studies were conducted in Japan, where 10 earthquakes with magnitudes of M=6.2-9 with anomalies in 4 parameters were recorded during the period from 1975 to 2024.

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