ANNALI DI GEOFISICA, VOL. 41, N. 4, October 1998

Historical geomagnetic measurements in Romania

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Abstract
Following studies which give complete compilations of declination and inclination data for some European sites, this paper presents the geomagnetic field behaviour in Bucharest, over more than two centuries. The paper also discusses all the early survey measurements (declination, *D*, inclination, *I*, horizontal component, *H*) made in Romania, since the end of the nineteenth century.

Key words *geomagnetism – historical measurements – Romania*

1. Introduction

Nearly four hundred years ago, Gilbert (1600) made a simple, but profound statement «*Magnus magnes ipse est Globus terrestris*», which may be considered as the beginning of the modern science of geomagnetism. It has developed from a philosopher's curiosity into an active science, through the improvements of theory, instruments, quality, quantity and distribution of the observation points (of course, not always in that order). When regular observations of the components of the Earth's magnetic field at a place commenced, one could discern systematic patterns in the temporal field variation. By spherical harmonic analysis of the observed field, Gauss was able to build models of the Earth's magnetic field. At present, we are interested in obtaining such models over the last four centuries (Bloxham and Jackson, 1992), and to do this a uniformly distributed collection of data at the Earth's surface is required. Old geomagnetic data are helpful in constructing an accurate picture of the geomagnetic field behaviour in the past, in order to understand the process by which it is sustained.

Due to the importance of the magnetic compass in navigation, measurements of magnetic *declination*, *D* (the angle between geographical north and magnetic north) have existed for many places around the globe since the early sixteenth century. The unfortunate delay of 200 years in gathering sufficient interest in *inclination*, *I* (the angle between the magnetic field vector and the horizontal) reflects the greater difficulty in measuring it and its lesser importance for navigation. This implies that the full directional unit vector cannot be accurately reconstructed before 1750.

When studying the secular variation of the geomagnetic field over the last four centuries it is important to evaluate the accuracy and reliability of the available time series of measurements. The purpose of this paper is to comple-

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ment equivalent studies presented recently for some Europeans sites, such as London (Malin and Bullard, 1981), Rome (Cafarella *et al.*, 1992), Edinburgh (Barraclough, 1995) and Paris (Alexandrescu *et al.*, 1996). In addition to examining time-series for three cities (Bucharest, Jassy and Cluj), we also present repeat station measurements made at the end of the last century and during this century, covering the present-day territory of Romania.

2. Sources of data

Three important sources of data have been used. The first is the important compilation of Constantinescu (1979). Constantinescu presents not only the results of his own research, but also includes information on earlier work related to the geomagnetic field variation in the former Romanian Principalities of Wallachia and Moldavia (Hepites and Murat, 1907), in Transylvania (Atanasiu, 1937, 1943; Barta, 1954), in Bukowina (Atanasiu, 1940) and in the whole territory of Romania (Procopiu, 1941). This work also discusses the quality of data, their resolution, timing and their use in describing geomagnetic field evolution in this part of Europe (fig. 1).

The second source of information is a series of original Romanian papers found in the Romanian National Library in Bucharest, related to geomagnetic field measurements made at the beginning of this century.

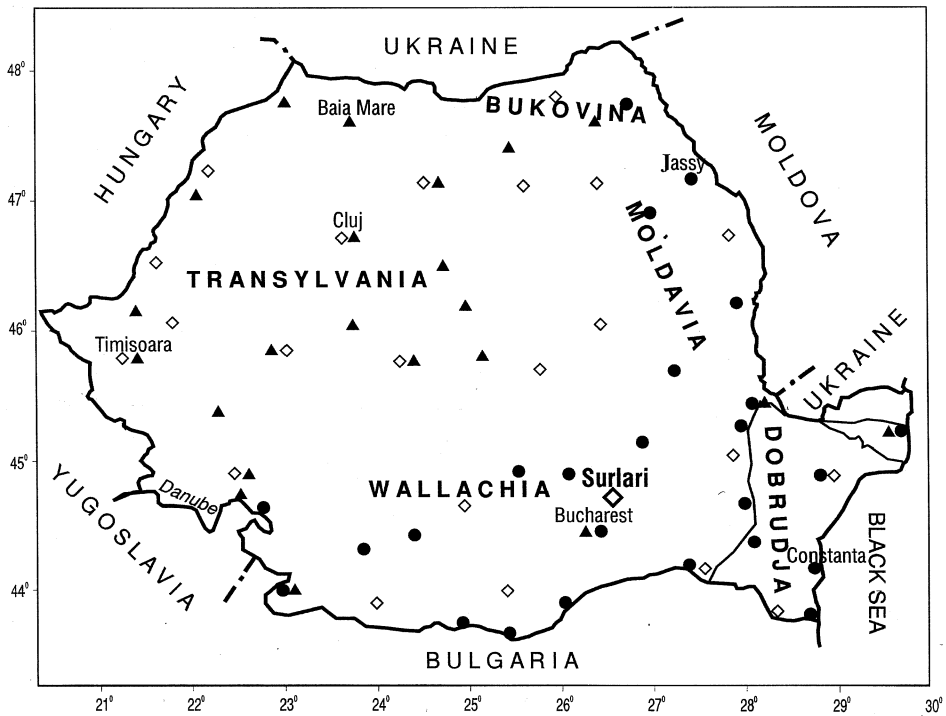


Fig. 1. Map showing the present-day Romanian territory (with the former Romanian Principalities) considered in this study. The sites of geomagnetic measurements during the first part of the last century, published by Struve (1845) (full circles) and by Kreil (1851, 1852) (full triangle) are shown. The present-day Romania repeat-station network (22 points) and the national geomagnetic observatory of Surlari are also shown (open diamonds).

The third source of data is a series of foreign compilations of data published during the last century (Sabine, 1838; Hamilton, 1838; Duperrey, 1840; Kreil and Fritsch, 1850; Kreil, 1851, 1852, 1862), and containing data on Romania (fig. 1).

3. Geographical distribution of geomagnetic data

For the Romanian territory, there are only three measurements of the Earth's magnetic field available before the nineteenth century. The oldest one is a determination of the declination at Bucharest in 1772, by the astronomer Islenieff (Hepites and Murat, 1907). The simple statement «*Declinatio acus magneticae Bucaresti 24 Jun. (5 Jul.) observato est* 11°36′1/2 *versus occidentum*» is important as being the first value of the geomagnetic declination for Romania's capital, where subsequent determinations were to be performed. Unfortunately, our efforts to find the original source were unsuccessful (according to Weinberg (1929, 1932) it is Rumovski (1773)). Another value for declination earlier than the nineteenth century is for Baia Mare, a town situated about 700 km north of Bucharest (fig. 1). The value 15°30′W for 1785 at Baia Mare is given by Barta (1954). The third measurement is again for Bucharest: in 1798 the declination is 13°50′W.

During the first half of the 19th century a number of measurements were made. One isolated measurement is reported by Duperrey (1840) as being made by Gauttier in the Danube Delta in 1824.

An important series of measurements were made between 1828 and 1831 in Moldavia, Wallachia and Dobrudja, by officers of the Imperial Staff of the Russian Army; their results were sent to the astronomer Struve. Published by Struve (1845) and in part by Duperrey (1840), these data from 25 stations in Romania are presented and discussed by Constantinescu (1979) and their positions are included in fig. 1. As recommended by this last author, attention must be paid to the names of the stations (the identification is more difficult for Shurshah which is Giurgiu and Chiastenza which is Constanta), the use of the Paris meridian as the reference for longitudes (in Duperrey's tables) and some very clear errors in declination values (for example, the value for Giurgiu must be erroneous by comparison with the values at two nearby stations and knowing that there is no significant magnetic anomaly in the region). Table I gives the corresponding values of declination, extracted from the tables of Struve and Duperrey.

More systematic measurements were made at 22 stations, from 1843 to 1858 by Kreil, sometimes aided by Fritsch (fig. 1). They used good quality instruments, quite modern for their time (Lamont magnetic theodolite and Repsold dip compass). They are the first three-component measurements (D, I and horizontal component, H) made in Romania. These measurements, after careful control of various disturbing causes, were adjusted to the epoch 1850.0. They have also been published by Constantinescu (1979). This data set (table II) is important for the knowledge of the geomagnetic field in Romania at this epoch.

At the end of the nineteenth century (1893-1894), measurements were made at 17 geomagnetic repeat stations and the results were published by Negreanu and Muresianu (1894). However, the Romanian territory at this epoch was rather different from present-day Romania, and so now the distribution appears to be biased towards the eastern and southern regions. The values of D, H and I were adjusted to the epoch 1895.0 (table III).

A very important survey was performed by Hepites and Murat (1907) who over a period of about twenty years (1881-1901) made measurements of D, H and I at 72 stations. This data set is remarkable for the uniform distribution of the stations over the territory and the accuracy of the measurements. Hepites and Murat (1907) also drew the first contour maps of geomagnetic field elements over Romania for the 1906.0 epoch, and plotted the variation of the geomagnetic field at five of these stations (these figures are not re-published in the present paper).

At the beginning of this century an important series of geomagnetic field measurements

Table I. Declination for sites in Romania before 1850.0.

Date[a]	Name[b]	λ^c	ϕ^d	D^e
1772.50	Bucharest	44 25 39	26 35 23	11 36.0
1785.50	Baia Mare	47 38 –	23 38 –	15 30.0
1798.50	Bucharest	44 25 39	26 35 23	13 50.0
1824.50	Danube Delta	45 14 –	29 20 –	10 10.0
1828.82	Babadag	44 53 40	28 44 25	12 09.8
1828.72	Braila	45 16 11	27 58 11	10 43.1
1828.93	Constanta	44 10 21	28 42 02	11 32.8
1828.70	Galati	45 26 12	28 02 56	11 01.9
1828.94	Hirsova	44 41 04	27 54 30	11 48.8
1828.56	Jassy	47 10 24	27 35 43	11 50.7
1828.98	Ploiesti	44 56 21	26 16 09	11 48.8
1828.67	Roman	46 55 22	26 55 19	11 30.5
1828.93	Seimeni	44 22 27	28 00 50	11 40.4
1829.05	Bucharest	44 25 39	26 35 23	9 14.4
1829.36	Buzau	45 09 01	26 48 52	12 04.8
1829.54	Calarasi	44 12 29	27 19 24	11 13.8
1829.30	Focsani	45 41 49	27 10 19	11 19.0
1830.69	Barlad	46 13.50	27 54 17	10 44.9
1830.48	Mangalia	43 48 31	28 37 18	12 13.1
1831.24	Botosani	47 45 05	26 39 38	09 43.5
1831.65	Calafat	43 59 34	22 55 36	11 42.8
1831.65	Cerneti	44 38 04	22 42 06	14 51.0
1831.64	Craiova	44 19 08	23 47 43	12 48.1
1831.39	Giurgiu	43 53 15	25 57 33	09 07.3 ?
1831.50	Pitesti	44 51 05	24 52 04	12 47.0
1831.60	Slatina	44 25 56	24 20 56	13 22.8
1831.50	Tirgoviste	44 56 15	25 26 27	12 48.0
1831.40	Turnu Magurele	43 44 39	24 52 09	11 01.7
1831.40	Zimnicea	43 39 08	25 21 14	10 15.2
1846.50	Jassy	47 10 24	27 35 43	09 30.0

[a] Date of the measurement, in fractional years; [b] Name of the measurement point; [c] Latitude (north), in degrees, minutes and seconds; [d] Longitude (east), in degrees, minutes and seconds; [e] Declination (west), in degrees and minutes.

Table II. Geomagnetic elements in Romania, adjusted to 1850.0.

No.[a]	Name[b]	λ^c	ϕ^d	D^e	I^f	H^g
1	Satu Mare	47 47	22 56	10 11	63 18	20660
2	Baia Mare	47 38	23 38	09 51	62 52	21000
3	Suceava	47 38	26 17	08 58	62 48	20880
4	Iacobeni	47 26	25 21	09 07	62 36	20980
5	Bistrita	47 07	24 33	09 50	62 34	21114
6	Oradea	47 04	21 59	10 54	62 47	20840
7	Cluj	46 45	23 40	09 54	62 21	21190
8	Tirgu-Mures	46 32	24 38	10 12	62 15	21360
9	Sighisoara	46 13	24 52	10 10	61 43	21660
10	Arad	46 11	21 19	10 55	62 00	21180
11	Alba Iulia	46 04	23 39	09 42	61 37	21690
12	Dobra	45 54	22 33	10 15	61 34	21480
13	Fagaras	45 50	25 03	09 41	61 20	21780
14	Sibiu	45 47	24 13	09 33	61 17	21850
15	Timisoara	45 45	21 12	10 50	61 41	21340
16	Caransebes	45 24	22 12	10 25	61 06	21620
17	Galati	45 26	28 03	07 40	61 31	21970
18	Sulina	45 09	29 40	07 17	– –	22450
19	Mehadia	44 53	22 25	10 37	60 30	21840
20	Orsova	44 42	22 24	10 35	60 47	21940
21	Bucharest	44 25	26 06	09 03	60 14	22440
22	Calafat	44 00	22 56	10 19	62 22	21360

[a] Number of the station, in decreasing order of latitude; [b] Name of the station; [c] Latitude (north), in degrees and minutes; [d] Longitude (east), in degrees and minutes; [e] Declination (west), in degrees and minutes; [f] Inclination, in degrees and minutes; [g] Horizontal component, in nT.

was made by Procopiu (1933, 1941), who made measurements at 85 stations, throughout a period of about ten years. Procopiu used the data previously published by Hepites and Murat (1907) and adjusted all the data to the epoch 1940.5. He also installed a geomagnetic station in Jassy, which worked from 1931 until 1971 (Procopiu, 1931).

An important event for Romanian geomagnetic research was the construction of the national observatory, at Surlari (latitude 44°40.8′N, longitude 26°15′E), in 1943. Located about 30 km north of Bucharest, the observatory is the reference point for geomagnetic observations for the whole of Romania. Some years after the beginning of the observatory's recordings, two teams led respectively by L. Constantinescu and G. Atanasiu organised magnetic measurements throughout Romania (Constantinescu and Steflea, 1961; Atanasiu *et al.*,

Table III. Geomagnetic elements in Romania, adjusted to 1895.0.

No.[a]	Name[b]	λ^c	ϕ^d	D^e	I^f	H^g
1	Adjud	46 06	24 50	–	60 27	22600
2	Bacau	46 34	26 54	–	60 47	22400
3	Barlad	46 14	27 54	–	60 33	22600
4	Botosani	47 44	26 38	04 25	–	–
5	Braila	45 16	27 59	03 50	59 33	22900
6	Bucharest	44 25	26 06	04 50	59 03	23300
7	Constanta	44 11	28 40	–	58 31	–
8	Craiova	44 19	24 38	–	59 15	23100
9	Dorohoi	47 56	26 25	–	62 24	21900
10	Focsani	45 42	27 10	04 30	–	–
11	Giurgiu	43 53	25 58	–	58 32	–
12	Husi	46 40	28 04	–	60 33	22400
13	Jassy	47 10	27 35	–	61 29	22300
14	Ploiesti	44 56	26 16	–	59 30	23000
15	Predeal	45 32	25 35	–	59 56	22800
16	Roman	46 55	26 55	04 22	61 12	22300
17	Turnu Severin	44 35	22 38	–	59 40	22900

[a] Number of the station; [b] Name of the station; [c] Latitude (north), in degrees and minutes; [d] Longitude (east), in degrees and minutes; [e] Declination (west), in degrees and minutes; [f] Inclination, in degrees and minute; [g] Horizontal component, in nT.

1965). In 1966 the Romanian repeat station network was established. It consists of 22 stations, uniformly distributed over the territory (fig. 1). Unfortunately, an absurd legislation restricted the publication of the declination values: the *D*, *H*, *Z* values for Surlari observatory are available, but the *D* data from the repeat stations have not been released, for military strategic reasons.

The above situation changed after 1990. In 1995-1996 the Surlari observatory team made absolute measurements at all 22 stations, using modern instruments (DI-fluxgate theodolite and proton magnetometer). These measurements and those published for the epoch 1940.5 have been used to draw maps of the geomagnetic field covering more than half a century. Figure 2a-c shows the field variations for the *D*, *H*, and the vertical component, *Z*. For 1940.5 the agonic line passes through the western part of Romania. The secular variation in *D* seems to be quite different in the western part, where its mean value is about 4′/yr, than in the eastern part of the territory, where its mean value is about 5.2′/yr. For *H* the general tendency is east-west. The secular variation is constant in the northern part (about 4 nT/yr), but changes between the southwestern (about 3.6 nT/yr) and the southeastern parts (less than 1.8 nT/yr). Comparison of the contours for 1940.5 and 1996.5 reveals an interesting reversal in the pattern of secular variation in the Eastern and Southern Carpathian mountains, and particularly in the well-known «curvature

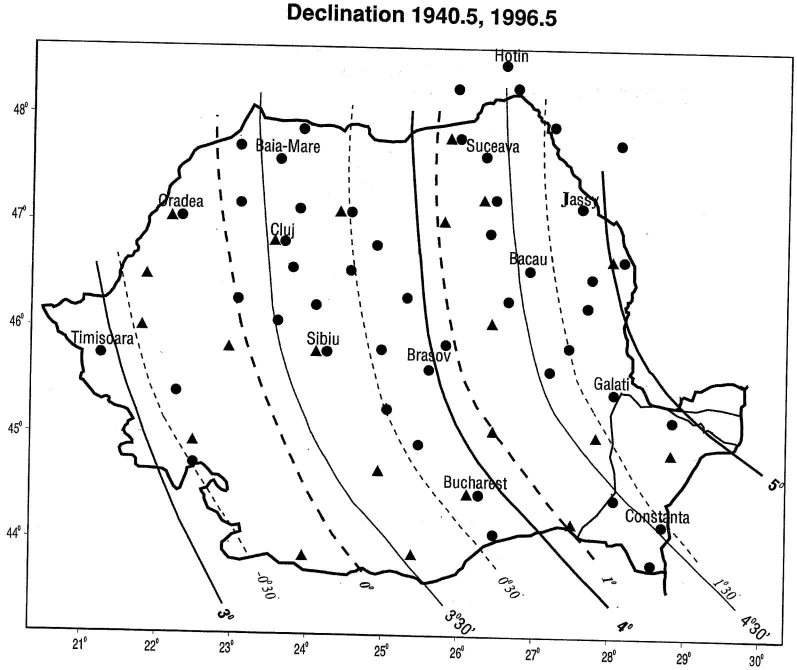


Fig. 2a. The geomagnetic field over Romania in 1940.5 (dashed lines) and 1996.5 (solid lines): lines of equal declination (*D*, in degrees). The repeat stations used are indicated by full circles (1940.5 epoch) or full triangles (1996.5).

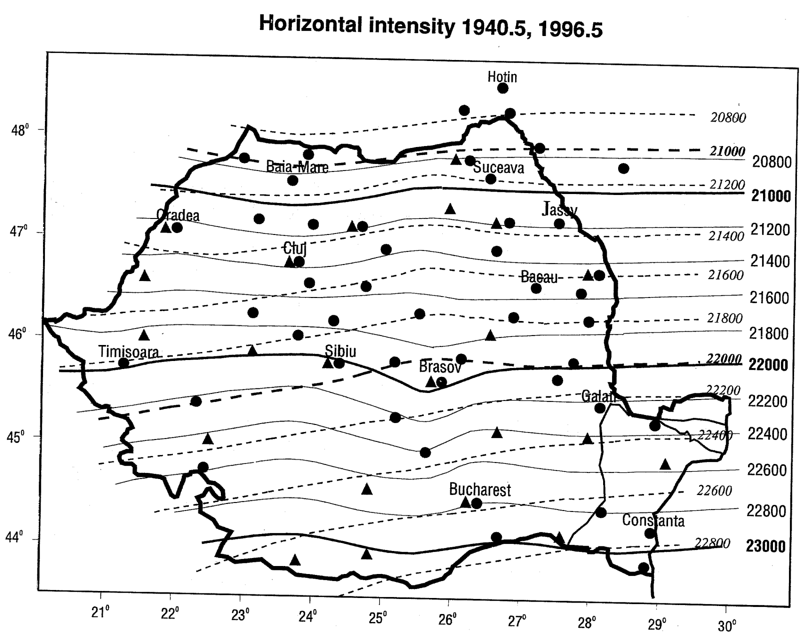


Fig. 2b. The geomagnetic field over Romania in 1940.5 (dashed lines) and 1996.5 (solid lines): lines of equal horizontal component (*H*, in nT). The repeat stations used are indicated by full circles (1940.5 epoch) or full triangles (1996.5).

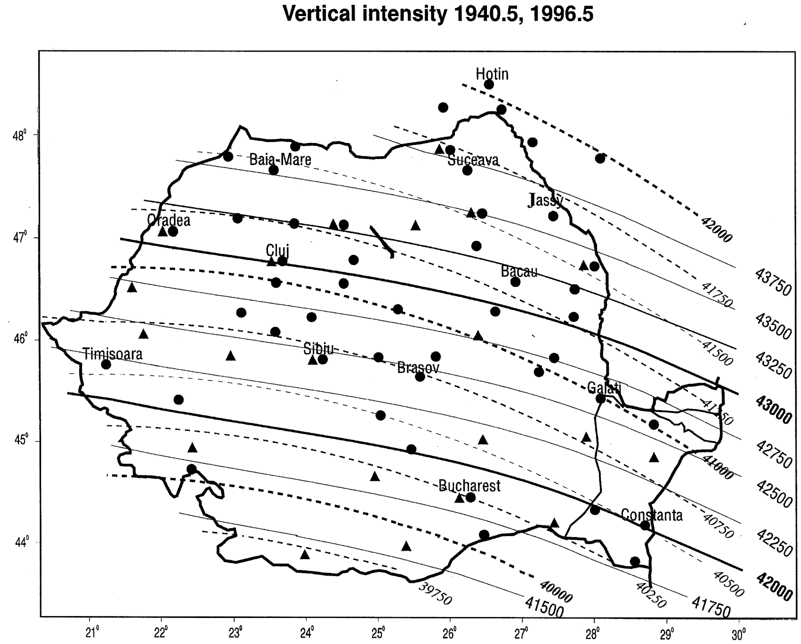


Fig. 2c. The geomagnetic field over Romania in 1940.5 (dashed lines) and 1996.5 (solid lines): lines of equal vertical component (Z, in nT). The repeat stations used are indicated by full circles (1940.5 epoch) or full triangles (1996.5).

zone» in the Brasov area. The isodynamic lines of *Z* are oriented nearly east-west. The secular variation of this component changes from about 18 nT/yr in the western part of Romania to about 26 nT/yr in the southeastern part.

Information on the rate of change of the geomagnetic field is very sparse if the whole of Romania is considered: the spatial field is only well known at two epochs, 1940.5 and 1996.5. However, for some sites longer time-series of measurements can be obtained, as described below.

4. Evolution of the geomagnetic field

The early geomagnetic data are of interest for a better understanding of the evolution of the geomagnetic field in eastern Europe. In Bucharest one can follow the evolution of *D* for the last 200 years, and of *I* and *H* for more than 150 years. The measurements made at Bucharest Astronomical Observatory, before the establishment of the national magnetic observatory, have been adjusted to the present-day reference point of Surlari by applying the following corrections: $\Delta D = +7'$, $\Delta H = -100$ nT and $\Delta I = +12'$ (table IV). The changes of these three geomagnetic elements are shown in fig. 3a-c. We note a minimum value for *D* around 1800 and for *I* around 1900; thereafter both angular components increase with time. The minimum in the declination observations fits well with the recent work by Barraclough and Malin (1998) on a fast-moving feature of westward drift (although the only available measurement around this time is for 1798 and it is separated by some tens of years from the previous and the subsequent measurements).

Table IV. Geomagnetic elements for three Romanian long-running stations.

Date[a]	D_B[b]	D_J[c]	D_C[d]	H_B[e]	H_J[f]	H_C[g]	I_B[h]	I_J[i]	I_C[j]
1772	−11 36.0	–	–	–	–	–	–	–	–
1798	−13 50.0	–	–	–	–	–	–	–	–
1828	−11 14.4	−9 27.6	–	–	–	–	–	–	–
1846	–	−9 30.0	–	22425	–	21188	–	–	–
1847	–	–	−9 50.0	–	–	–	–	–	–
1848	–	–	–	–	–	–	–	–	62 25.2
1850	−9 03.0	–	−9 54.4	22440	–	–	60 14.0	–	62 25.0
1854	–	−9 00.0	–	–	–	–	–	–	–
1856	–	–	–	22638	–	–	–	–	–
1858	−7 55.4	–	–	–	–	–	59 51.5	–	–
1860	–	–	–	–	–	–	–	–	62 24.0
1864	–	–	−8 09.8	–	–	21625	–	–	62 33.0
1870	–	–	–	–	–	–	–	–	62 10.8
1875	–	–	−7 05.0	–	–	21925	–	–	–
1880	–	–	–	–	–	–	–	–	61 51.0
1890	–	–	−5 58.0	–	–	–	–	–	61 36.6
1893	−5 00.0	–	–	–	–	–	59 05.0	–	–
1894	–	–	–	–	–	–	–	61 30.0	–
1895	–	–	–	–	22300	–	–	–	–
1898	−4 31.8	−3 37.8	–	23302	22259	–	58 51.1	–	–
1900	–	–	–	–	–	–	–	–	61 46.2
1901	−4 12.7	–	–	23330	–	–	58 46.0	60 50.0	–
1910	–	–	–	–	–	–	–	–	62 00.6
1920	–	–	–	–	–	–	–	–	62 15.0
1930	–	–	–	–	–	–	–	–	62 27.0
1931	–	0 23.0	–	–	21438	–	–	62 10.0	–
1932	–	0 34.2	–	–	21432	–	–	62 38.9	–
1933	–	0 38.2	–	–	21424	–	–	62 45.3	–
1934	–	0 46.1	–	–	21415	–	–	62 48.4	–
1935	–	0 53.4	–	–	21397	–	–	62 48.5	–
1936	0 21.5	1 01.1	–	22684	21396	–	60 41.0	62 55.6	–
1937	–	1 04.3	–	–	21389	21351	–	62 51.7	–
1938	–	1 10.4	−0 01.7	–	21377	–	–	63 02.3	–
1939	–	1 13.5	–	–	21369	21325	–	62 54.7	–
1940	0 41.8	1 18.7	0 13.1	22643	21355	–	60 43.5	62 58.1	62 41.7
1941	–	1 23.7	–	–	21324	–	–	63 01.1	–

Table IV (*continued*).

Date[a]	D_B[b]	D_J[c]	D_C[d]	H_B[e]	H_J[f]	H_C[g]	I_B[h]	I_J[i]	I_C[j]
1942	–	1 28.6	–	–	21340	21300	–	63 01.2	–
1943	–	1 32.8	0 24.0	–	21333	21375	–	63 07.5	–
1944	0 53.9	–	–	–	–	–	–	–	62 38.0
1945	–	1 41.7	–	–	21331	–	–	63 14.5	–
1946	0 57.9	1 50.7	–	–	21299	–	–	63 17.0	–
1947	–	1 55.3	–	–	21297	–	–	63 17.7	–
1948	1 09.9	2 03.3	–	–	21296	–	–	63 21.6	–
1949	1 34.2	2 06.9	–	22438	21304	21275	–	63 27.1	–
1950	1 39.2	2 12.0	–	22474	21301	–	61 14.5	63 31.1	62 56.4
1951	1 43.8	2 18.0	–	22483	21281	–	61 13.5	63 30.8	–
1952	1 48.1	2 18.5	–	22508	21310	–	61 12.1	63 30.0	–
1953	1 50.8	2 21.3	–	22546	21325	–	61 11.2	63 32.9	–
1954	1 52.5	–	–	22555	21300	–	61 11.3	63 31.1	–
1955	1 56.3	2 37.4	1 45.0	22560	21303	–	61 11.0	63 35.4	–
1956	2 02.5	2 46.2	–	22548	21261	–	61 12.4	63 32.3	–
1957	2 04.9	2 52.5	–	22553	21223	–	61 13.4	63 31.6	–
1958	2 06.4	–	–	22548	21212	–	61 14.0	63 33.6	–
1959	2 08.1	–	–	22560	–	–	61 15.2	–	–
1960	2 10.3	–	1 48.3	22547	–	21300	61 17.2	63 34.4	63 14.4
1961	2 13.3	2 58.8	–	22567	21280	–	61 17.5	63 34.9	–
1962	2 17.1	2 51.0	–	22578	–	–	61 17.2	63 34.0	–
1963	2 18.1	2 48.0	–	22594	21231	–	61 17.1	63 34.7	–
1964	2 21.2	–	1 59.8	22602	–	–	61 17.2	–	–
1965	2 21.5	–	–	22606	21281	–	61 17.5	63 47.3	63 15.0
1966	2 23.4	–	–	22606	–	–	61 17.6	–	–
1967	2 25.0	–	–	22611	21282	–	61 18.2	63 44.3	–
1968	2 25.2	–	–	22604	–	–	61 19.6	–	–
1969	2 24.9	–	–	22616	21289	21413	61 18.7	63 44.2	–
1970	2 25.4	–	–	22641	–	–	61 18.2	–	–
1971	2 26.0	–	–	22651	21327	–	61 18.3	63 42.8	63 15.0
1972	2 27.4	–	–	22668	–	–	61 17.9	–	–
1973	2 28.8	–	–	22681	–	–	61 17.7	–	–
1974	2 30.3	–	–	22686	–	21488	61 18.5	–	–
1975	2 32.9	–	–	22710	–	–	61 17.7	–	–
1976	2 34.2	–	–	22727	–	–	61 17.6	–	63 14.0
1977	2 37.7	–	–	22741	–	–	61 17.6	–	–

Table IV (*continued*).

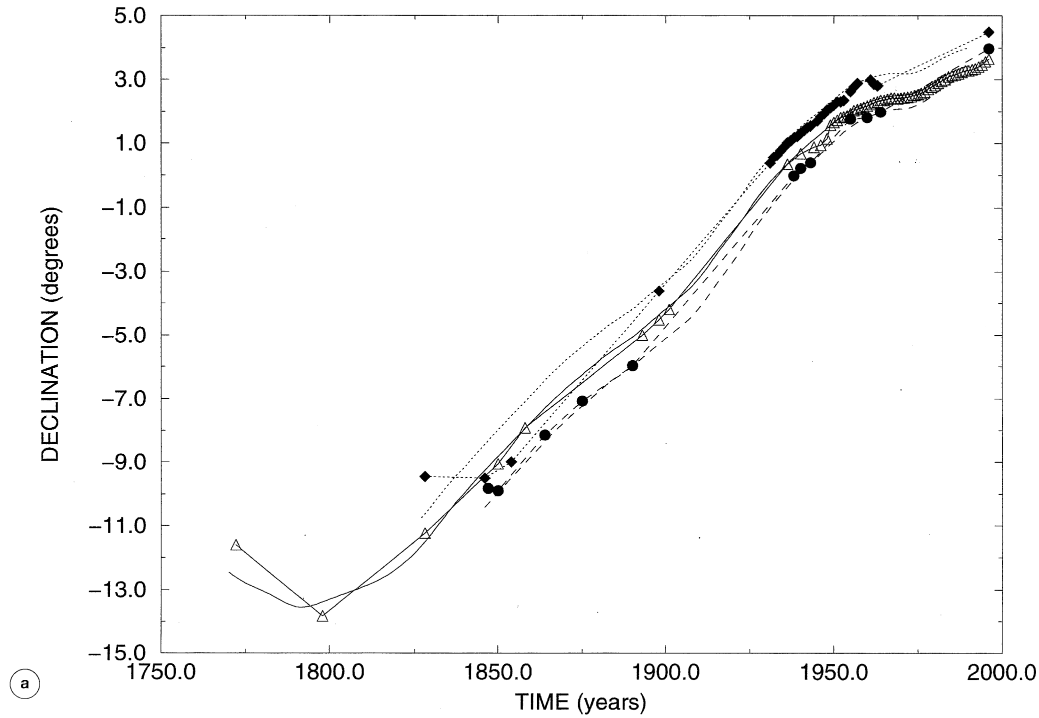
Date[a]	D_B[b]	D_J[c]	D_C[d]	H_B[e]	H_J[f]	H_C[g]	I_B[h]	I_J[i]	I_C[j]
1978	2 42.3	–	–	22736	–	–	61 19.0	–	–
1979	2 46.0	–	–	22722	–	21500	61 21.0	–	–
1980	2 49.1	–	–	22725	–	–	61 21.5	–	–
1981	2 53.4	–	–	22710	–	–	61 23.2	–	63 13.0
1982	2 57.9	–	–	22694	–	–	61 25.3	–	–
1983	3 00.6	–	–	22691	–	–	61 26.4	–	–
1984	3 05.3	–	–	22682	–	21575	61 27.9	–	–
1985	3 07.4	–	–	22683	–	–	61 28.7	–	–
1986	3 08.7	–	–	22677	–	–	61 30.0	–	63 16.0
1987	3 10.4	–	–	22677	–	–	61 30.8	–	–
1988	3 13.4	–	–	22658	–	–	61 33.6	–	–
1989	3 16.6	–	–	22643	–	21475	61 35.5	–	–
1990	3 16.8	–	–	22634	–	–	61 37.0	–	–
1991	3 18.7	–	–	22617	–	–	61 38.9	–	63 28.0
1992	3 20.3	–	–	22624	–	–	61 39.0	–	–
1993	3 23.5	–	–	22629	–	–	61 39.3	–	–
1994	3 27.1	–	–	22626	–	21475	61 40.4	–	–
1995	3 33.6	–	–	22636	–	–	61 40.4	–	–
1996	3 38.4	4 30.0	3 58.0	22644	21298	21486	61 40.7	63 48.0	63 30.0

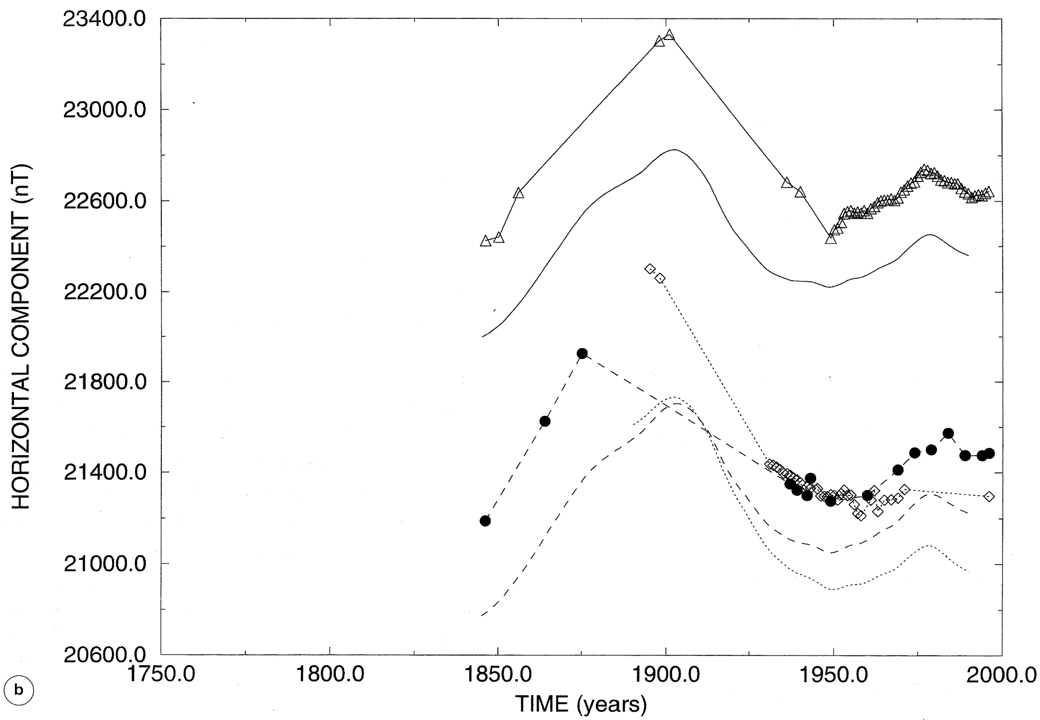
[a] Date, in years; [b] Declination for Surlari, in degrees and minutes; [c] Declination for Jassy, in degrees and minutes; [d] Declination for Cluj, in degrees and minutes; [e] Horizontal component for Surlari, in nT; [f] Horizontal component for Jassy, in nT; [g] Horizontal component for Cluj, in nT; [h] Inclination for Surlari, in degrees and minutes; [i] Inclination for Jassy, in degrees and minutes; [j] Horizontal component for Cluj, in nT.

Two other sites also provide long time series, Jassy and Cluj (table IV). The changes of D, H, I at these three sites are also plotted in fig. 3a-c.

It is also of interest to compare the early data with values from the models published by Bloxham and Jackson (1992). Figure 3a-c shows the evolution of D, H, I at Bucharest, Jassy and Cluj, and also the corresponding variations obtained by computing annual values of D, H, I for each site from the Bloxham and Jackson main-field model. For D the discrepancies between the computed and measured values are not very important, but for H and I they are significant (of the order of hundreds of nT in H and about half a degree in I). These differences can be partially explained by the effect of the crustal field, which is not considered in a main-field model.

Figure 4 shows the classical Bauer diagram (Bauer, 1895) for the Bucharest data, together with the corresponding curves for London (Malin and Bullard, 1981), Paris (Alexandrescu *et al.*, 1996), Rome (Cafarella *et al.*, 1992) and Dusheti (Karin, 1997, personal communication). The series are reduced to the sites of the present-day observatories, which have been moved away from the magnetically disturbed cities. But for simplicity they will still be referred to as the Bucharest, London, Paris, Rome and Dusheti series. For Bucharest, the changes in the direction of the geomagnetic


DECLINATION (degrees)
5.0
3.0
1.0
−1.0
−3.0
−5.0
−7.0
−9.0
−11.0
−13.0
−15.0
1750.0
1800.0
1850.0
1900.0
1950.0
2000.0
TIME (years)
a


HORIZONTAL COMPONENT (nT)
23400.0
23000.0
22600.0
22200.0
21800.0
21400.0
21000.0
20600.0
1750.0
1800.0
1850.0
1900.0
1950.0
2000.0
TIME (years)
b

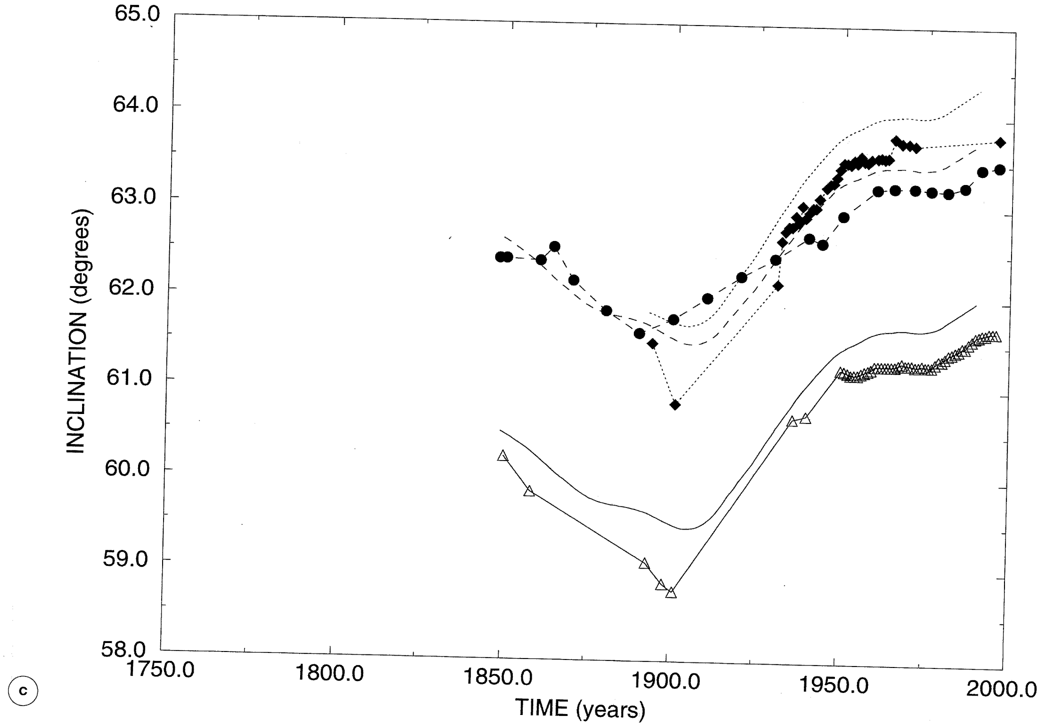


Fig. 3a-c. Raw declination (a), horizontal component (b) and inclination (c) obtained from measurements or from Bloxham and Jackson (1992) model: Bucharest (solid lines with open triangles or solid lines), Jassy (dotted lines with full diamonds or dotted lines) and Cluj (dashed lines with full circles or dashed lines).

field are fairly reliable from 1850 on, but only a general extrapolated trend can be obtained back to 1772, because only isolated data exist for the two angular components, and not for the same epoch (in 1772 declination is available, but not inclination; in 1838 the reverse).

The long series from London, Paris and Rome display the same behaviour from the seventeenth century up to the present. For the Paris and London series, declination decreases steadily from around 10°E in the late sixteenth century to about 22°W in Paris and 26°W in London in the late eighteenth century. It is rather stationary from ~ 1790 to ~ 1830 and then increases with a slope similar to that of the period before 1780 (same absolute value, opposite sign). For Rome and Bucharest the *D* variations are of smaller amplitude (about 19° for Rome and 17° for Bucharest).

The apparent quasi-cyclical character of the geomagnetic field direction in London, Paris and Rome is also apparent in the geomagnetic variations in Bucharest over more than two centuries. The curve for Dusheti (east of Bucharest) completes the picture of the variation of the direction of the geomagnetic field in a longitudinal scale. For this last location the available timeseries is for the last century only, but the different behaviour of the geomagnetic field direction can be seen.

5. Concluding remarks

The last ten years have seen tremendous advances in the ability to generate realistic maps of the Earth's magnetic field at the interface between the fluid core and the overlying solid

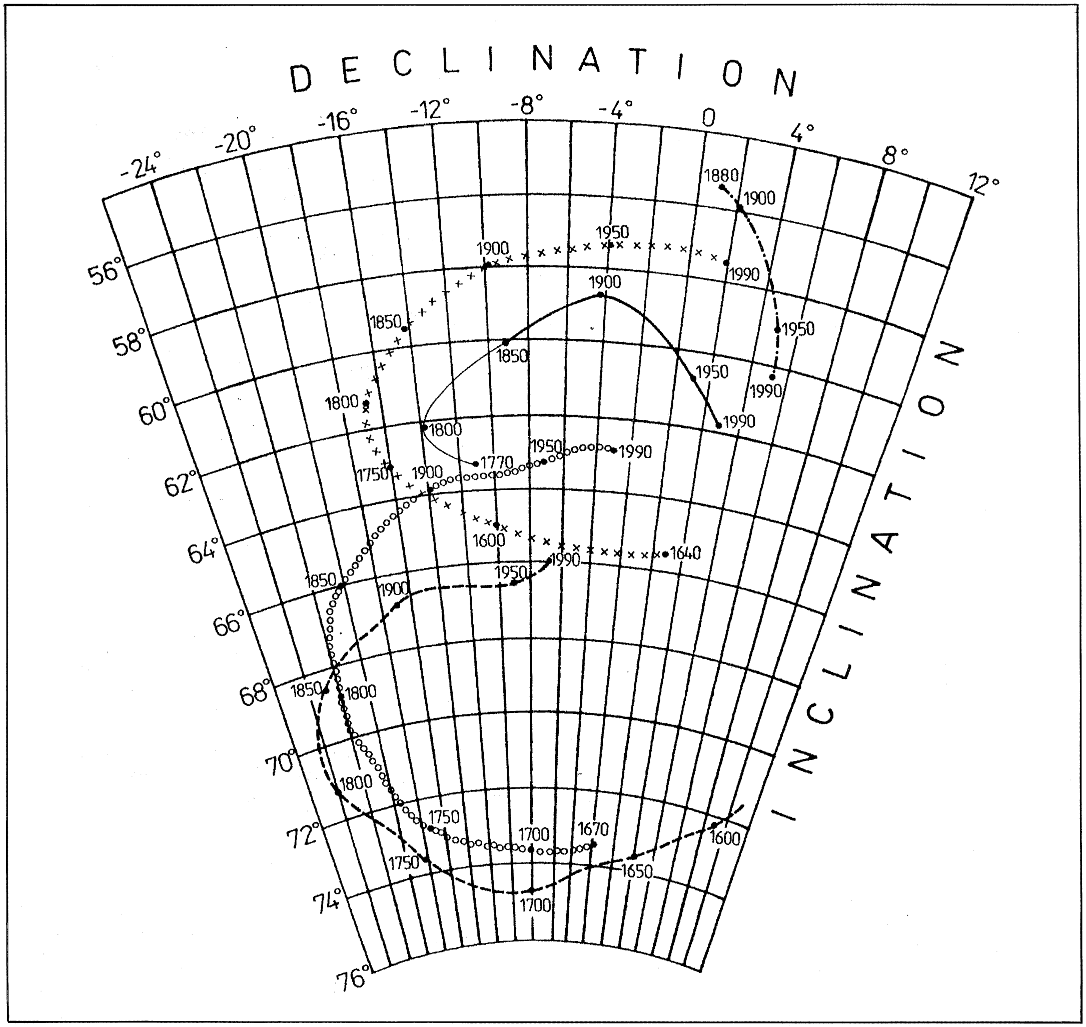


Fig. 4. The direction of the Earth's magnetic field for five geomagnetic time series: London (dashed line), Paris (open circles), Rome (crosses), Bucharest (solid line when annual means available, thin solid line when based on extrapolation), Dusheti (dot-dashed line); zenithal equidistant projection (Bauer diagram); points labelled every 50 years (except for the first and last).

mantle, using data collected at or above the Earth's surface. These studies have demonstrated the importance of going back to the original sources of data, despite the large amount of work and difficulties involved.

This study aims to improve the database of historical magnetic field measurements in Romania by extracting and organising observations from manuscript records and previous works, widely spread in many publications and, in most cases, rather difficult to access. The reported results on the geomagnetic field in Romania give a picture of its time evolution and a sketch of its distribution. As they are, these results can be used for representations of the secular variation at the planetary scale, and as well as for geological research in Romania, at regional or local scales.

In comparison with work concerning several sites in Europe which are rich in historical magnetic observations (London, Paris, Rome, Edinburgh), this present work could be considered of less importance. However, it shows that some interesting features of the geomagnetic field behaviour can be obtained using series which are not very long, but which are situated in areas without other similar information. We hope other geomagneticians will exploit old records housed in different libraries around the world.

Acknowledgements

The authors are pleased to thank Associate Editor David R. Barraclough and the two referees, Susan Macmillan and Stuart Malin, for helpful comments. This is IPGP contribution No. 1535.

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(received February 4, 1998;
accepted July 28, 1998)