Geomagnetic ground survey in Slovakia for the 2007.5 epoch

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Abstract: New geomagnetic ground survey was carried out in years 2006–2008. The survey was accomplished under fair geomagnetic-activity conditions during the minimum phase of a solar activity cycle No. 23. The measurements of the geomagnetic field were reduced to the 2007.5 epoch using magnetograms of the Hurbanovo Geomagnetic Observatory. The distribution of the geomagnetic field over the territory of Slovakia is presented in the paper in terms of isoline contour maps of the northern, eastern, and vertical geomagnetic components together with the total magnetic intensity. The map of magnetic declination is added because of its practical importance. In addition, the maps of the normal geomagnetic field represented by first-degree polynomial model are shown here. The maps are also available on the web site `http://www.geomag.sk/GMP/MagnMapsSk`. Data of some nearby repeat stations in the adjoining countries were also employed in order to create the isoline contour maps.

Key words: geomagnetic survey, magnetic repeat stations, secular variations

1. Introduction

The geomagnetic field in its nature is variable in time and space. The main part of the geomagnetic field has its origin in the magnetohydrodynamic processes in the Earth's core. It varies slowly with time and these changes are called secular variations. An additional source of the geomagnetic field contributes to the Earth's core's secular variations on the long time scales. This is the part of the geomagnetic field, which is caused by the crustal field – anomalies caused by differences in the magnetic properties of the various geological formations. Besides these slow (secular) variations of the geomagnetic field - time scales of these processes range from several decades to several thousand years, there are also faster changes, which have extraterrestrial origin, with time scales ranging from fractions of seconds to several years. Both of them, geomagnetic storms and eleven-year variation of the geomagnetic activity are their well known representatives, the first of them to be an irregular event and the latter, which is connected directly to the cycle of the solar activity, to be a regular variation, respectively.

The knowledge of the geomagnetic anomalies caused by the crustal field, is important information for exploration of the geological structures. To obtain such information, the geomagnetic ground survey has to be accomplished at a dense network of observation points regularly distributed over the whole territory. The measurements have to be accompanied by continuous registration of the geomagnetic field at a nearby working variation station or geomagnetic observatory. Using such magnetograms the fast geomagnetic variations, i.e. those from the external sources, are removed from the data.

Several geomagnetic surveys have been performed at the territory of Slovakia since the middle of the 19th century. The first one was carried out by Karl Kreil in 1843–1851 *(Kreil and Fritsch, 1850; Barta, 1954)*. He measured at 8 points throughout the territory of present-day Slovakia (This territory was a part of the Austro-Hungarian Monarchy at that time.) The next two surveys were done by Guido Schenzl in 1867–1869 at 19 observation points *(Schenzl, 1869; Barta, 1954)* and by Ignátz Kurländer in the years 1892–1894 at 7 points *(Barta, 1954)*. No complete geomagnetic survey was carried out in the first half of the 20th century. Only magnetic declination was mapped twice in that time and they were published in *(Čechura, 1934)* and *(Běhounek, 1939)*. The next complete surveys, when three independent geomagnetic elements were determined, were carried out after the World War II. These were the measurements done in 1951–1953 (93 points, 1952.5 epoch) *(Ochaba, 1959)*, in 1967–1968 (120 points, 1967.5 epoch) *(Krajčovič and Németh, 1972)*, in 1979–1982 (128 points, 1980.5 epoch) *(Podsklan, 1987)* and in 1993–1995 (119 points, 1995.5 epoch) *(Váczyová, 1999)*. The last geomagnetic ground survey, which is the subject of this paper, was performed in 2006–2008 at 121 observation points and it was reduced to the epoch 2007.5. However, after the preliminary analysis the data of three points were excluded (Dolné Trhovište, Ludrová and Svederník) because we suspected them to be incorrect.

2. Preparatory stage of the survey

The previous geomagnetic ground surveys widely employed observation points, which were established in the past, many of them during the first survey after World War II. This practice was abandoned in the last survey, because many old established observation points were lost, destroyed, or contaminated by man-made magnetic matters (e.g. agricultural or silvicultural devices, industrialization). If an observation point was found and it passed through the first examination with proton precession magnetometer (PPM), i.e. we excluded the presence of some unnatural gradient of the geomagnetic field in the surroundings of the point, we used this point for the measurement. Otherwise, we found a new place in the vicinity of the old point and after checking the geomagnetic field homogeneity, we accepted it as a new observation point. The list of the points is given in the Table 1 and their territorial distribution is shown in the Fig. 1. Altogether 131 points were employed for the geomagnetic ground survey performed in 2006–2008. The average area for one point in the territory of Slovakia was approximately 400 km^2. In addition to the geomagnetic data, which we measured at observation points over the Slovak territory and abroad (in the closest vicinity of the Slovak borders), some magnetic repeat station data from the neighbouring countries are also listed in the Table 1. Those data can be found on web site `http://www.geomag.bgs.ac.uk/gifs/surveydata.html`. We employed them together with our own data for determining of the geomagnetic elements distribution models as extension data.

Váczyová and Valach (2006) showed that the field measurements at the stronger geomagnetic activity, $Kp > 4$, should not be performed, because the error (after the reduction to the epoch) is much greater compared to a commonly acceptable error for field measurements. For this reason, years 2006–2008 were suggested to be the most suitable period for realization of the ground survey. This period fits into the minimum phase of the solar activity cycle. Indeed, the average value of Kp, which is a commonly used index for describing geomagnetic activity, was only of 1.9 during the period

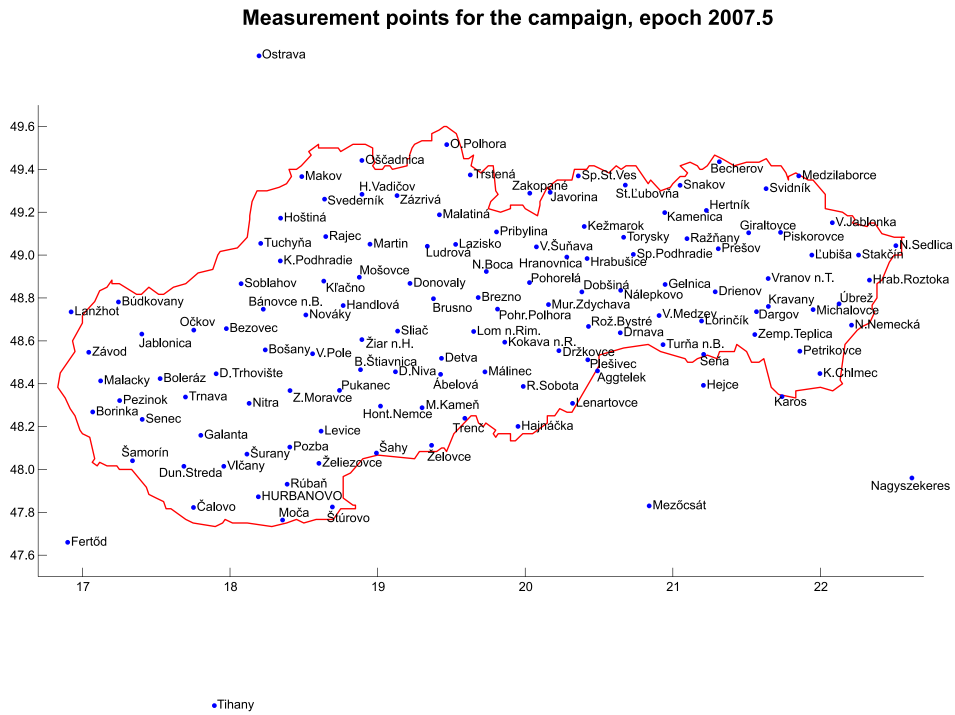

Fig. 1. Distribution of observation points in the territory of Slovakia and in its close vicinity.

when geomagnetic measurements were carried out, the median value of Kp was 2 and the inter-quartile range extended between 1 and 2. (Geomagnetic index Kp ranges from 0, for the quietest geomagnetic field, to 9, for the most disturbed field.)

3. Equipment and methods of data processing

Complete series of D and I measurements with the DI-flux theodolite, Zeiss Theo 015B with Elsec 810, were performed at the observation points *(Newitt et al., 1996)*. Each DI-flux measurement was supplemented with 10 proton-precession-magnetometer (PPM) measurements of the total magnetic field with the EDA magnetometer or magnetometer PMG-1.

Table 1. List of the observation points, their geographic coordinates, and the values of geomagnetic field elements X, Y, Z, F and D reduced to the 2007.5 epoch.

Name	lat [deg]	long [deg]	X [nT]	Y [nT]	Z [nT]	F [nT]	D [deg]
Ábelová	48.444	19.427	20555.5	1180.9	43979.1	48560.5	3.29
Bánovce nad Bebravou	48.747	18.225	20471.8	1204.2	44036.8	48577.9	3.37
Banská Štiavnica	48.466	18.884	20626.6	1246.0	44039.5	48647.1	3.46
Becherov	49.435	21.315	20098.2	1493.9	44625.9	48966.3	4.25
Bezovec	48.657	17.975	20519.8	1206.2	43956.6	48525.4	3.36
Boleráz	48.424	17.527	20666.9	1149.3	43808.1	48452.2	3.18
Borinka	48.268	17.070	20767.1	1116.2	43670.8	48370.2	3.08
Bošany	48.557	18.239	20539.8	1182.1	43933.8	48512.5	3.29
Brezno	48.802	19.682	20423.5	1345.1	44171.3	48683.5	3.77
Brusno	48.796	19.378	20438.4	1333.2	44146.3	48666.3	3.73
Búdkovany	48.781	17.244	20549.3	1040.1	44027.2	48597.9	2.90
Čalovo	47.822	17.752	21004.0	1150.1	43495.3	48315.1	3.13
Dargov	48.736	21.567	20426.0	1598.4	44238.0	48752.9	4.47
Detva	48.519	19.433	20500.6	1432.9	43781.1	48364.7	4.00
Dobrá Niva	48.456	19.121	20680.3	1180.7	43790.9	48443.2	3.27
Dobšiná	48.828	20.384	20343.7	1433.2	44265.3	48738.0	4.03
Donovaly	48.868	19.220	20383.9	1300.6	44171.4	48665.4	3.65
Drienov	48.829	21.287	20382.1	1477.7	44301.6	48787.7	4.15
Drnava	48.638	20.644	20511.7	1414.5	44207.3	48755.3	3.94
Držkovce	48.554	20.228	20564.7	1369.8	44126.0	48702.5	3.81
Dunajská Streda	48.015	17.688	20890.5	1154.1	43668.4	48422.0	3.16
Galanta	48.159	17.802	20715.3	1189.3	43749.8	48421.1	3.29
Gelnica	48.863	20.948	20371.9	1443.6	44186.1	48678.1	4.05
Giraltovce	49.104	21.514	20261.9	1501.6	44461.6	48883.6	4.24
Hajnáčka	48.201	19.951	20759.4	1353.2	43934.5	48611.0	3.73
Handlová	48.764	18.767	20444.0	1281.2	44092.4	48618.1	3.59
Hertník	49.208	21.227	20201.3	1489.9	44463.7	48860.1	4.22
Hontianske Nemce	48.295	19.020	20692.0	1292.6	43852.6	48506.7	3.57
Horný Vadičov	49.284	18.894	20218.2	1270.1	44381.2	48785.4	3.59
Hoštiná	49.173	18.343	20291.3	1219.4	44292.9	48735.0	3.44
Hrabová Roztoka	48.883	22.332	20375.2	1596.5	44420.7	48897.0	4.48
Hrabušice	48.984	20.419	20328.6	1407.2	44398.5	48851.6	3.96
Hranovnica	48.991	20.281	20462.4	1523.3	44357.9	48873.8	4.26
Hurbanovo	47.873	18.192	20975.0	1209.0	43532.0	48337.0	3.30
Jablonica	48.632	17.402	20618.8	1093.1	43891.6	48505.8	3.03
Javorina	49.293	20.169	20180.4	1378.8	44466.1	48850.2	3.91
Kamenica	49.198	20.945	20204.6	1447.8	44463.6	48861.0	4.10
Kežmarok	49.134	20.400	20249.5	1427.2	44393.5	48814.7	4.03
Kľačno	48.879	18.635	20388.2	1249.6	44130.8	48629.1	3.51
Kokava nad Rimavicou	48.594	19.861	20501.6	1420.6	44129.8	48680.9	3.96
Košecké Podhradie	48.973	18.341	20366.1	1228.7	44143.0	48630.7	3.45
Košice-Lorinčík	48.693	21.195	20460.3	1485.8	44239.4	48764.6	4.15
Kráľovský Chlmec	48.448	21.997	20643.6	1574.5	44232.7	48838.1	4.36
Kravany	48.760	21.647	20354.6	1505.7	44360.5	48830.6	4.23
Lazisko	49.050	19.529	20313.9	1345.6	44274.4	48730.6	3.79
Lenartovce	48.308	20.321	20672.6	1391.3	43958.1	48596.4	3.85
Levice	48.179	18.617	20882.6	1144.8	43712.9	48458.5	3.14
Lom nad Rimavicou	48.644	19.651	20482.2	1344.6	44061.9	48608.7	3.76
Ľubiša	49.000	21.942	20312.6	1573.4	44444.3	48891.1	4.43
Makov	49.366	18.486	19980.6	1219.4	44542.2	48833.6	3.49
Malacky	48.413	17.123	20838.6	1045.2	43599.8	48335.4	2.87
Malatiná	49.188	19.418	20247.1	1325.1	44354.9	48775.4	3.74

Table 1. First continuation

Málinec	48.455	19.727	20513.9	1585.1	44356.4	48893.7	4.42
Martin	49.051	18.949	20323.2	1290.2	44226.8	48690.1	3.63
Medzilaborce	49.370	21.853	19934.4	1541.0	44700.3	48968.4	4.42
Michalovce	48.746	21.950	20377.6	1519.5	44341.3	48823.4	4.26
Moča	47.764	18.356	20995.3	1251.0	43528.4	48343.6	3.41
Modrý Kameň	48.288	19.301	20780.5	1332.4	43882.6	48572.9	3.67
Mošovce	48.896	18.876	20376.6	1271.2	44149.5	48642.0	3.57
Muránska Zdychava	48.769	20.158	20385.7	1418.4	44204.5	48699.6	3.98
Nálepkovo	48.836	20.646	20431.2	1379.6	44307.9	48811.2	3.86
Nitra	48.308	18.130	20712.9	1216.5	43800.9	48466.9	3.36
Nižná Boca	48.924	19.737	20354.8	1334.8	44216.4	48695.5	3.75
Nižné Nemecké	48.673	22.211	20424.4	1548.8	44260.7	48770.9	4.34
Nová Sedlica	49.044	22.511	20304.3	1631.4	44518.6	48956.6	4.59
Nováky	48.721	18.514	20504.4	1409.2	44023.3	48584.5	3.93
Očkov	48.650	17.754	20556.4	1172.1	43943.5	48528.3	3.26
Oravská Polhora	49.515	19.469	20053.5	1344.4	44576.6	48898.1	3.84
Oščadnica	49.442	18.894	20122.5	1261.0	44533.3	48884.9	3.59
Petríkovce	48.552	21.861	20530.6	1550.3	44275.2	48828.4	4.32
Pezinok	48.321	17.252	20738.0	1149.1	43717.5	48400.7	3.17
Piskorovce	49.106	21.730	20255.9	1539.9	44478.5	48898.1	4.35
Plešivec	48.511	20.424	20505.9	1375.9	44082.5	48671.7	3.84
Pohorelá	48.872	20.029	20300.0	1412.2	44218.0	48675.7	3.98
Pohronská Polhora	48.748	19.812	20421.6	1402.8	44074.6	48596.2	3.93
Pozba	48.104	18.405	20813.6	1231.0	43686.6	48407.3	3.38
Prešov	49.030	21.308	20283.2	1469.0	44417.9	48851.9	4.14
Pribylina	49.108	19.806	20299.7	1335.0	44341.2	48785.1	3.76
Pukanec	48.369	18.742	20778.8	940.5	43809.1	48496.3	2.59
Rajec	49.087	18.649	20303.3	1233.3	44223.4	48675.9	3.48
Ražňany	49.077	21.096	20242.4	1460.9	44442.8	48857.9	4.13
Rimavská Sobota	48.387	19.987	20529.0	1289.0	44045.9	48612.3	3.59
Rožňavské Bystré	48.667	20.428	20466.8	1361.4	44195.7	48723.9	3.81
Rúbaň	47.931	18.387	20925.1	1222.4	43658.0	48429.2	3.34
Seňa	48.537	21.209	20621.2	1462.7	44196.9	48793.1	4.06
Senec	48.234	17.405	20772.8	1151.4	43689.5	48390.3	3.17
Spišské Podhradie	49.003	20.733	20259.5	1434.2	44390.7	48816.6	4.05
Sliač	48.646	19.135	20491.9	1271.4	44043.7	48594.3	3.55
Snakov	49.326	21.049	20166.8	1466.4	44543.1	48917.2	4.16
Soblahov	48.867	18.075	20431.9	1189.5	44060.7	48582.4	3.33
Spišská Stará Ves	49.370	20.360	20166.4	1394.8	44532.6	48906.0	3.96
Stakčín	49.000	22.258	20321.3	1602.9	44482.2	48929.7	4.51
Stará Ľubovňa	49.326	20.678	20135.7	1589.0	44526.5	48893.6	4.51
Svidník	49.310	21.632	20165.1	1537.3	44584.1	48957.9	4.36
Šahy	48.077	18.992	20644.3	1357.0	43784.2	48426.1	3.76
Šamorín	48.041	17.340	20822.6	1176.7	43587.1	48319.9	3.23
Štúrovo	47.825	18.693	20995.6	1267.3	43591.4	48400.9	3.45
Šurany	48.071	18.115	20817.8	1193.9	43737.8	48454.3	3.28
Torysky	49.083	20.667	20264.1	1368.7	44405.3	48830.3	3.86
Trenč	48.239	19.591	20715.6	1332.4	43843.4	48509.0	3.68
Trnava	48.338	17.699	20681.2	1183.2	43787.0	48440.1	3.27
Trstená	49.374	19.628	20166.7	1351.3	44503.4	48878.0	3.83
Tuchyňa	49.055	18.208	20324.0	1199.8	44200.5	48664.1	3.38
Turňa nad Bodvou	48.582	20.933	20530.5	1440.5	44161.7	48722.2	4.01
Úbrež	48.772	22.126	20417.5	1539.8	44347.5	48846.2	4.31
Veľké Pole	48.540	18.560	20967.9	1223.4	43523.0	48512.2	3.34
Vlčany	48.014	17.958	20931.8	1171.6	43616.0	48393.0	3.20
Vranov nad Topľou	48.891	21.646	20314.1	1501.2	44376.7	48828.7	4.23
Vyšná Jablonka	49.151	22.080	20239.3	1579.4	44551.5	48958.8	4.46

Table 1. Second continuation

Vyšná Šuňava	49.039	20.076	20492.9	1388.3	44209.8	48748.2	3.88
Vyšný Medzev	48.718	20.907	20455.5	1428.4	44184.0	48710.3	3.99
Závod	48.547	17.043	20697.3	1060.8	43905.0	48550.7	2.93
Zázrivá	49.278	19.132	20233.7	1312.1	44388.2	48800.5	3.71
Zemplínska Teplica	48.629	21.555	20515.4	1533.8	44287.8	48832.6	4.28
Zlaté Moravce	48.368	18.407	20651.1	1225.8	43830.6	48467.8	3.40
Želiezovce	48.028	18.603	20844.8	1243.1	43668.4	48404.4	3.41
Želovce	48.113	19.365	20740.9	1341.8	43779.9	48463.0	3.70
Žiar nad Hronom	48.606	18.893	20457.3	1300.3	44080.5	48614.0	3.64
Hejce	48.392	21.207	20664.9	1442.4	44145.5	48764.5	3.99
Aggtelek	48.460	20.490	20594.4	1399.7	44060.8	48656.1	3.89
Fertőd	47.660	16.900	21081.4	1131.1	43346.9	48214.4	3.07
Karos	48.340	21.740	20625.8	1541.7	44074.7	48686.1	4.27
Lanžhot	48.735	16.924	20581.0	1054.0	44161.0	48733.0	2.93
Mezőcsát	47.830	20.840	20916.2	1448.5	43740.1	48504.5	3.96
Nagyszekeres	47.960	22.620	20780.6	1556.6	44000.7	48685.1	4.28
Ostrava	49.933	18.194	19713.0	1122.0	44651.0	48821.0	3.26
Tihany	46.900	17.890	21464.9	1194.8	42966.7	48044.8	3.19
Zakopané	49.289	20.031	20187.0	1367.0	44461.0	48848.0	3.87

The measurements were carried out in daytime with no special requirements, about what part of day to use, adopted. The only limitation arose out of the method for the determination of astronomical azimuths, for which the observations of the Sun were used. The azimuth of the azimuth mark was determined from observations of the Sun according to the method described e.g. in *(Holub, 1963).* Three series of observations were made at each point.

The data obtained were reduced to the 2007.5 epoch with the help of the records of the geomagnetic field from the Hurbanovo Geomagnetic Observatory. The assumption of identical transient variations of the geomagnetic field, together with the assumption of uniform secular variations in the whole territory of Slovakia during the three-year period of the survey were assumed for this purpose. The following formula was used to obtain the reduced value of an element at an observation point:

$$E_{OP;\,epoch} = E_{OP;\,t} - (E_{HRB;\,t} - E_{HRB;\,epoch})$$

where $E_{OP;\,t}$ is the value of the geomagnetic field element measured at the observation point at the time of the measurement t, $E_{HRB;\,t}$ is the element's value at Hurbanovo Observatory for the time t and $E_{HRB;\,epoch}$ is the observatory value for the 2007.5 epoch. In this paper the X (northern), Y (eastern) and Z (vertical) components are discussed together with the total magnetic field F. It is because X, Y and Z elements are registered at the Hurbanovo Observatory (HRB), whose data were used for the reduction of the measured field data. In addition, the magnetic declination is shown, as well. It is included in the paper, because the magnetic declination is widely used for practical purposes, e.g. in the aircraft's navigation.

The location of the HRB observatory is characterized by:

$\phi_{\mathrm{HRB}} = 47.9°, \quad \lambda_{\mathrm{HRB}} = 18.2°, \quad \mathrm{h} = 112$ m.

The mean values of X, Y, Z and F at the HRB observatory for the 2007.5 epoch have been accepted as:

X = 20975 nT, Y = 1209 nT, Z = 43532 nT and F = 48337 nT.

4. Maps of geomagnetic elements

The mapping of Slovakia resulted in maps of isolines displaying the graphical representation of the distribution of the individual elements for the 2007.5 epoch. The maps of isolines of X, Y, Z and F were constructed with a step of 50 nT. Figs. 2–5 refer to the X, Y, Z and F elements, respectively. Magnetic declination (D) is widely used for practical purposes. Therefore, we also prepared a map with the distribution of D. The isogones for epoch 2007.5 are shown in Fig. 6. The spacing between the adjacent isogones is 0.1°. The colour versions of these maps are available on the web site `http://www.geomag.sk/GMP/MagnMapsSk`.

5. The normal geomagnetic field for the 2007.5 epoch

The normal field over the area has to approximate the true field as well as possible. A polynomial expressing the value of the geomagnetic field element as a function of geographical longitude and latitude has also various practical purposes. For such a small territory as the territory of Slovakia is, the first degree polynomial approximation is quite sufficient *(Váczyová, 1999)*.

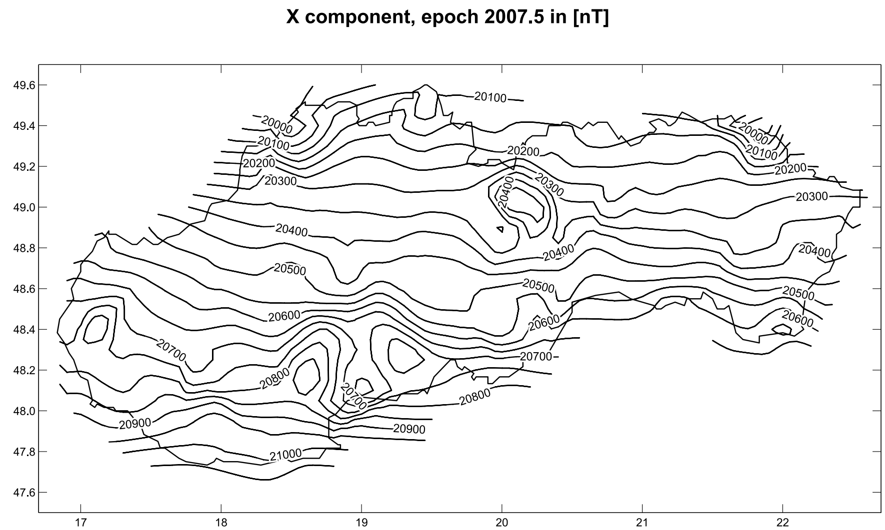

Fig. 2. Map of isolines of the northern component (X) in the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

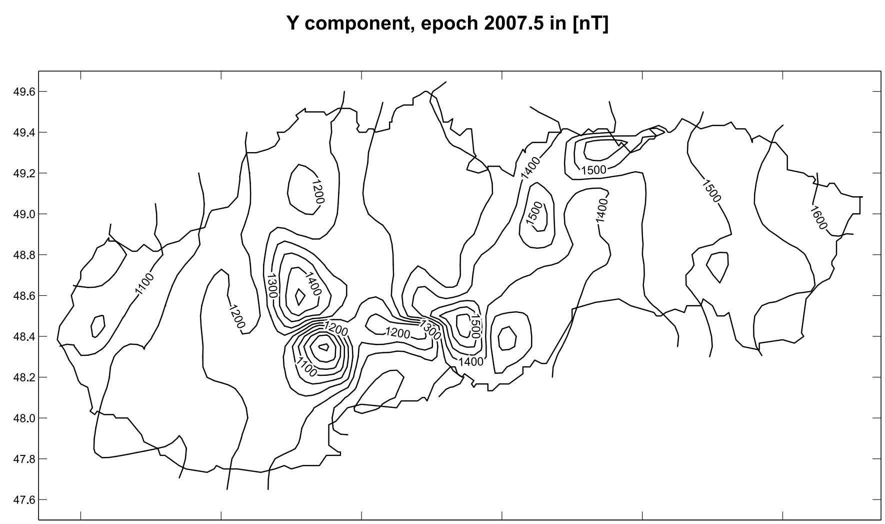

Fig. 3. Map of isolines of the eastern component (Y) in the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

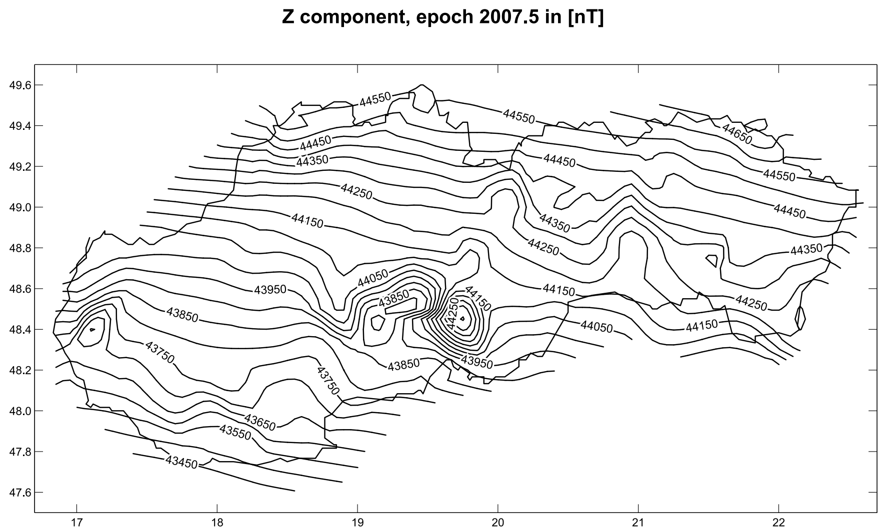

Fig. 4. Map of isolines of the vertical component (Z) in the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

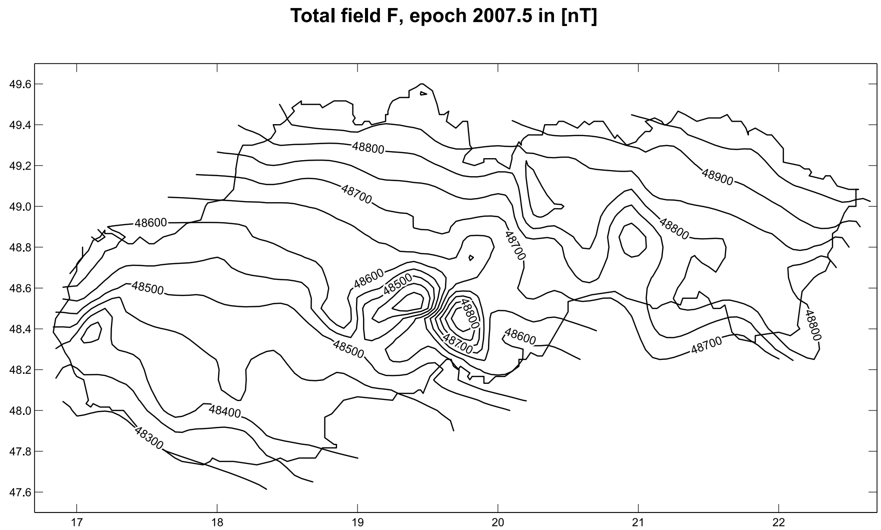

Fig. 5. Map of isolines of the total field (F) in the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

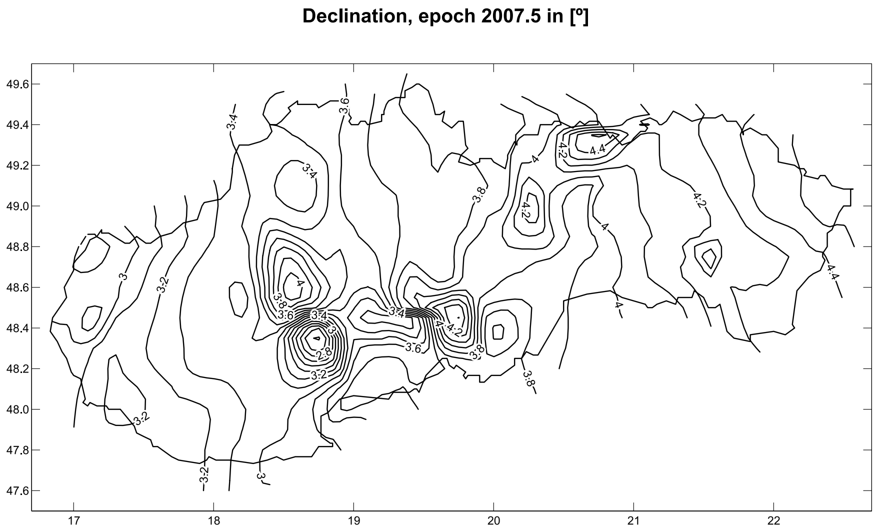

Fig. 6. Map of isogones (declination D) in the territory of Slovakia for the 2007.5 epoch. The values assigned to isolines are given in arc degrees. The spacing between adjacent contours is 0.1°.

We derived the normal field in two steps: In the first step, the linear models of the distribution of the geomagnetic elements X, Y, Z and F were computed using the values obtained at all observation points (preliminary linear model). Some of the points are situated in the regions, which are anomalous, i.e. the magnetic field in these regions are influenced by some local magnetic anomalies.

The normal field must be free of the influences of local magnetic anomalies. For this reason, differences between the preliminary linear model and the observed values of geomagnetic elements for each observation point were computed. Observation points with the highest differences were excluded from the data sets (15 or 16 points, i.e. approximately 14 per cent of points were excluded). The values of the remaining observation points were used in order to derive the final linear models of normal geomagnetic field.

The models of normal field were calculated as the first-degree polynomials that best fitted the observations. The polynomials were fitted by the method of multilinear regression. The normal field for X, Y, Z and F is as follows:

$$X = (20936.5 \pm 6.8)\,\mathrm{nT} - (513.3 \pm 8.0)\,\mathrm{nT}/^\circ \cdot (\phi - \phi_{\mathrm{HRB}}) - \\ - (17.8 \pm 2.2)\,\mathrm{nT}/^\circ \cdot (\lambda - \lambda_{\mathrm{HRB}})$$

$$Y = (1207.8 \pm 4.9)\,\mathrm{nT} + (0.3 \pm 5.8)\,\mathrm{nT}/^\circ \cdot (\phi - \phi_{\mathrm{HRB}}) + \\ + (90.2 \pm 1.6)\,\mathrm{nT}/^\circ \cdot (\lambda - \lambda_{\mathrm{HRB}})$$

$$Z = (43576.2 \pm 6.3)\,\mathrm{nT} + (517.2 \pm 7.5)\,\mathrm{nT}/^\circ \cdot (\phi - \phi_{\mathrm{HRB}}) + \\ + (81.6 \pm 2.0)\,\mathrm{nT}/^\circ \cdot (\lambda - \lambda_{\mathrm{HRB}})$$

$$F = (48357.0 \pm 1.5)\,\mathrm{nT} + (251.3 \pm 1.9)\,\mathrm{nT}/^\circ \cdot (\phi - \phi_{\mathrm{HRB}}) + \\ + (68.0 \pm 0.5)\,\mathrm{nT}/^\circ \cdot (\lambda - \lambda_{\mathrm{HRB}})$$

The errors written in brackets are standard errors (σ). The geographical positions ϕ (latitude) and λ (longitude) of the locality in question are expected to be given in arc degrees. (The coordinates of the Hurbanovo Geomagnetic Observatory are $\phi_{\mathrm{HRB}} = 47.9^\circ$, $\lambda_{\mathrm{HRB}} = 18.2^\circ$.)

Figures 7–10 show the normal fields for X, Y, Z and F, respectively. As expected according to *(Váczyová, 1999)*, the isolines of the normal field enumerated on the basis of the previous measurements, expressed by first-degree polynomials, are in general consistent with the measured values of the field.

6. Secular variation of the geomagnetic field

Comparison of the first-order polynomial models of the 2007.5 epoch with those of the 1995.5 epoch *(Váczyová, 1999)* suggests that the geomagnetic field between epochs 1995.5 and 2007.5 changed rather uniformly. The dependence of the secular variation estimated on geographical coordinates using these two linear models turns out to be less significant than an error (standard deviation) resulting from these models. In order to have information about the secular variation in the territory of Slovakia, which is of relatively small area, the secular variation at Hurbanovo Geomagnetic Observatory can be presented. Secular changes of the geomagnetic elements X, Y, Z, F and D are shown in Figs. 11a-e . The time series on the figures begin in 1949 because starting from this year no gaps in data sets occurred.

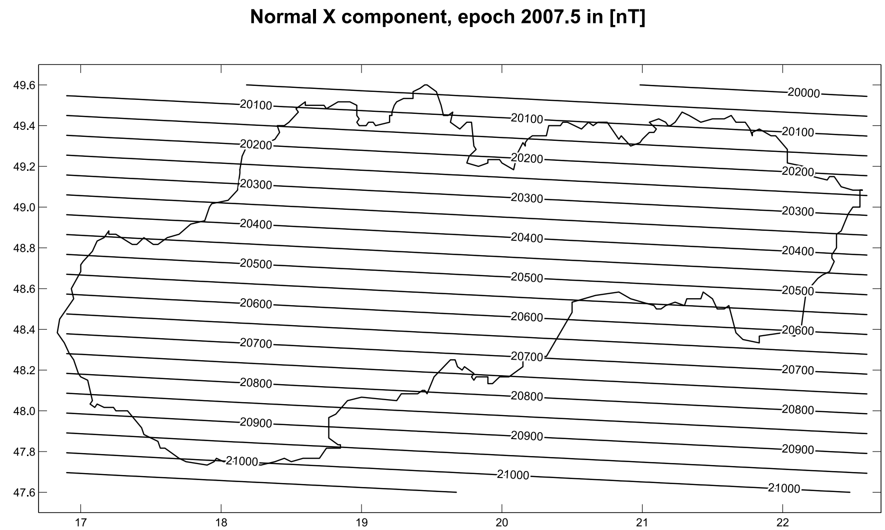

Fig. 7. Map of isolines of the normal distribution of the northern component (X) in the territory of Slovakia for the 2007.5 epoch (First-degree-polynomial model). The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

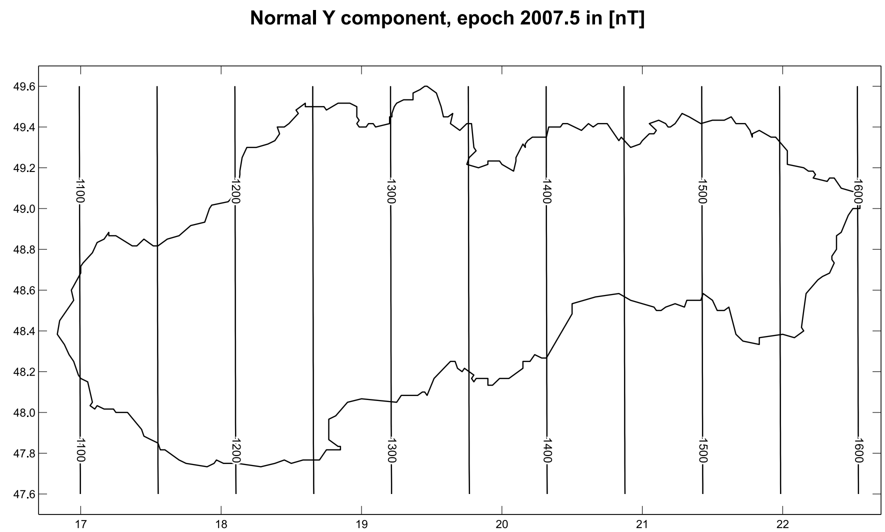

Fig. 8. Map of isolines of the normal distribution of the eastern component (Y) in the territory of Slovakia for the 2007.5 epoch (First-degree-polynomial model). The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

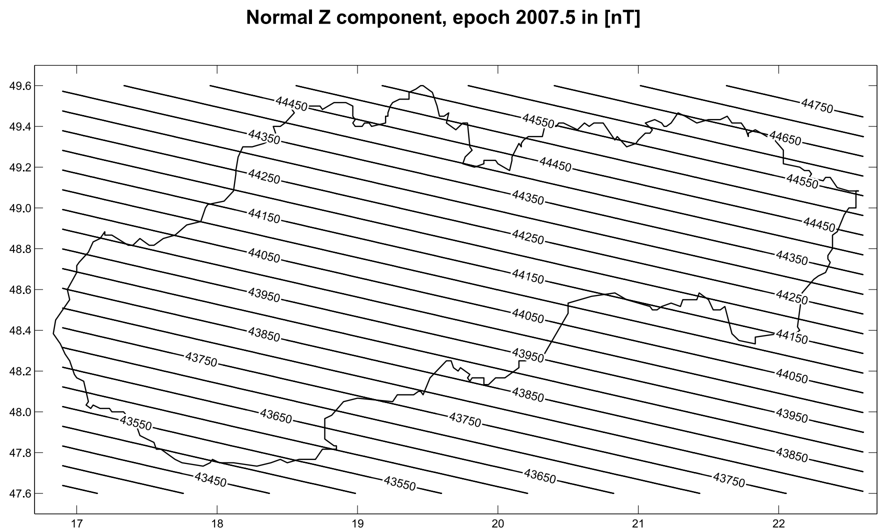

Fig. 9. Map of isolines of the normal distribution of the vertical component (Z) in the territory of Slovakia for the 2007.5 epoch (First-degree-polynomial model). The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

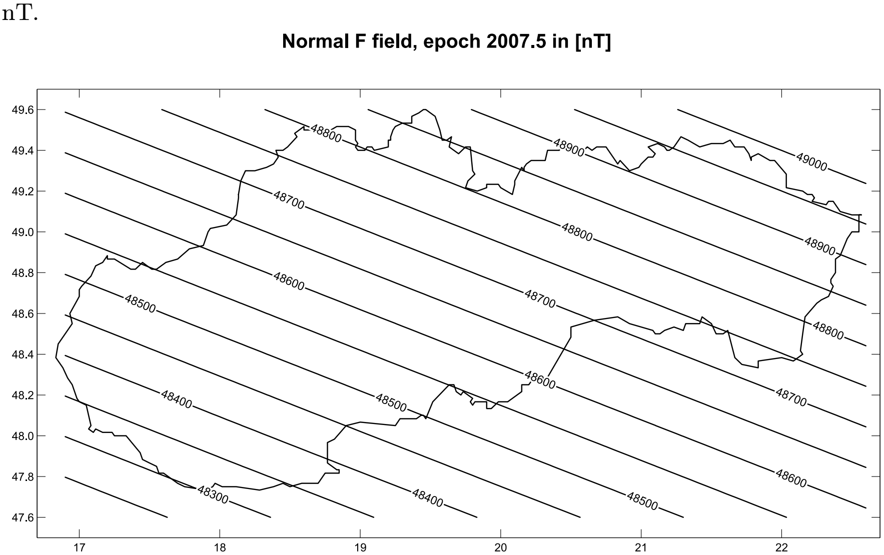

Fig. 10. Map of isolines of the normal distribution of the total field (F) in the territory of Slovakia for the 2007.5 epoch (First-degree-polynomial model). The values assigned to isolines are given in nanoteslas. The spacing between adjacent contours is 50 nT.

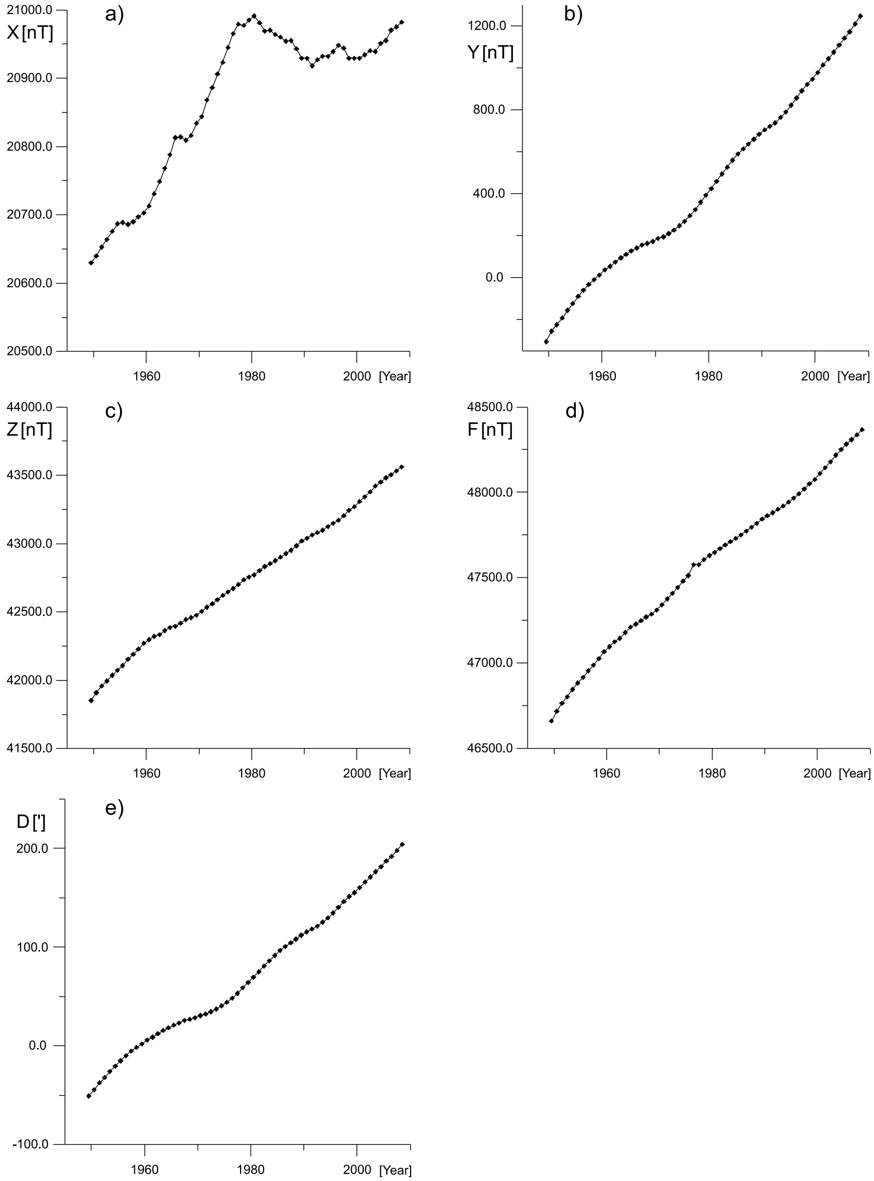

Fig. 11. Secular variation of the geomagnetic field at the Hurbanovo Geomagnetic Observatory since the year 1949. Five geomagnetic elements are shown here: **(a)** northern component X, **(b)** eastern component Y, **(c)** vertical component Z, **(d)** total field F and **(e)** magnetic declination D.

7. Discussion and conclusion

The magnetic survey in question has yielded some new facts about the geomagnetic field distribution in the territory of Slovakia and confirmed most of its features, which resulted from the previous geomagnetic ground surveys in the 1995.5, 1980.0 and 1967.5 epochs. Comparing with the previous surveys, nowadays it is very hard to find locations, where no artificial disturbances exist. Because of this fact, the measurements had to be carried out very carefully and an emphasis had to be on the on-site seeking for suitable observation places during the expeditions. For the majority of localities we were forced to abandon the common practice of reoccupation the observation points of the previous surveys. It was because the old points were either destructed or they were contaminated by man-made sources of magnetic disturbances. These reasons are also lightly reflected in differences of contour maps for isolines of the geomagnetic field elements if we compare them with those of 1995.5 or the previous ones, but main reasons of differences are secular variations of GMF. However, we have found only minor discrepancies and we do not consider them to be an error. They represent an independent picture of the geomagnetic field distribution, which is unbiased by the fixed network of the observation points used in the past. Of course, the measured data were after processing checked carefully and those that were suspected to be corrupted were excluded from our data set. Therefore, the differences from the previous maps are not errors, but the new information yielded by independent distribution of the observation points. All main features of the geomagnetic anomalies were well-preserved in the new maps. Central-Slovakian anomaly still remains the most conspicuous geomagnetic anomaly in Slovakia.

Generating the geomagnetic maps for the 2007.5 epoch, the data of ten abroad observation points were also included to the data-base. They were mostly the points of national repeat station networks in Poland, Czech Republic and Hungary (Note: European repeat station surveys are coordinated by the MagNetE Group, see e.g. `http://space.fmi.fi/MagNetE2009/`). Including these data improves the linking of the geomagnetic field elements' isolines over the Slovak territory to those of the neighboring countries.

By comparing the geomagnetic isoline maps (Figs. 2–6) with the geological map of Slovakia *(Ibrmajer et al., 1989)*, we can conclude that the geomagnetic anomalies in Slovakia are due to the significantly extended neovolcanic rocks, which are the carriers of inhomogeneous magnetic properties, natural remanent magnetization and magnetic susceptibility. These rocks constitute mountains of horizontal extent of about 100–250 km^2, which is situated mainly in the Central and Eastern Slovakia *(Krs, 1966; Orlický et al., 1974; Váczyová, 1999).*

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