PALAEOMAGNETISM OF LITHUANIAN UPPER PLEISTOCENE SEDIMENTS

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Abstract: In the Lithuania, a palaeomagnetic study of Upper Pleistocene and Late Glacial sediments at five sections has been carried out. The palaeomagnetic study of the varved clays in the Maskauka, Didžiasalis and Girininkai sections cover the time interval since 18,000 to 14,000 BP and Mančiagirė section covers the time interval since 12,700 to 11,630 BP. The palaeomagnetic research of the Merkinė (= Eemian) Interglacial sediments (Netiesos section) cover the time interval since 112.0±25 to 101.5±11.5 ka BP. The declination (D), inclination (I) and intensity (J) of the natural remanent magnetization of glaciolacustrine clays (Maskauka, Didžiasalis and Girininkai sections), as well as Merkinė (=Eemian) Interglacial deposits (Netiesos section) and interstadial sediments (Mančiagirė section) were measured. The result of these studies is presented in diagrams. The study reveals that considerable palaeomagnetic information can be obtained from the varved clays.

1. INTRODUCTION

Application of palaeomagnetic methods has shown that such investigations may be a valuable tool for stratigraphical research of Pleistocene sediments in Lithuania. Palaeomagnetic investigations of Late Pleistocene sediments in Lithuania previously have been published by M. Pevzner and A. Gaigalas (1976) and A. Gaigalas *et al.* (1991).

Various anomalous and even negative inclinations are found in some deposits of Late Pleistocene in Lithuania (Gaigalas *et al.*, 1991). Anomalous magnetization of a transitional type from normal to reverse inclination was noted in the Merkinė (=Eemian) Interglacial deposits (Maksimonys and Jonionys section). Reverse magnetization was noted in the Grūda (=Brandeburgian) till (22,000-18,000 years ago) with an otherwise normal magnetization (Padubysis section). Anomalous magnetization, transiting to negative, was noted in varved clays, dated to about 13,500-13,000 years ago (the Kuršėnai section). Negative magnetization was also noted in lacustrine deposits, aged 11,600-12,700 years ago.

A palaeomagnetic study of varved clays of the Late Glacial has been carried out at Karelia in the north of Lake Ladoga and in the west and east of Lake Onega for the time interval 16,000-10,200 BP (Ekman *et al.*, 1987; Batchmutor and Zagniy, 1990). The detailed curves of declination and inclination can be used for regional magnetostratigraphic studies and for correlation of sediments in adjacent regions of East European plain. A palaeomagnetic study can be used not only in stratigraphy and correlation of Late Pleistocene sediments, but in palaeogeographic reconstructions too. New information on fine structure of palaeomagnetic field should be analysed in a palaeoclimatic aspect. The task is to establish relationships between climatic variations and the geomagnetic field in the Pleistocene.

In Lithuania glaciolacustrine deposits and varved clays are distributed widely in surface formation. They have been formed in dammed periglacial basins near the margin of the retreating ice sheet. The study of varved clays can be used to obtain the secular variations and for the construction of a detailed time-scale of the geomagnetic field in the Late Pleistocene.

2. RESEARCH METHODS

In the present study more than 400 samples from five sections (Girininkai, Didžiasalis, Maskauka, Mančiagirė and Netiesos) have been magnetically investigated (**Fig. 1**). Declination (D), inclination (I) and intensity (J) of the natural remanent magnetization (NRM) of glaciolacustrine clay (Girininkai, Didžiasalis and Maskauka sections), as well as Merkinė (=Eemian) interglacial deposits (Netiesos section) and interstadial sediments (Mančiagirė section, **Fig. 2**) were measured by a spinner magnetometer (Digico Ltd.). These sections are located in different deglaciation zones of the Last Glaciation that allow us to cover a wide time interval. Oriented, 1-inch specimens were collected in vertically cleaned profiles, using magnetic compass and a spirit level for the orientation. After performing an initial pilot study, all specimens were AF-demagnetized in small steps up to typical 50 or 60 mT, and re-measured on the spinner after each step. By a PCA-analysis (principal component analysis), using Linefind in the IAPD (Interactive analysis of Palaeomagnetic Data) program (Torsvik, 1992), the ChRM (characteristic remanent magnetization) of each specimen was isolated. In some cases SIRM (saturation isothermal magnetization) experiments were performed, and also the frequency-dependant magnetic susceptibility was measured. Results are plotted in the diagrams (**Figs 3** and **4**). The magnetic minerals vary between different environments, and hence they may hardly be stated as a general conclusion. However, the main ferromagnetic component carrying the NRM is usually fine grained magnetite, although maghemite may sometimes be present. In some cases, according to the magnetic saturation experiments, the carrier of the magnetic remanence appear to be hematite (or goethite?) rather than magnetite or maghemite.

The palaeomagnetic study of the varved clays (Maskauka, Didžiasalis and Girininkai) covers the time interval from 18,000 to 14,000 BP. The sediment age has been defined by varvometric, palynological, optically stimulated luminescence, electron spin resonance and radiocarbon analyses as well as concluded from geological and geomorphological data. Sedimentological and palaeomagnetic studies were carried out for each section. High sedimentation rates of varved clays allowed us to collect oriented samples with high resolution over the time interval and without problems of material limitation. The bedding of sediments used for studying the geomagnetic secular variation is in a horizontal or near horizontal position.

3. MASKAUKA SECTION

The section represents the Grūda (=Branderburgian) and Žiogeliai (=Frankfurtian) glaciolacustrine varves. Magnetic declination, inclination and intensity of the sediments of Maskauka profile have been combined in one plot (**Fig. 5**). Both angles of magnetic declination and inclination appear to show systematic trends, but with high scatter. On the diagram (**Fig. 5**), each dot indicates the AF-cleaned ChRM (characteristic remanent magnetization) of one oriented specimen.

The declination may show a systematic trend, but the scatter is quite high (**Fig. 5**). The westerly values between 4.7 and 5.1 m above the river level are situated just above the Grūda sediment (4.3 m to 4.65 m).

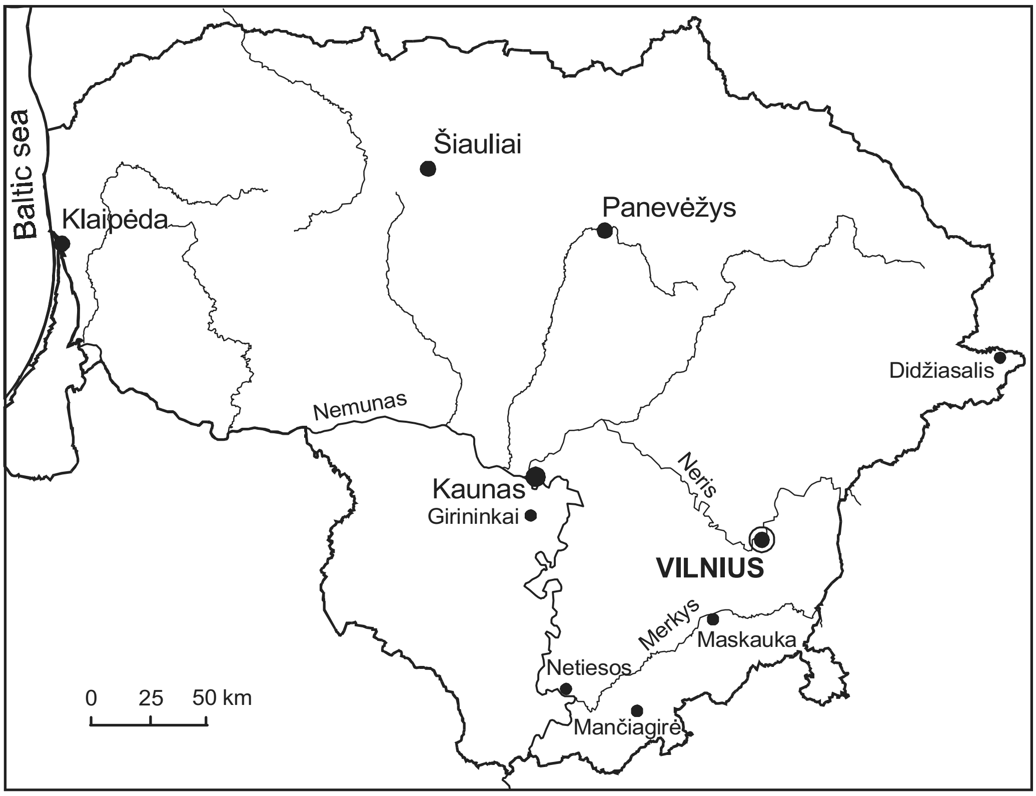

Fig. 1. Location of the Maskauka, Didžiasalis, Mančiagirė and Netiesos sections of Late Pleistocene deposits.

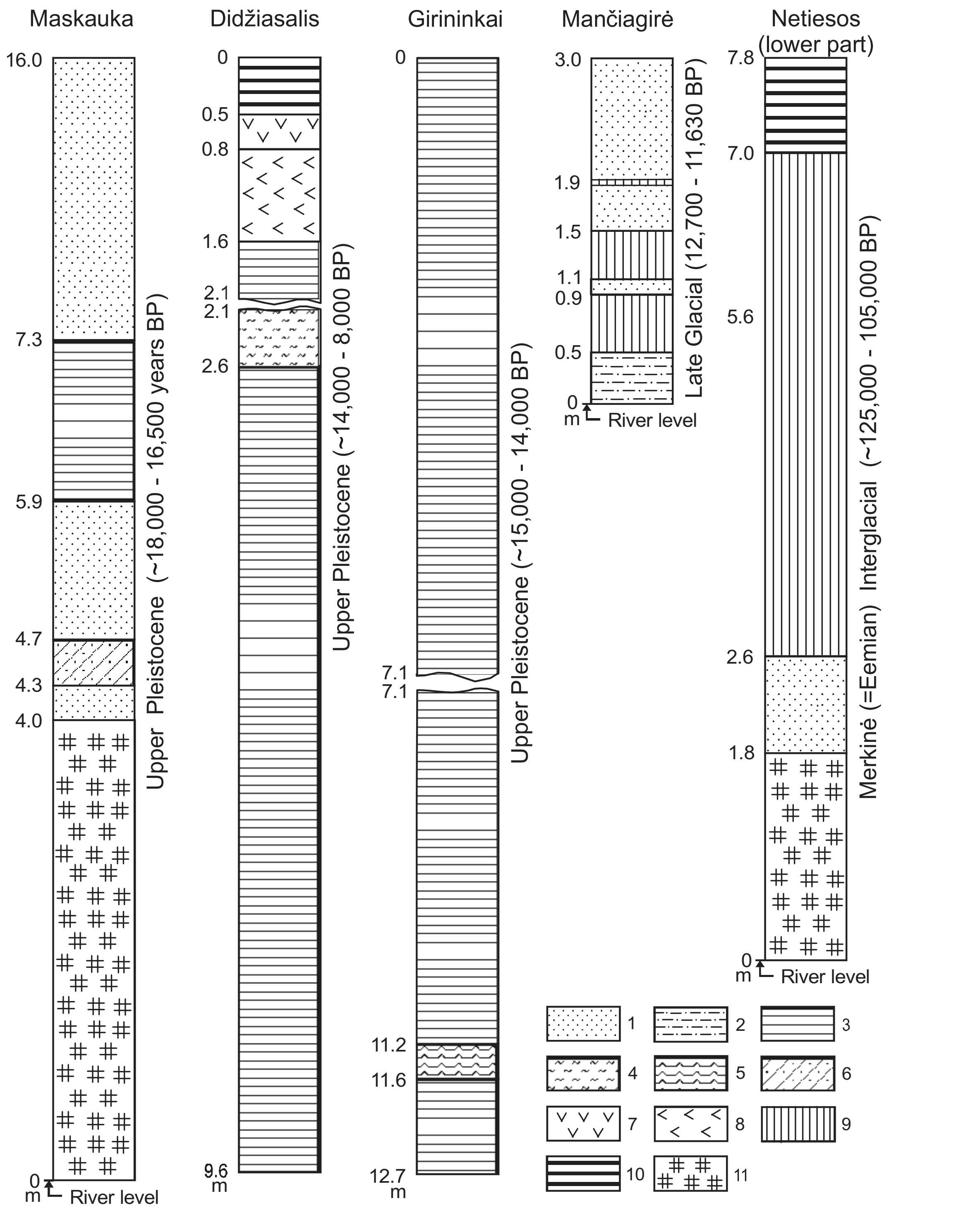

Fig. 2. *Palaeomagneticaly investigated sections: Maskauka, Didžiasalis, Mančiagirė and Netiesos. 1 – sand, 2 – silt, 3 – varved clay, 4 – homogeneous clay, 5 – clay disturbed by cryogenic process, 6 – till, 7 – limnic tufa, 8 – sapropelite, 9 – gyttja, 10 – peat, 11 – deluvium.*

Žiogeliai (=Frankfurtian) varves cover the interval between 5.1 m and 7.4 m (sandy and silty lake sediments). The top part between 7.45 m and 8 m consists of reddish disturbed clay.

A certain pattern in the inclination may be present, but the scatter is quite high (**Fig. 5**). Most values are more shallow than the expected geocentrical axical dipole (GAD) value of the site, Io=70.2°. The shallow inclination may indicate a sediment compaction. The low values between 4.7 m and 5.1 m are situated just above the Grūda sediment (4.3 m to 4.65 m). The top part between 7.45 and 8 m consists of reddish disturbed clay. The small maximum in the intensity between 4.7 m and 5.1 m is situated just above the Grūda sediment (4.3 m to 4.65 m; **Fig. 5**). Stereogram of the AF-cleaned direction of individual specimens, with their individual α_{95} confidence circles is given in **Fig. 3**. The mean direction of glaciolacustrine varved clay, sand and silt of Grūda–Žiogeliai age is (Dm,Im)=(7.0°W, 55.7°), N=52, α_{95} =8.1°.

4. DIDŽIASALIS SECTION

In the Didžiasalis section of varved clays both magnetic declination and inclination show a long-wave variation (**Fig. 6**), the declination with more westerly values between 6 and 3.5 m depth, and a short-wave variation at the top of the profile between 2.5 and 0 m. On the diagrams, each dot indicates the AF-cleaned ChRM of one oriented specimen. The swings in declination between 3 and 2.5 m are likely to be due to some kind of sediment disturbance, the intensity being quite high (**Fig. 6**).

Smoothed declination varies around 0° between ±30° (**Fig. 6**). Except the top, the inclination is systematic low as compared to the geocentrical axical dipole (GAD) value of Io = 70.9°, which may indicate some compaction of the sediment (**Fig. 6**). The variation as well as the local scatter in the intensity values are likely to indicate lithological variations in the clay and silt proportions of the thin-laminated varved clays (**Fig. 6**).The mean direction of glaciolacustrine clay of Didžiasalis section is (Dm,Im)=(6.5°E, 55.0°), N=58, α_{95} =5.7° (**Fig. 3**).

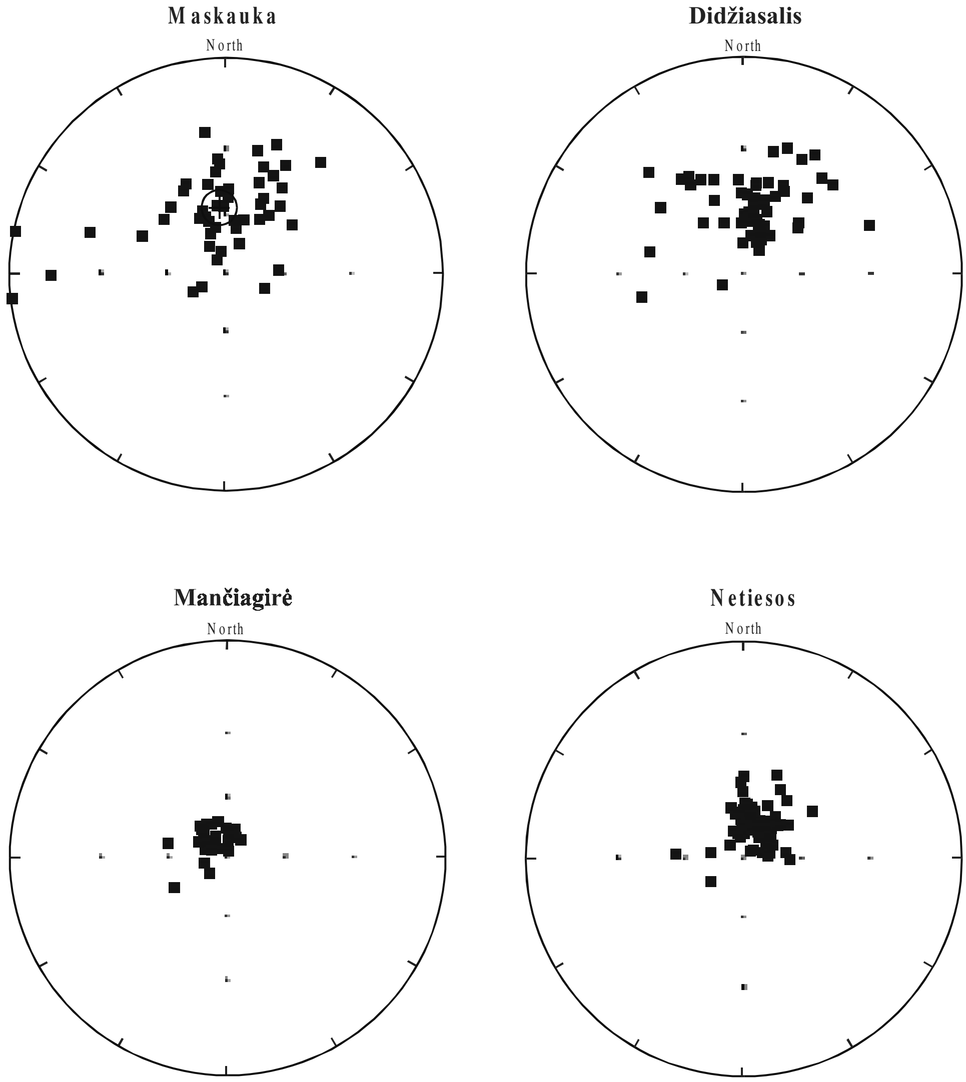

Fig. 3. *Stereographic plot of AF-cleaned ChRM – directions of the Maskauka, Didžiasalis, Mančiagirė and Netiesos profiles.*

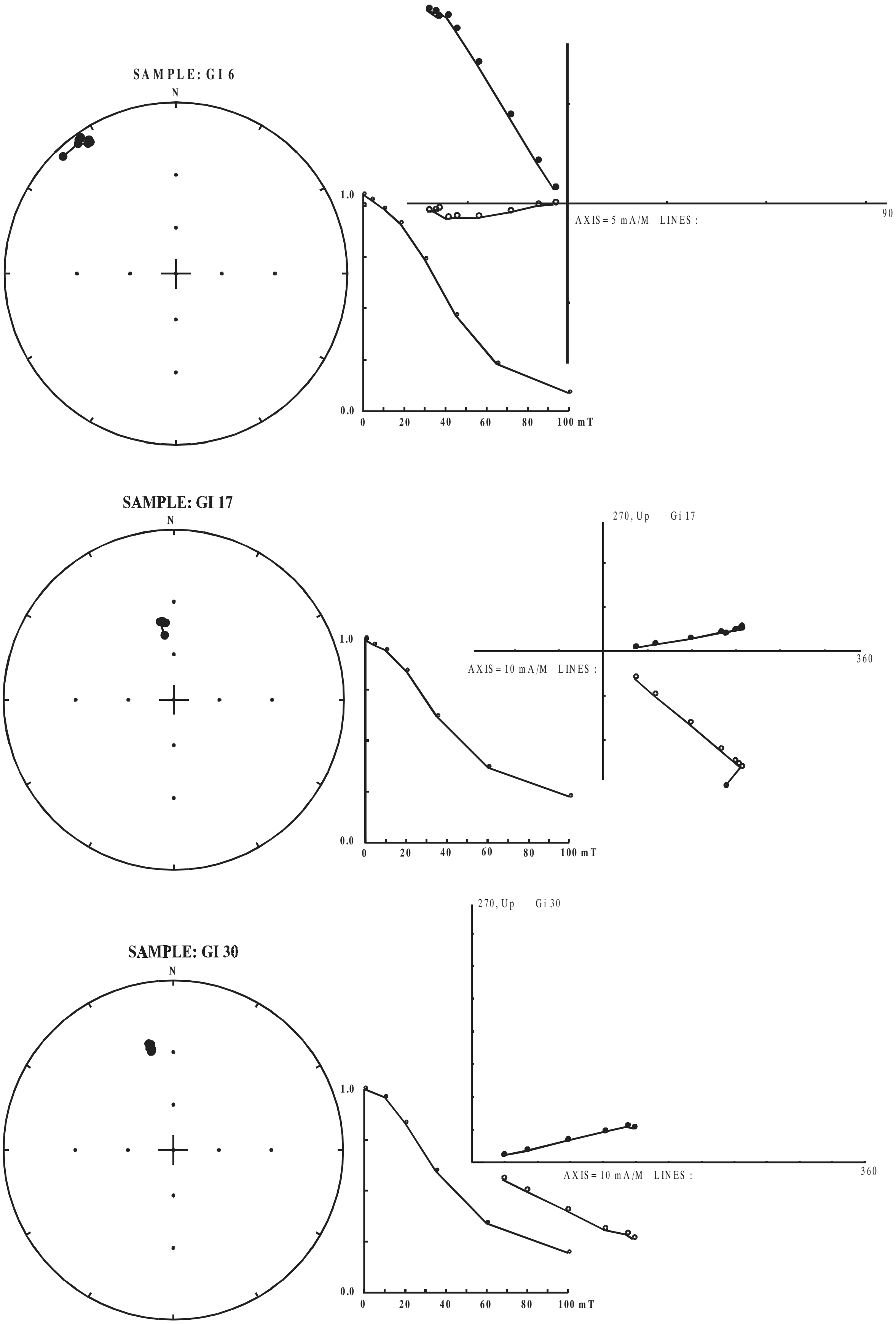

Fig. 4. *Stereographic, intensity decay and orthogonal plots of AF-cleaned ChRM-directions of 3 pilot specimens (samples No. 6, 17 and 30) from the Girininkai profile.*

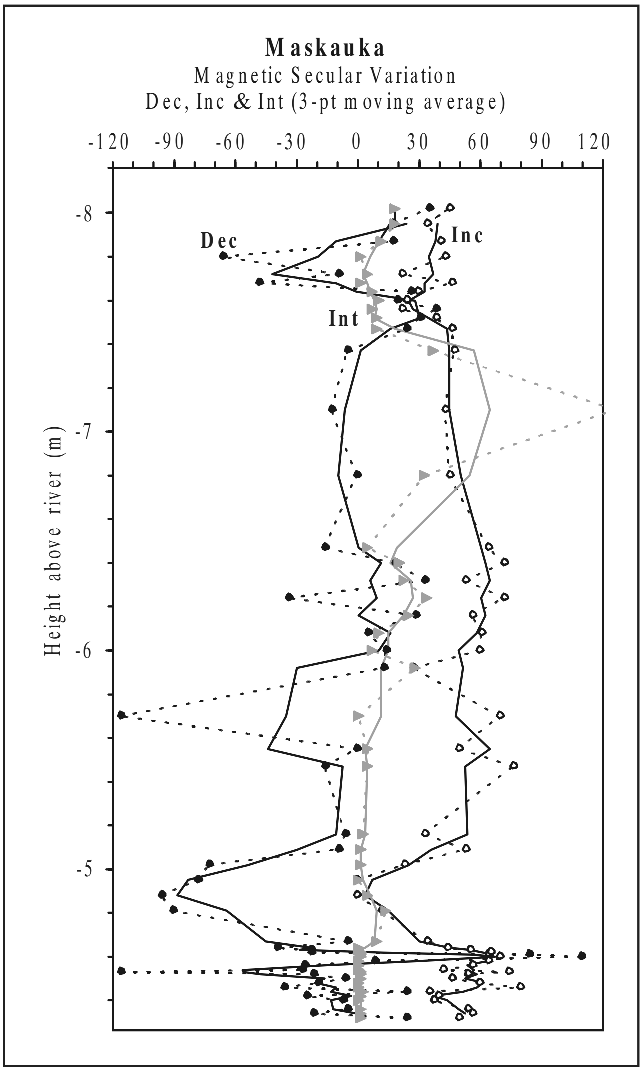

Fig. 5. Magnetic inclination (Inc), declination (Dec) and intensity (Int) of deposits of Maskauka profile. Full lines are 3-point moving averages.

5. GIRININKAI SECTION

Judging from 6 pilot specimens from the Girininkai profile, the magnetic direction is fairly stable (**Fig. 7**). However, magnetic declination is rather scatter, and is hardly diagnostic for the geomagnetic secular variation, expected variation of which would be close to true North, i.e. 0°±20°. Inclination is also somewhat strange, being rather shallow around 30°±30°, whereas the expected inclination for an average geomagnetic field in Lithuania would be around 70°±10°. This shallow inclination may indicate compaction of the sediment. The palaeomagnetic investigation of the interstadial sediments covers the time interval from 11,630±120 to 12,700±80 years ago in the Mančiagirė section (Gaigalas, 1994).

6. MANČIAGIRĖ SECTION

The Mančiagirė section spans the Alleröd interstadial over the Ūla River. AF-cleaned declination and inclination both show a systematic trend with low values and low scatter between 0.4 m and 1.3 m above the river level, superposed upon a short-wave variation at the lower half of the profile. The general trend in declination is a change from westerly declination at the lower part towards easterly declination at the top (**Fig. 8**). The swings in declination between 1.15 m and 1.35 m are likely to be due to some kind of sediment disturbance, the intensity being quite high. The upper part of the profile may be disturbed due to roots and due to low intensity of more sandy sediment on the top.

As mentioned above, systematic short wave pattern appears between 0.4 m and 1.3 m in inclination from around 70° at 0.8 m to around 80° at 2 m (**Fig. 8**). The GAD value of the site is Io=70.1°. The NRM intensity of black gyttja is systematically higher than of the sandy intervals at 1 m and above 2 m (**Fig. 8**). Mean direction of the Mančiagirė profile (Alleröd) is (Dm, Im)=(30.0°W, 77.8°), N=44, α_{95} =2.7 (**Fig. 3**).

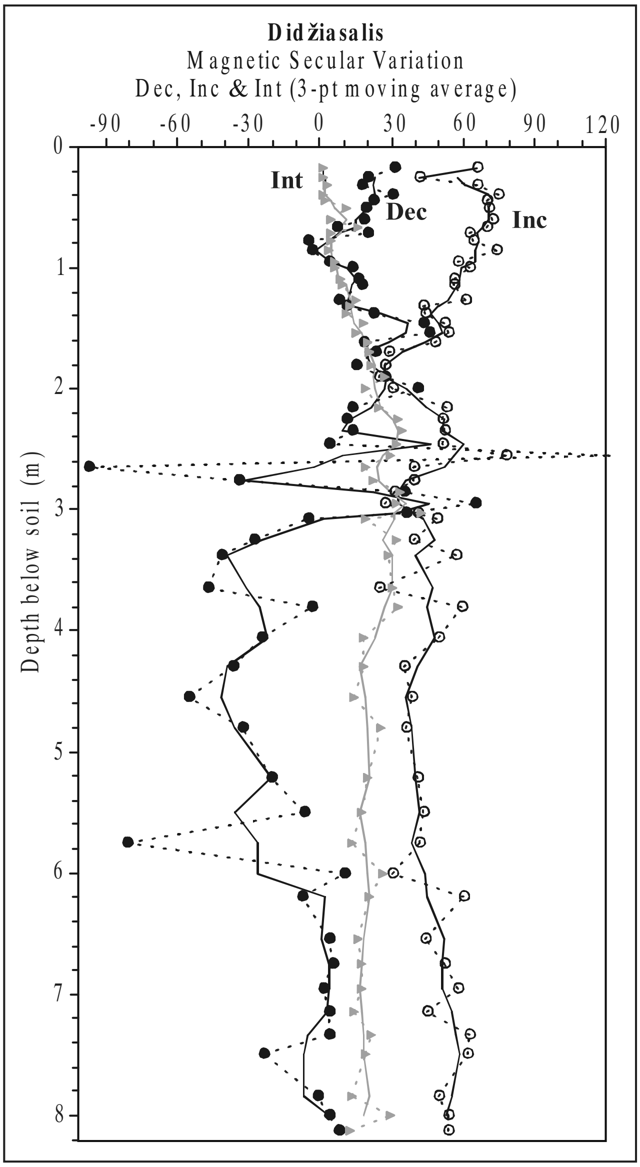

Fig. 6. Magnetic inclination (Inc), declination (Dec) and intensity (Int) of deposits of Didžiasalis profile. Full lines are 3-point moving averages.

7. NETIESOS SECTION

The palaeomagnetic research of the Merkinė (=Eemian) Interglacial sediments covers the time interval since 112±25 ka to 101.5±11.5 ka years BP in the Netiesos section. The Merkinė deposits are represented by gyttja and peat with silt in the bottom part of the section. The geomagnetic Blake event, some times recorded in Eemian deposits (e.g. Abrahamsen, 1995), is not found in the Netiesos profile (**Fig. 9**).

Declination (AF-cleaned) is mostly East of North, but the scatter is quite high, due to sandy character of sediments (**Fig. 9**). In inclination, a certain pattern may be seen in the 3-point moving average (full line), but the scatter is rather high due to sandy character of sediments (**Fig. 9**). There has been no compaction of the sediments, as the average inclination is close to the GAD value of the site, Io=70.2°. The NRM intensity of the profile decreases upwards, the sediments becoming more sandy towards the top (**Fig. 9**). Stereogram of the AF-clean direction of individual specimens. The mean direction is (Dm,Im)=(19.4°E, 71.1°), N=66, α_{95} =3.2°, k=30.1 (**Fig. 3**).

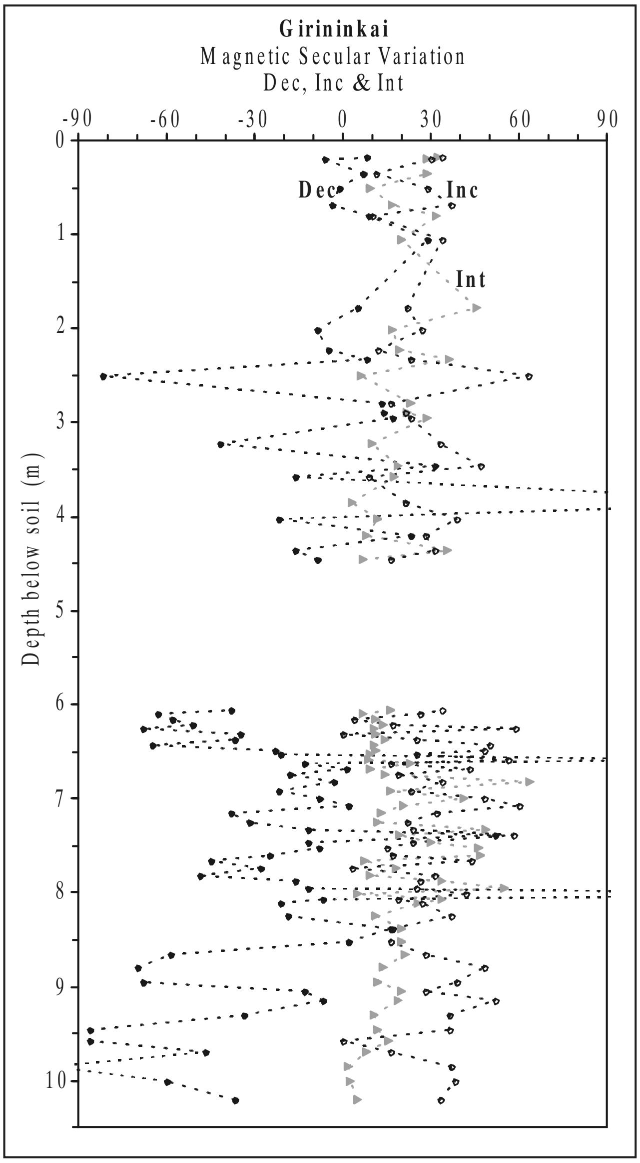

Fig. 7. Magnetic inclination (Inc), declination (Dec) and intensity (Int) of deposits of Girininkai profile.

8. CONCLUDING REMARKS

Our data appear to be too scattered to define any significant excursion of the geomagnetic pole in the time interval of 18,000-14,000 BP (Maskauka, Didžiasalis and Girininkai) and in 11,600-12,700 BP (Mančiagirė interstadial), as well as in the time of the Last interglacial (112±25 ka to 101.5 ± 11.5 ka BP). However, some magnetic information can be obtained from the varved clays of the Late Pleistocene time. The variation as well as the local scatter in the intensity values are likely to indicate lithological variations in the clay and silt proportions of the thin laminated varved clays. The swings in declination are likely to be due to some kind of sediment disturbance (sediment compaction due to glacial activity), the intensity being quite high.

We do not find the Gothenburg excursion in the time interval of 18,000-11,000 BP. The VGP (Virtual geomagnetic pole) do not fall below 60° N. The geomagnetic Blake event, some times recorded in Eemian deposits is not found in the Netiesos profile of the Merkinė Interglacial.

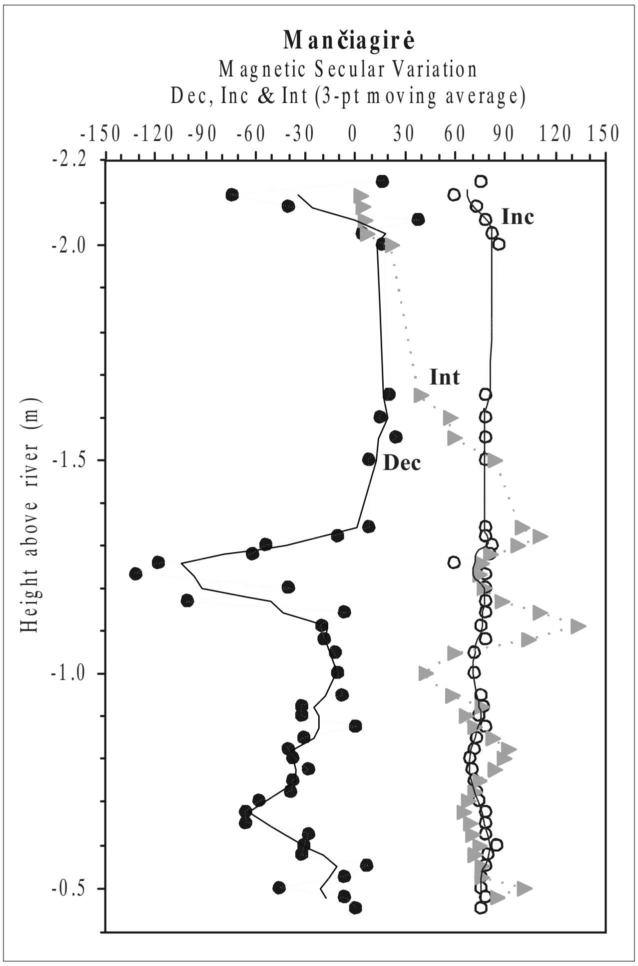

Fig. 8. Magnetic inclination (Inc), declination (Dec) and intensity (Int) of deposits of Mančiagirė profile. Full lines are 3-point moving averages.

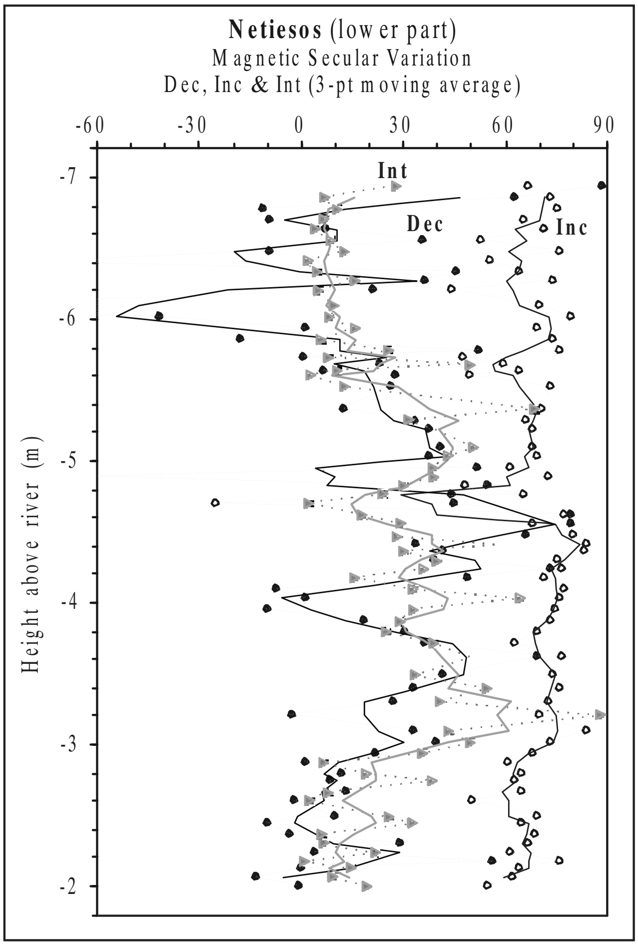

Fig. 9. *Magnetic inclination (Inc), declination (Dec) and intensity (Int) of deposits of Netiesos profile. Full lines are 3-point moving averages.*

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