GEOLOGICA CARPATHICA, 44, 5, BRATISLAVA, OCTOBER 1993
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PALAEOMAGNETISM AND LITHOLOGY OF LATE WEICHSELIAN DEPOSITS IN UST-PJALKA'S PERIGLACIAL LAKE, SOUTH-EAST OF THE KOLA PENINSULA

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(Manuscript received August 15, 1992; accepted November 15, 19993)

Abstract: Detailed complex lithological and palaeomagnetic studies of Late Weichselian varved clays of an ancient periglacial lake carried out in the valley of the Ust-Pjalka River in the South Eastern Kola Peninsula (66.3° N, 39°E). It is shown that the lake-glacial deposits are typical turbidites and the sediments of the proximal and distal zone differ greatly. A sections of these deposits was taken from the profile along the ancient periglacial lake. It has been found that the structure of the proximal zone varves simplifies both in a distal direction and laterally. Common laws of these changes associated with the character of turbidity currents have been discovered. The varves of the proximal zone are reduced, while the distal zone sections are continuous and include more than 600 varves. From the results it follows that the varved clays of the proximal zone can hardly be used for the varvometric method and for studying palaeosecular geomagnetic variations. The informative distal varved clays show geomagnetic variations of declination with an amplitude over 80°. The palaeomagnetic data show that the sediments were accumulated in the Middle Dryas - Early Alleröd.

Key words: Ust-Pjalka, varved clays, rhythms, deposit, secular variation.

Introduction

The study of Quaternary deposits on the Kola Peninsula carried out from the middle of last century to the present was focused on the questions of stratigraphy and palaeogeography, and on prospecting for building materials. A small number of lithological investigations have being carried out only in the last 30 years. The investigations have been concerned mostly with tills, glaciofluvial, glaciomarine and marine sediments. Glacial lacustrine sediments, so far, remain the least studied, since they are almost absent in the western well explored part of the region, and in the eastern part they are commonly covered with peat bog. The present paper to some extent fills the gap in our knowledge on this type of sediment and provides a sufficiently complete conception on the structure of glacial lacustrine sequences.

Object of study

The area studied is situated in the south-east of the Kola Peninsula (Fig. 1). Two systems of marginal glacial deposits are developed in the region. In literature they are called Keiva I and Keiva II (Lavrova 1960). Lavrova correlated them with the studial deposits of Salpausselkä I and II located in Northern Finland, and interpreted by Finnish scientists as of Young Dryas age. The data obtained by the authors (Bakhmutov at al. 1991) suggest that Keiva I and II have an older age, and Keiva I formed later than Keiva II. The main system of Late Weichselian ice marginal formations is located to the north of Keiva I (Fig. 1). The present study was focused on the deposits of a periglacial basin, which was situated in front of the established

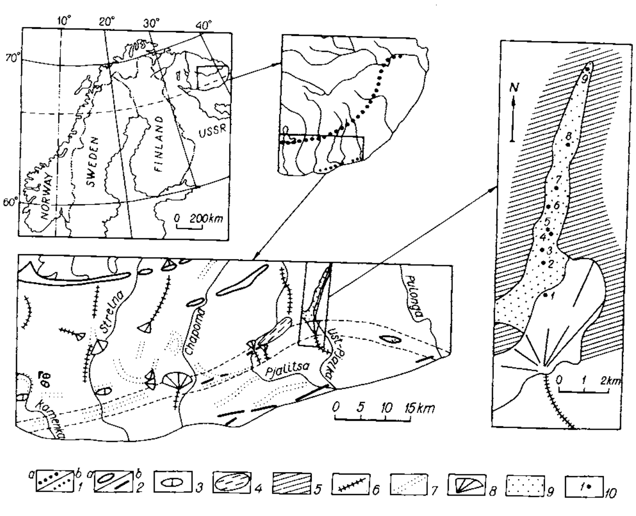

Fig. 1. Glacial marginal formations in the south-east of the Kola Peninsula.
Legend: 1 - ridges of Tersky Keivy: Keiva II (a) and Keiva I (b); 2 - push (a) and dump (b) morains; 3 - morainic hill; 4 - a positive landscape form of an imbricated structure (Pargameevsky Keivy); 5 - morainic plain; 6 - esker; 7 - late glacial meltwater channel; 8 - glaciofluvial delta fan; 9 - periglacial dammed lake bed; 10 - position of the section and its number. Dash lines delineate marginal formations of the Weichselian glaciation stage that took place in the Middle Dryas time.

system of marginal formations and occupied the middle part of the valley of the Ust-Pjalka River. The deposits occur in two terraces, with the surfaces dipping in the same directions but less steeply than the slopes of the depression that accommodates the river valley (Fig. 2a). The upper terrace is mainly constructive, being 150 - 145 m a.s.l.; the lower terrace is predominantly destructive, being 142.5 - 140 m a.s.l. It should be noted that in the Late post-glacial period the central regions of the Kola Peninsula were uplifting at a greater rate than the peripheral ones. Therefore, according to the isobase plot (Koshechkin 1979), the deposits under investigation used to be 10 meters higher in the northern part of their distribution area, in comparison with the sediments deposited at the northern boundary of the lake. Taking into account the modern hight of occurrence of coeval sediments (Fig. 2b), this means that during the sedimentation the basin bottom was dipping towards the north. Clastic material was transported to the basin from the slope of a glaciofluvial delta bordering the lake in the south (Bakhmutov at al. 1991). At present the glacial lacustrine deposits are almost completely exposed along the river. This fact permitted us to trace the changes in lithological and palaeomagnetic properties with space and time, and to determine the age of the deposits.

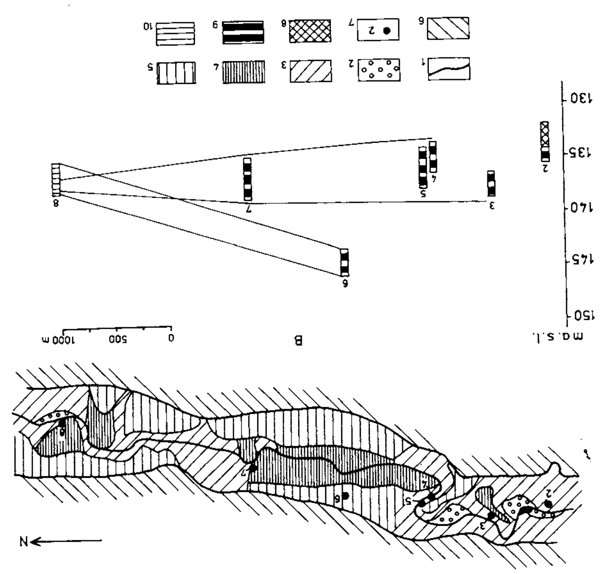

Fig. 2. A geomorphological scheme (A) and the correlation of the sections of glacial lacustrine sediments (B) occurring in the region of the river Ust-Pjalka mid-channel.
1 - river bed; 2 - flood plain; 3 - gentle slopes; 4 - lower terrace; 5 - higher terrace; 6 - slopes of the depressions; 7 - position of the section and its number; 8 - glaciofluvial delta deposits; 9 - glacial lacustrine deposits of the proximal zone; 10 - glacial lacustrine deposits of the distal zone.

Lithology

Seven cross-sections of glacial lake sediments have been studied in detail. Fig. 2b shows their correlation based on the interpretation of palaeomagnetic and geologic-geomorphologic data. Two zones of proximal and distal sediments can be distinguished in the sequence of the glacial lake sediments. The boundary between them on the surface goes approximately between sections 7 and 8. The data obtained allowed us to establish the changes in the structural-textural properties of the sediments of the first zone both distally (sections 2 - 5 and 7) and partly laterally (section 6 compared with the others). Sections 2 - 5 and 7 are confined to the lower terrace (see Fig. 2a). They consist of sediments deposited in the submeridionally elongated, relatively deepwater middle part of the lake. Section 6 occurs in the upper terrace and tends to the coastal part of the lake, and therefore, its formed in shallower water.

The bottom (2.25 m) of section 2 is represented by sediments of a glaciofluvial delta. The top of the section (1.55 m), as well as sections 3 - 5 and 7, that do not reach the base of the glacial lacustrine sequence, are composed of proximal varves. Each varve can be divided into a lower part, which is predominantly silt and which generally has a complicated structure, and an upper part, which is clay. Near the delta, the lower parts of the varves contain not only silt, but also sand with an average grain size of about 0.1 mm. Here, clay beds locally contain sandy laminate, and in the northern sections the sandy laminate are replaced by silty ones.

Proximal varves generally have a rhythmic structure. The established rhythms are similar to the rhythms of typical turbidites. This is described in detail in the work by Banerjee (1973) on the example of glacial varves in Ontario, Canada. Most rhythms represent assemblages of sediments. A complete assemblage consists of 5 elements (ABCDE) and corresponds to a complete turbidite according to Bouma (1962). Tab. 1 presents the structure and composition of a rhythm.

Cumulative curves of grain size distribution in the sediments composing the rhythm are shown in Fig. 3. As seen from the figure, the medium grain size of the clastic material becomes finer from bottom to top. This is roughly in agreement with the conception implying that the elements A, B, C and D are produced by a turbidity current that is slowing down. The uppermost clay bed is partially deposited in summer directly from a turbidity current, and partially in winter from a suspension that is functioning much longer than each turbidity current. We would like to mention, that in the sections studied the components of the rhythm element E differ in colour: the lower component is greenish-grey and it looks like a silt bed, and the upper one has a characteristic reddish-brown colour. The difference in colour is evidently related to the oxidation of iron due to the fact that water in winter is highly saturated with oxygen. The Fe_2O_3 to FeO ratio in green clay is 1.3 (the mean value of four analyses), whereas in brown clay the ratio is up to 1.9 (the mean value of three analyses).

In the sediments of sections 2 - 5 and 7, as well as in typical turbidites, complete rhythms are rare, and rhythms lacking one or several elements are abundant. The total number of rhythm types established in the sediments of the proximal zone is 21. The types and the changes in the structure of the sediments in the distal direction are presented in Tab. 2. By the percentage of rhythms of all the sections, they can be divided into 4 groups. The rhythms ABCDE, CDE, ABC, BCD, ABDE, and ACE are

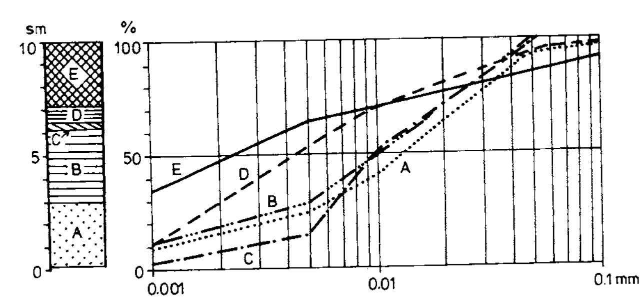

Fig. 3. Cumulative curves of grain size distribution in the elements of the rhythm ABCDE at a depth interval of 380 - 389.8 cm in section 5.

the rarest (less than 2 %). The rhythms ACDE, ABE, AC, AE, A and E make up 2 - 5%. The rhythms DE, ADE, BCE, BDE, BE and B make up 5 - 10 % and the rhythms BCDE and BC occur relatively frequently (10 - 20 %). Tab. 2 shows that there are 14 rhythm types in the southern peripheral part of the proximal zone, 20 rhythm types in the central part, and only 11 types in the northern part. Such distribution of the rhythms is probably caused by variations in the dynamics of the turbidity currents. The currents accelerated along the frontal delta slope; their speed was high and almost constant in the central part; and in the northern part their speed decreased.

Table 1: Composition and structure of a rhythm ABCDE.

Element of the rhythm	Material	Structure
E	clay	structureless
D	silt and clay	parallel lamination
C	silt	cross lamination
B	silt	parallel lamination
A	silt	graded lamination

The evidences of erosion observed in the sections testify that the turbidity currents eroded the underlying sediments. That is why the sections studied are considerable reduced. However, the analysis of variations in the percentage of each element of a complete rhythm along the proximal zone presents a certain interest. The data obtained are given in the plot (Fig. 4). The rhythm elements apparently fall into two groups: the first group consists of elements A, B and C: the second one comprises elements D and E. The elements of the first group are characterized by a tendency for their percentage to decrease distally, and the percentage of the elements in the second group tends to increase. Here it seems reasonable to note that in the distal zone all the rhythms consists of the elements D and E. Thus the observed percentage pattern of the rhythm elements is in accordance with the conception about the change in the rhythm structure that takes place in the direction of a turbidity current (Gradzinsky at al. 1980). According to this conception, with the distance from the site of the current origination, the elements A, B and C consecutively disappear, whereas the elements D and E are developed everywhere.

The sediments studied occur in varves of variable thickness, from 1 to 40 cm. The most abundant are 1 to 15 cm thick varves. The average varve thickness in the southern peripheral and central parts of the proximal zone is about 12 cm; in the northern zone the average varve thickness is close to 10 cm. Apart from the turbidity current sediments, the varves are composed of structureless sand and silt deposited from grain flows. Locally, due to this type of sediment the varve thickness is considerably increased. The varves consist of one or several rhythms, the percentage of varves is composed of a varied number of rhythm changes in the direction of the flow movement. The plot (Fig. 5) indicates that the varves of the southern and central parts of the proximal zone almost do not differ from each other in the above factor; the share of varves composed of one-two rhythms is 34 - 42 %; of three rhythms 12 - 18 %; four rhythms 6 - 8 %. The varves of the northern part have a simpler structure. 73 % of them are represented by a single rhythm; 23 % by two rhythms; 2 % by three rhythms and 2 % by four rhythms. If each rhythm

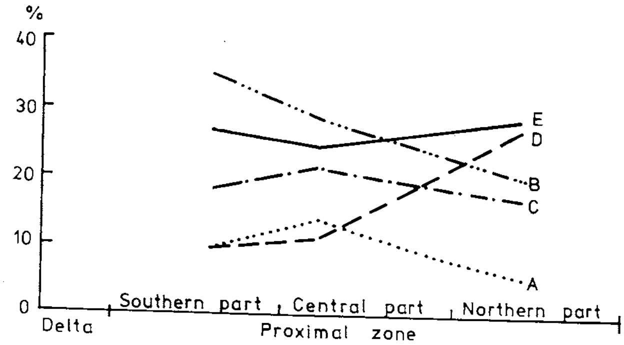

Fig. 4. Variations of the percentage of each element of the rhythm ABCDE in the deposits of the proximal zone, with the distance from the glaciofluvial delta.

is assumed to be formed by one current then the simplification found in the varve structure provides evidence that not all the currents, that originated in the frontal delta slope reached the northern peripheral part of the proximal zone. However, those currents that did not fail to reach that part of the zone, had a lower speed than in the central part, for example. This is also suggested by the mentioned decrease in the average varve thickness. Moreover, there the currents influenced the underlying sediments with less energy than in other zones. Thus, in the northern peripheral part of the zone, the components of the element E, deposited from turbidity currents, are preserved much more commonly within the complicate structure of the varves.

Lateral changes in the structure of proximal varves are rather prominent. However, the data available on these variations are limited. In fact, only section 6 located 147.5 m above the sea level is confined to the coastal part of the palaeolake. 177 rhythms of 13 types similar to those described above have been distinguished in the section. Their major characteristic feature is the reduction of element E. Its thickness being small, element E is hardly observed, and if observed, then not in all the rhythms. There is a tendency for this element to disappear towards the top of the section. Thus, is the lowermost 1 m thick section segment the element E is found in 20 % of the rhythms, and in the top of the section the element is present only in 3 - 4 % of the rhythms. This tendency can explained by a decrease in the lake's depth in

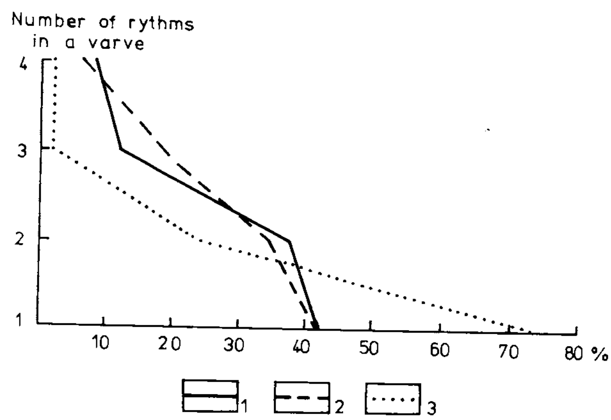

Fig. 5. Amount of rhythms in the varves of the proximal zone. Parts of the zone: 1 - southern; 2 - central; 3 - northern.

Table 2: Distribution of various types of rhythms in deposits of the proximal zone.

N rhythms	Proximal Zone: Southern part, sections 2, 3		Proximal Zone: Central part, sections 4, 5		Proximal Zone: Northern part, section 7		Total in the proximal zone	
	amount	%	amount	%	amount	%	amount	%
1.ABCDE	-	-	1	1.0	-	-	1	0.5
2.BCDE	1	2.3	4	4.0	16	27.6	21	10.3
3.ABC	1	2.3	1	1.0	-	-	2	1.0
4.BCD	1	2.3	2	2.0	-	-	3	1.5
5.CDE	2	4.5	-	-	1	1.7	3	1.5
6.BC	8	18.2	22	21.8	8	13.8	38	18.7
7.DE	-	-	3	3.0	15	25.9	18	8.9
8.A"CDE	-	-	3	3.0	2	3.4	5	2.5
9.AB"DE	-	-	1	1.0	2	3.4	3	1.5
10.ABC"E	-	-	2	2.0	-	-	2	1.0
11.AB""E	2	4.5	2	2.0	1	1.7	5	2.5
12.A"C"E	-	-	1	1.0	-	-	1	0.5
13.A""DE	-	-	9	8.9	4	6.9	13	6.4
14.BC"E	2	4.5	13	12.9	2	3.4	17	8.4
15.B"DE	5	11.4	5	4.9	6	10.3	16	3.0
16.A"C	2	4.5	4	4.0	-	-	6	3.0
17.A"""E	2	4.5	6	5.9	-	-	8	3.9
18.B""E	8	18.2	8	7.9	-	-	16	7.9
19.A	2	4.5	3	3.0	1	1.7	6	3.0
20.B	4	9.1	9	8.9	-	-	13	6.4
21.E	4	9.1	2	2.0	-	-	6	3.0
Total	44	99.9	101	100.2	58	99.8	203	100.3

Note: For the location of the sections see Figs.1 and 2.

the course of sedimentation. As a result, more and more clay particles were transported from the coastal part to the relatively deep-water and stable parts of the lake.

The varve thickness in section 6 ranges from 0.5 to 3 cm, averaging 1.2 cm. This is almost one order of magnitude lower than the varve thickness in sections 2 - 5 and 7. All the varves in section 6 are represented by single rhythm, whereas the varves in the sections mentioned above have a more complicated structure. By palaeomagnetic data presented in the following part of this paper section 6 formed during a period of approximately 450 years. Therefore, even if we assume that each of the 117 rhythms represents an annual layer, the geologic records still would be rather fragmental. Apparently, peripheral segments of turbidity currents contained less clastic material than the central parts. Consequently, the varve thickness became lower and the structure became less complicated in the direction from the submeridionally elongated deep-water area of sedimentary accumulation towards the periphery. Nevertheless, the erosion produced by turbidity currents in the underlying deposits affected the whole periphery of the proximal zone.

Sediments of the distal zone were examined in section 6.606 and varves have been distinguished in the sequence. The varve thickness varied from 0.2 to 2 cm, the average was 0.5 cm. All the varves are represented by the rhythm DE. The summer silty part of varves (D) is commonly thicker than the winter clayey part (E), although in some cases their thicknesses are the same or even the latter is thicker than the former. The content of clay particles generally decreases from bottom to top of the section. This can be explained only by the fact that the lake level was lowering with the accumulation of clays. Therefore, the delta was restructured, and the proportion of silt particles was increasing in the composition of clastic material coming to the frontal slope and generating turbidity currents.

Palaeomagnetic studies

Our palaeomagnetic studies were primarily aimed at obtaining information on the ancient geomagnetic field vector of lithologically heterogeneous sediments. The main questions are: **a** - with what accuracy has been the defined ancient magnetic field direction for different lacustrine-glacial clays; **b** - can different lithologic types of sediments be correlated by the palaeomagnetic method and; **c** - what distortions may affect the "record"

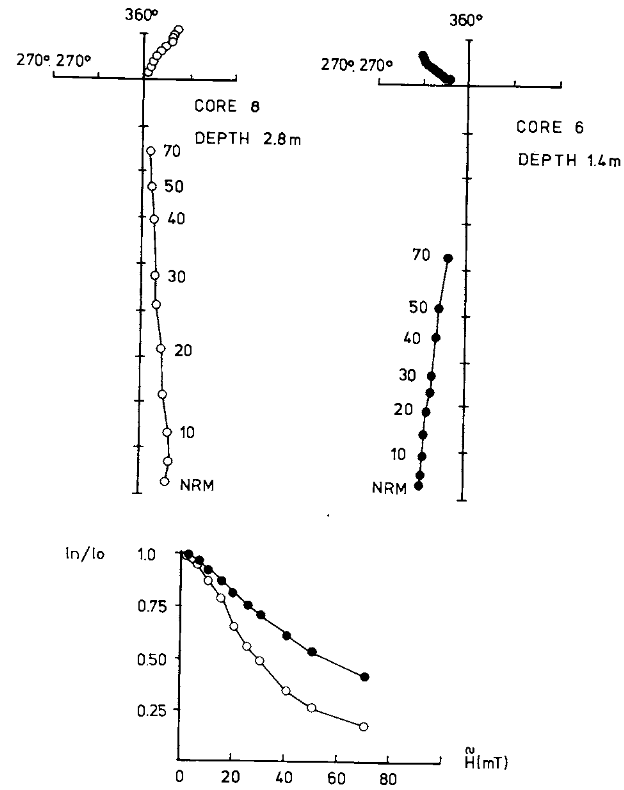

Fig. 6. Orthogonal projections and alternating magnetic field demagnetization curves of the Ust-Pjalka lake samples.

and where do they stem from? Considering the uniqueness of such a geological object in studying sedimentary rock magnetism we omit in this section the problems of chemical magnetization, effect of near-floor streams on the magnetization direction, magnetic anisotropy etc which are rather wide and are published separately.

For the palaeomagnetic studies 5 cm - face cubic samples were used. At each level 3 - 4 samples oriented at magnetic meridian and horizontal plane were selected. On sections 6 and 8 samples were selected at each 5 cm depth level in the whole clay mass exposed. On sections 3, 5 and 7 samples were taken on clayey interbeds (E-element of rhythm) and included both E-element whose thickness averages 2 - 3 cm, and a part of the foregoing element of rhythm.

The magnetic characteristics were measured with an astatic magnetometer LAM-22. A detailed stepwise AF demagnetization of representative samples by AF-demagnetization field to 70 mT with 2.5 - 5 mT steps shows that, as a whole, declination changes to 5° and 10 - 15° only for some samples, while the mean inclination change does not exceed 2° of its initial value. After the effect of the field above 15 - 20 mT the vector direction is stabilized. The median demagnetizing field $I_n/I_{no} = 0.5$ is at least 20 mT (Fig. 6), the curves of demagnetization by alternating magnetic field differing from each other in stability. For example Fig. 6 shows the results for "magnetically soft" and "magnetically hard" samples. An analysis of the demagnetization results from representative samples permitted us to choose a magnetic cleaning field H = 15 mT. The results of thermal demagnetization of I_n also gave evidence for different thermal stability of the samples by analogy with AF data. One-hour heating of the samples in a zero magnetic field at 150 °C yielded the same mag-

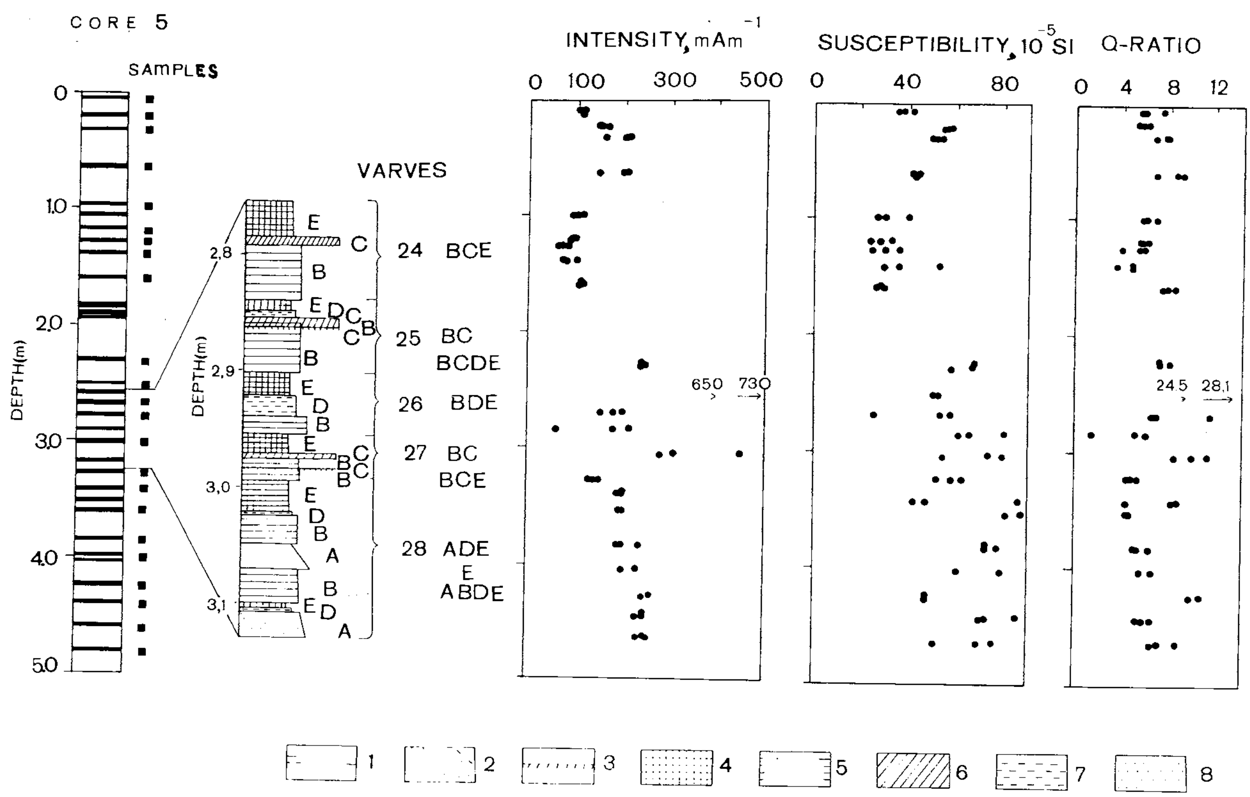

Fig. 7. Lithological column and magnetic characteristics of varved clays; (intensity, magnetic susceptibility, Q - ratio) of section 5.
1 - varved clays; 2 - clays with disturbed varves; 3 - element of rhythm C (silt); 4 - element of rhythm E (clay); 5 - element of rhythm B (silt); 6 - element of rhythm C (skew-wavy silt); 7 - element of rhythm D; 8 - element of rhythm A. In the rights of column rhythms 28 - (ADEB, ABDE); 27 - (BC, BCE); 26 - (BDE); 25 - (BC, BCDE); 24 - (BCE).

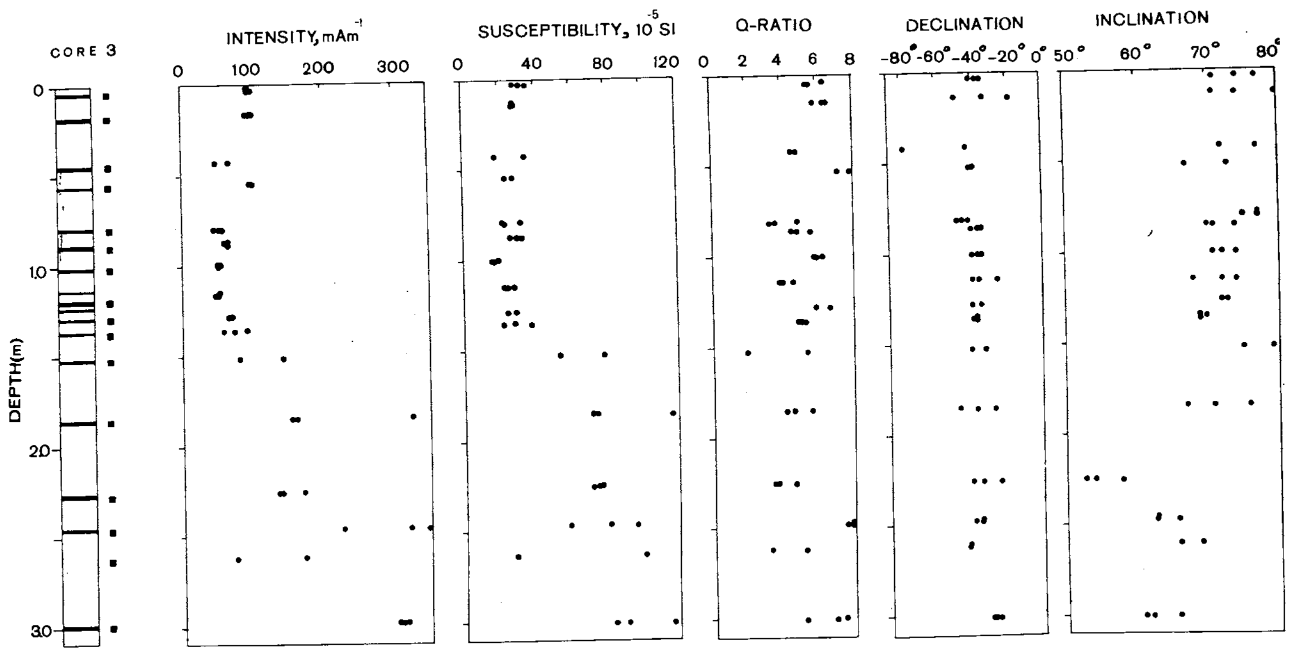

Fig. 8. Results of the palaeomagnetic studies for section 3.

netic cleaning effect as that of AF (H = 20 mT). All samples were cleaned magnetically and the results completely confirm the data of representative samples and show slight magnetization direction changes after cleaning. The further magnetic cleaning results are deliberately omitted (except those of section 8) since they carry no additional information.

Structural and textural differences between the argillic deposits of the proximal and distal zone are emphasized by differences in their magnetic parameters. This is primarily caused by sediment formation conditions in different parts of the lake. The magnetic fraction of fine-sand and aleurite particles deposited mainly at high flow speed near the fluvioglacial delta, were partly carried out to the central part of the deepest abyssal zone, while the fine argillic particles deposited almost everywhere and concentrated in the peripheral part of the lake furthest from the delta. The magnetic parameters obtained from the varved clays are given in Figs. 7 - 11. Consider them successively beginning from the proximal zone deposits.

The clays of sections 3 and 5 are characterized by greatly scattered intensity, magnetic susceptibility and Q-ratio of neighbouring levels or even samples of the same level, as well as by the intensity and magnetic susceptibility of their values becoming higher as the position of the section approaches the delta (Figs. 7, 8). The abnormally high magnetization at a depth of 2.5 m on section 5 is ascribed to the grain flow deposits. In this sections intensity and magnetic susceptibility slightly decrease from bottom to top. In section 6 situated in the outlying part intensity is by 4 - 5 times and magnetic susceptibility by 2 - 3 times lesser than in the sections 3 and 5 (Figs.7 - 9). This section shows a very interesting magnetic parameter variation. Up to a depth of 2.5 m the intensity slightly changes against the evenly increasing magnetic susceptibility. The sharp intensity increase by an order of magnitude at a depth of 2.5 m is not associated with magnetic susceptibility, i.e. with a sharp change of the sediment accumulation regime. No visible lithological changes occur here, but the colour of clays change from gray to slightly brown. As mentioned above, a characteristic feature of the section rhythms is the E-element reduction caused by carrying of fine particles out to the deeper off-shore part of the lake with lake shallowing due to choppiness. However, this process could hardly increase the magnetic "hardness" of the sediment. It would be more likely to do the opposite. Nevertheless, above 2.5 m the rock increases its magnetization and also elevates its stability to alternating magnetic field. We think, it may be related to stable hard chemical magnetization formation.

In sections 3 (Fig. 8) and 5 (Fig. 11), declination and inclination are greatly scattered even within the same level. We associate the relatively low inclination, especially in the lower and middle median part of these sections (about 60 - 65°) with "inclination error" mentioned below. These values are lower than the geocentric axial dipole (GAD) inclination for this territory which is 78.5°. Here and on other sections declination is undoubtedly more informative. Its mean direction from the main turbidity current direction measured in skew-wavy layering of the C elements and whose azimuth is 10° E. The absolute declination values are ca. 40 - 60° W. Distinguishing of any variations seems impossible except for the tendency to an eastward shift at the bottom of section 5. Quite different is the change of angular components of section 6 (Fig. 9) with clear change of declination with amplitude of ca. 100° or more, the mean inclination values approaching the GAD inclination or even exceeding it. The declination and inclination variations seen from Fig. 9 are not associated with changes of scaler magnetic parameters. For section 7 where only 20 samples were taken from the middle part of the rock mass the declination is ca. 40° W with 70 - 75° inclination. The intensity and magnetic susceptibility are somewhat lower than in section 5.

These results confirm the data on the decrease of capability of turbidity currents as carriers in a distal direction and are evidence of the "inclination error" decreasing with distance from the foreslope of the delta. The data presented show section 6, whose rhythms are structurally most similar to those of distal zone sediments, to be most informative for distinguishing geomagnetic field variations.

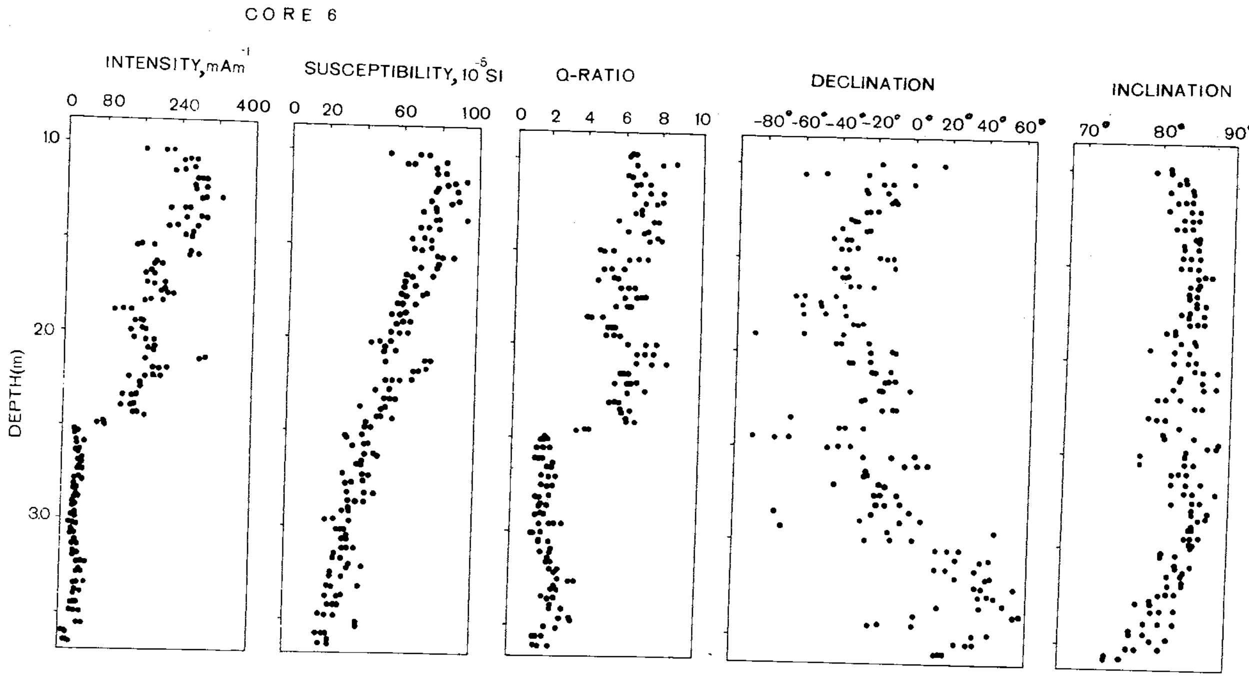

Fig. 9. Results of the palaeomagnetic studies for section 6.

In section 8 distal zone discloses a more than 3 m thick mass of distal varved clays (Fig. 10). The intensity and magnetic susceptibility change significantly from the bottom to top of the section, reflecting different hydrodynamic situations of sediment accumulation. At the bottom, the intensity and magnetic susceptibility of the clays approach those of proximal clays. Up the section intensity decreases by more than one order, while magnetic susceptibility decreases by three times and the Q-ratio easily reaches the values 1 - 2.

The different structure of the proximal and distal zones and the absence of marking horizons exclude their correlation by the varvometric method. The sections also cannot be correlated with each other by scalar magnetic parameters since there are neither general laws of their change nor marker beds which could be observed on all sections. The only possible means is comparison of the directions of remanent magnetization vectors and analysis of their general time variations. Here primarily declination variations can be informative since: 1 - we do not know the "inclination error" which can change from section to section depending on flow dynamics; 2 - the amplitude of declination variations at high latitudes much exceed that of inclination variations. On our sections 6 and 8 the declination and inclination variation amplitude are 100° and not more than 10°, respectively; 3 - the samples are strongly oriented at the present magnetic declination, which enables us not only to compare characteristic variation features but also to mark its absolute values, which is very important for short time spans. A comparison of absolute declination data for the proximal zone shows that sections 3 - 5 and 7 may be compared with interval 1. 3 - 2.6 m of section 6 and interval 1.15 -2.1 m of section 8. On the latter section this interval includes ca. 200 varves. The declination variations for section 6 and 8 are generally identical. Probably, clays at the bottom of section 6 began to accumulate somewhat earlier than in section 8 (50° E in section 6 and not more than 10° E in section 8) but this is uncertain since the section 8 bottom clays are deformed. This question remains open.

The GAD inclination for the area of the Ust-Pjalka is 78.5°. The mean inclination for section 8 approaches this value, while that for section 6 even slightly exceeds it. The mean inclinations of proximal varves of sections 3 and 5 are by 10 - 15° less. Evidently inclination is lower, its "error" (10 - 15°) being comparable with those estimated by other authors who studied varved clays (e.g. (Barton et al. 1980). The "inclination error" is probably controlled by the turbidity current intensity and depends on flow velocity in the near-floor layer where sediments are deposited.

The difference in inclination variations of sections 6 and 8 at 1 - 2 m depths may be due, both to the hydrodynamic conditions of sediment formation and to chemical magnetization in the upper part of section 6. An analysis of the data gives all reasons to detail just the second version since no data show a great difference in hydrodynamic regimes, except the turbidity flow erosional effect on the underlying deposits in the outlying part of the proximal zone which is minimal in the distal zone.

Considering the above fact section 8 should undoubtedly be held most informative for the palaeomagnetic data analysis.

Interpretation of results

The left-hand part of Fig. 12 shows the results for section 8 obtained after magnetic cleaning H = 20 mT and T° = 150 °C and which are averaged with a step of 30 years, i.e. each point shows the mean value for the 30 y. interval and is presented depending on the sediment accumulation rate 15-20 cm depth level including an average of 9 - 12 samples or more. The right -hand part of the figure shows the same results at another time scale in correspondence with the regional magnetochronological scale of the Late Weichselian (Bakhmutov & Zagniy 1990; Fig. 9). Each point of the magnetochronological scale represents an average interval of 50 years. The proposed interpretation is probably the only one possible. Increase of the amplitude of

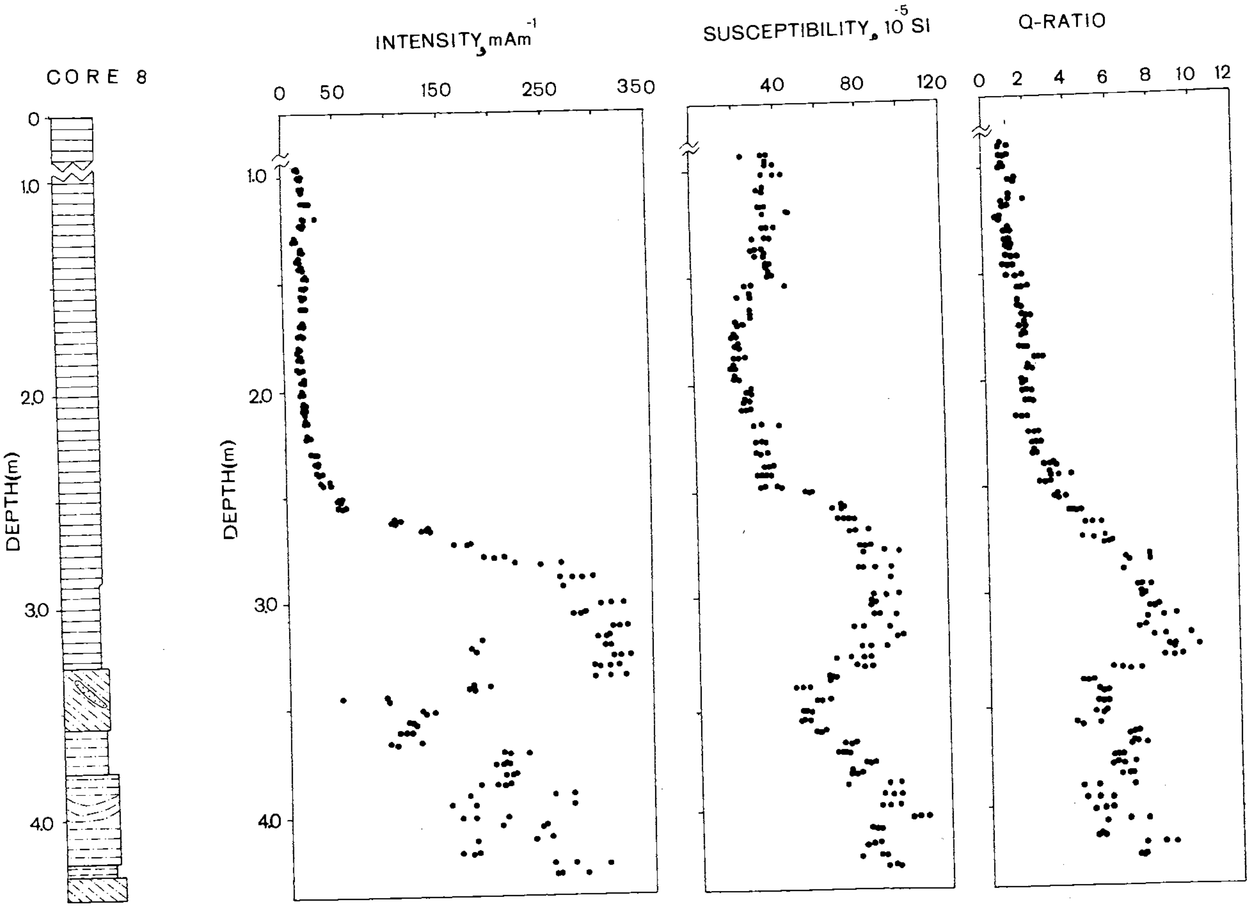

Fig. 10. Lithological column and magnetic parameters of varved clays of section 8. Symbols are given in Fig. 7.

western peak of declination is partly due to location of the Kola Peninsula further north than Karelia. A comparison of the average 30 years values of section 8 with average 30 years values of the same peak on sections of South Karelia (Bakhmutov & Zagniy 1990; Figs.3 - 5) shows that the westward shift on the Ust-Pjalka lake exceeds the corresponding Karelian values by 10°.

The eastward declination shift at the bottom of section 8 may be said to have not reached its maximum. Section 6 shows that the eastern maximum of this peak reachs 50°.

The difference of absolute inclination values is ca. 10° (Fig. 12). Which much exceeds the difference of the GAD values for Kola Peninsula (78.5°) and South Karelia (75°). As shown in (Bakhmutov 1987), we estimated the inclination error for Karelia at 10°. This correction equalizes the absolute inclinations of the sections from the Kola Peninsula and Karelia. The inclination variations are also generally similar and their best detailed coincidence will be reached when regarding the section 8 to be 100 years older then that interpreted by the right-hand part of Fig. 12.

The proposed scheme of correlation of section 8 with a regional magnetochronologic scale estimates the age of the bottom and top of clays at 12 200 and 11 600 years, respectively. This may serve as a basis for interpretation of the marginal glacial formation Keiva I and Keiva II with respect to the marginal formations of Karelia. Note that Keiva I corresponds to marginal formations of the Neva stage of the last glaciation clearly seen within the south-eastern margin of the Baltic Shield.

Now let us return to the problems of sedimentary formation in the Ust-Pjalka periglacial lake with a consideration of the palaeomagnetic data. The sediment accumulation rate for sections of varved clays of the proximal zone (sections 3 and 5) represented by several tens of rhythms of complicated structure with many signs of erosion cannot be estimated. The questions of whether the sediments were deposited for several tens of years, or whether they accumulated for ca. 600 years (as the 3.5 m thick clay of section 8) with periodic erosion of underlying layers may be partly answered by palaeomagnetic data. As seen from the above the declination of the proximal clay of sections 3 and 5 corresponds with that seen in the 1.15 - 2.1 m interval of section 8, on which we separated ca. 200 rhythms DE, each lasting one year. This exceed by several times the number of varves separated on sections 3 and 5 but is only one third of the total number of varves of section 8. Therefore the analyses of proximal clays cannot suggest the sediment rates; but it only indicates that the clays of sections 3 and 5 were formed during the period of less than 200 years. The rhythms were completely or partly eroded by turbidity currents, and the single rhythm fragments cannot provide sediment accumulation rate estimation. The distal varved clay sections most completely reflect the chronological scale and are most convenient for varvometric and palaeomagnetic definitions.

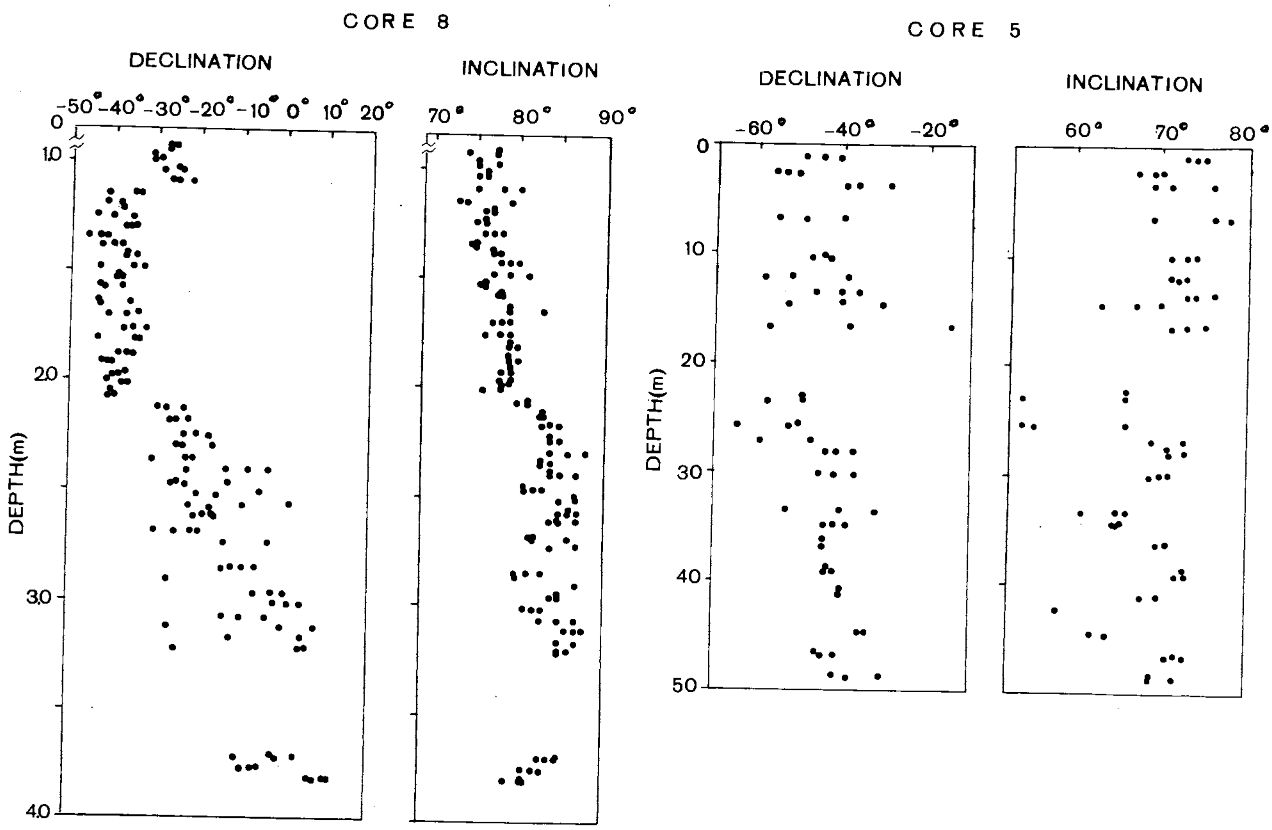

Fig. 11. Declination and inclination of section 8 and 5 (distal and proximal zone respectively).

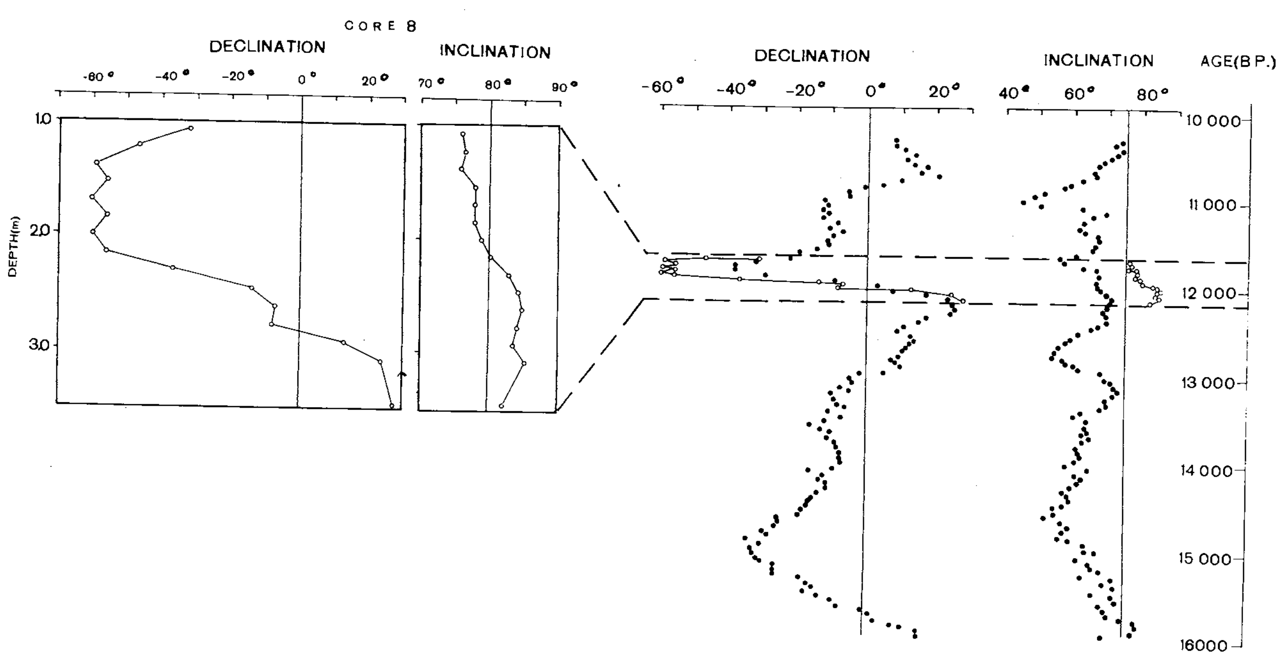

Fig. 12. Averaged declination and inclination of section 8 (left-hand part) adjusted to the regional magnetochronological scale (right-hand part).

Conclusion

The sediment of the Ust-Pjalka periglacial lake, represented by differently structured varves have been formed by turbidity flows in a shallowing reservoir. Their mass is divided into a proximal zone with reduced sections and a distal one with continuous sections. The varves are becoming thinner and structurally simpler in distal direction and laterally.

The palaeomagnetic studies of the proximal and distal sections of varved clays show a significant difference in the magnetic characteristics of the sediments and their different informativity. The proximal clay sections are featured by high intensity and magnetic susceptibility, great magnetization directions (inclination, declination) scatter within one level and between the levels, "inclination error". The distal varved clays are informative for palaeomagnetic determinations and may be used to distinguish palaeosecular variations.

On the basis of palaeomagnetic data sections of proximal and distal clay have been correlated and tied to the regional magnetochronologic scale. It has been found that the marginal glacial deposit Keiva I in the eastern Kola Peninsula corresponds to marginal formations of the Neva stage of the last glaciation. Sediments of the Ust-Pjalka's near-glacial reservoir were accumulated in the older Driassic - beginning of Alleröd.

Great caution should be used in handling the results of varvometric determinations and estimating the sediment accumulation rate of varved clays not preliminarily classified as the sediments of distal or proximal zones. The latter can hardly be studied reliably, while the former are convenient both geochronologically and for studying the fine structure of the ancient geomagnetic field.

References

Bakhmutov V. & Zagniy G., 1990: Secular variation of the geomagnetic field: data from the varved clays of Soviet Karelia. *Phys. Earth Planet Inter.*, 63, 121 - 134.

Bakhmutov V., Yevzerov V., Zagniy G., Kolka V. & Gorbunov E., 1991: Conditions of formation and the age of marginal formation of the last ice sheet in the SE Kola Peninsula. *Geomorphology* (Moscow), 2, 52 - 59 (in Russian).

Banerjee J., 1973: Sedimentology of Pleistocene glacial varves in Ontario, Canada (Part A). Nature of grain-size distribution of some Pleistocene glacial varves of Ontario, Canada (Part B). *Geol. Surv. Canada Bull.*, 226, 1 - 60.

Barton C., McElhinny M. & Edwards D., 1980: Laboratory studies of depositional DRM. *Geophys. J. Roy. Astron. Soc.*, 61, 355 - 377.

Bouma A., 1962: Sedimentology of some flysch deposites. *Elsevier Publishing Co.*, Amsterdam, 168 .

Gradzinsky P., Kostetskaya A., Radomsky L., Unrug O., 1980: Sedimentology. *Nedra*, Moscow, 646 (in Russian).

Koshechkin B., 1979: Holocene tectonics of the Eastern Baltic Shield. Nauka, Leningrad, 157 (in Russian).

Lavrova M., 1960: Quaternary geology of the Kola Peninsula. *USSR Acad. Sci.* (Moscow - Leningrad), 233 (in Russian).