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NEW AGE DATA OF BURIED PEAT DEPOSITS FROM THE SITE "FILI PARK" (MOSCOW, RUSSIA) BY THE URANIUM-THORIUM DATING AND PALYNOLOGICAL ANALYSIS AND ITS STRATYGRAPHIC SIGNIFICANCE

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Abstract: The chronostratygraphically important Quaternary buried peats from the site "Fili Park" (located on the territory of Moscow) on the Russian Plain were studied by the methods of uranium-thorium dating (UTD) and palynological analysis. The deposits under study were the subject of intense debate: some number of the palynologists assigned ones to the Mikulino (Eem) Interglacial, while the another investigators - to the Odintzovo Interglacial (Middle Pleistocene).

Detailed palynological study gave the possibility to mark out the 3 palynozones (M2, M3 and M4) in section vertical profile and refer the deposits to the Mikulino (Eem) Interglacial. The uranium-thorium dating (by "leachate alone" method) was carried out in the middle layers, which would be expected to be a closed system in respect to uranium and thorium isotopes. The direct uranium-thorium dating of inner layers showed the first UTD ages from 78.9 to 105.0 ka for deposits from the site "Fili Park". The corrected uranium-thorium age of buried peat turned out to be younger than the currently adopted boundaries of the last Interglacial (116-128 ka) and comprised 89±11 ka. There was probably an additional post-deposition uranium uptake in the internal section layers that in general have led to an underestimated age value. Nevertheless, we refered these questionable in chronostratigraphic respect deposits to the Mikulino Interlacial.

The geochronological data obtained were compared with the uranium-thorium dating results (113±11 ka) for the closed geochemical samples from the Mikulino (Eem) Interglacial peats of the stratotypical section "Mikulino" (Russian Plain). This comparison confirmed the reliability of our conclusions.

1. INTRODUCTION

Determination of the age of Quaternary continental deposits is closely connected with application of adequate methods for dating these formations. It is known that to address the problems of chronostratigraphy of the Holocene and Late Pleistocene sediments, a radiocarbon method is widely used. It allows obtaining age data ranging between several hundreds of years to 50-55 ka. At the present time, for dating continental organogenous deposits (peat, gyttja), whose age is greater than the radiocarbon dating limits, one of the non-equilibrium geochronology methods is applied, namely the uranium-thorium method (UTD) with the age determination limit of up to 300-350 ka. This method is based on the established fact of the disturbed radioactive equilibrium in the uranium series in buried peat or gyttja deposits. With time, from the parent uranium contained in the organic fraction of the sample in significant quantities (up to 10 ppm and more), a daughter ^{230}Th isotope is accumulated while the $^{230}Th/^{234}U$ ratio is a measure of the sample age.

The first results of using the uranium-thorium method of dating buried peat were published in 1980 (Vogel and Kronfeld, 1980). Then, a number of investigators conducted studies of the geochemical behavior of uranium and thorium isotopes in organogenous deposits, working over the conditions for using UTD of these formations. In combination with a palinological analysis, the chronostratigraphy of buried peat deposits from the sections in the West European territory was established (van der Wijk *et al.*, 1986 and 1988; van der Wijk, 1987; Hejnis *et al.*, 1993; Hejnis, 1995; Hejnis and van der Plicht, 1992).

In recent years in Russia, we have began introducing the uranium-thorium method for dating the Mikulino (Eem) continental deposits in the Russian Plain territory (Kuznetsov *et al.*, 1998 and 2000a). A detailed study of the geochemical behavior of uranium and thorium isotopes in the Mikulino (Eemian) Interglacial buried peats in the Russian Plain allowed us to identify the layers of these sediments suitable for dating and obtain the isochron corrected age values of 113±11 ka for a stratotypical "Mikulino" section from the Smolensk province (Kuznetsov *et al.,* in press).

This study aims to resolve a disputable issue of the age of buried peat deposits from the "Fili Park" section located in the Filevsky Park area in Moscow. Up to now, there were two viewpoints of the chronostratography of these sediments, namely whether they were the Late Pleistocene deposits of Mikulino time (Mikulino, Eem Interglacial) or belong to the Penultimate Interglacial (Odintzovo Interglacial). Therefore, the main aim of the studies was to determine the age and chronostratigraphy of buried peat deposits from the "Fili Park" section by the methods of uranium-thorium dating and palynological analyses.

2. SECTION DESCRIPTION

The "Fili Park" section in the Filevsky Park in Moscow was carefully described in 1982 (Pisareva and Lobachev, 1982). The outcrop is situated in the scarp of the left slope of a deep gully in the upper portion of a steep right bank slope of the Moskva River in the territory of the Filevesky Park in Moscow (**Fig.1**). The following layers were outstripped in the outcrop (from top to bottom; Pisareva and Lobachev, 1982):

Depth [m]

1. Yellow-brown sandy loam with plant remains passing at a depth of 0.65 m to loam with rare gravel and pebble 0,0-0,7
2. Yellow-brown close-grained sand with lenticular "twisted" interlayers of dark-grey clay 0,7-1,9
3. Light-grey fine-close-grained sand 1,9-2,5
4. Loam with peat formation 2,5-2,7
5. Yellow-grey fine-grained sand with sandy clay interlayer, horizontally-laminated towards the foot 2,7-4,2
6. Clayey gyttja 4,2-4,3
7. Peat 4,3-5,1
8. Platy gyttja 5,1-5,4
9. Gleying loam 5,4-5,6
10. Yellow close-grained sand with cryoturbations, medium-grained from a depth of 6.75 m 5,6-7,1
11. Brownish-brown light loam with inclusion of pebble and debris of limestone, crystalline and effusive rocks 7,1-7,9
12. Grey, fine-grained clayey thin-laminated sand 7,9-8,5
13. Yellow close-grained sand, inequigranular from a depth of 9.3 m 8,5-10,4
14. Bluish-grey thin clay, brown from a depth of 11.3 m with rare pebble of quartzite and silicon. Visible thickness is 1.05 m 10,4-11,45

In 1998 we collected samples from a buried peat layer in 2 meters from the previous outcrop stripping in 1982. The 1998 striping was made not in the central part of the peat lens (there is now a landslide there), but closer to its margin where the peat layer is undisturbed but has a smaller thickness (55 cm against 80 cm in the central part outstripped in 1982).

3. ANALYTICAL METHODS

The buried peat samples were collected every 5 cm over the entire section depth (with a thickness of deposits of 55 cm). For radiochemical studies, dried peat samples with a mass of 3-5 g were used. The determination of the levels of uranium and thorium isotopes was made only in the organic fraction of specimens (using the so-called „leachetes alone" method). Ashing of peat samples was made at t = 600°C for 24 hours. The residue after calcination was leached by 7N HNO_3. At this stage of the analysis, the spikes of ^{232}U and ^{234}Th were injected. After centrifuging (with mineral residue discarded), the uranium and thorium isotopes were purified and separated using chromatographic columns and then deposited from alcohol solutions to the Pt-disks. The alpha-spec-

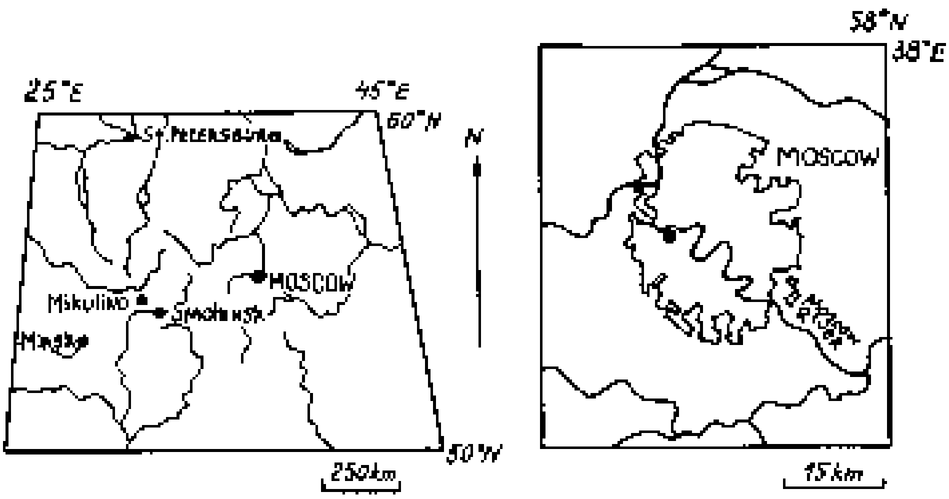

Fig. 1. Location map of the sections "Fili Park" and "Mikulino"

trometric measurements were made for several days (Kuznetsov *et al.*, 2000b). We used the ^{234}Th (β-emitter, $T_{1/2}$=24.1 d) to determine thorium chemical yield. The preparation of the spike is based on separation of the ^{234}Th from the parent ^{238}U (Kuznetsov *et al.,* 1963). The alpha-spectrometric measurements and checking of β-decay curve were used to control the ^{234}Th radiochemical purification. The injection of the ^{234}Th spike with activity of 2000-5000 pulse/minute enabled to determine the thorium chemical yield quickly.

The preliminary treatment and preparation of peat specimens for a pollen and spores analysis were undertaken by standard methods (Arslanov *et al.,* 1999). The percentage of tree and herb pollen taxa are based on the sum of terrestrial pollen; those of aquatic and unknown taxa are based on the total pollen sum. Spores are calculated as percentages of the pollen and spores combined. The Tilia and Tilia-Graph programs were used for drawing of the diagram (Grimm, 1991).

4. RESULTS AND DISCUSSION

Palynological analysis of the buried peat bog samples

The results of previous palynological studies of peat deposits carried out in 1982 (Pisareva and Lobachev,1982) indicated the interglacial sedimentation conditions. Some investigators refered the buried peat layer and underlying gyttja to the Odintzovo Interglacial, while others to the Mikulino time. The detection of single pollen of *Picea sec. Omorica, Pinus sec. Strobus, P. sec. Cembra, Larix sp. and Abies sp.* in the preparations, recorded during the palynological analyses served as a basis for an older age. In addition, a comparatively small content of hazel and alder pollen was noted as well as the absence in the diagram of pollen of broad-leaved species specific to the Mikulino Interglacial culmination. The latter fact is probably due to insufficiently good clearing of the outcrop. The presence in the underlying layers the exotic conifers pollen for this area can be attributed to redeposition. This was confirmed by the fact that preparations contained *Tsuga sp., Pterocarya sp.*, as well as single Mesozoic and Paleozoic spores evidently in the secondary bedding. In this respect, specimens from the new 1998 clearing were more promising to determine the age of deposits as they did not actually contained the traces of redeposition (**Fig. 2**).

The palynological study of the samples (a total of 11 samples 5 cm thick each) has confirmed the interglacial nature of the peat bog. As follows from the composition of palynological spectra and plant remains, the peat bog formed at the place of a mort lake and existed in the surrounding of forest massifs. The species determinations were difficult due to the absence of acetolysis treatment. However, the floristic composition even at the generic level and by the character of the change of the vegetation cover is evidence of the Mikulino age of the buried peat bog. The plant remains detected in the preparations allow us to refer peat deposits to a lowland type. Among them, rootlets and epidermis of different sedges, epidermis of bur reed, buckbeen, more rarely of cat-tail and other bog plants were found. Along with them, crust of deciduous trees was detected at an almost complete absence of macro-remains of coniferous species. Pine, whose pollen is abundant in all spectra, grew probably at the slopes of the valley and water divides rather than in a bog. Three palynological zones are identified in the diagram.

Based on the results of the palynological analysis, a spore-pollen diagram was constructed (**Fig. 2**), where in accordance with the adopted subdivision scheme of the Mikulino Interglacial (Grichuk, 1961 and 1989), the following 3 palynological zones are delineated:

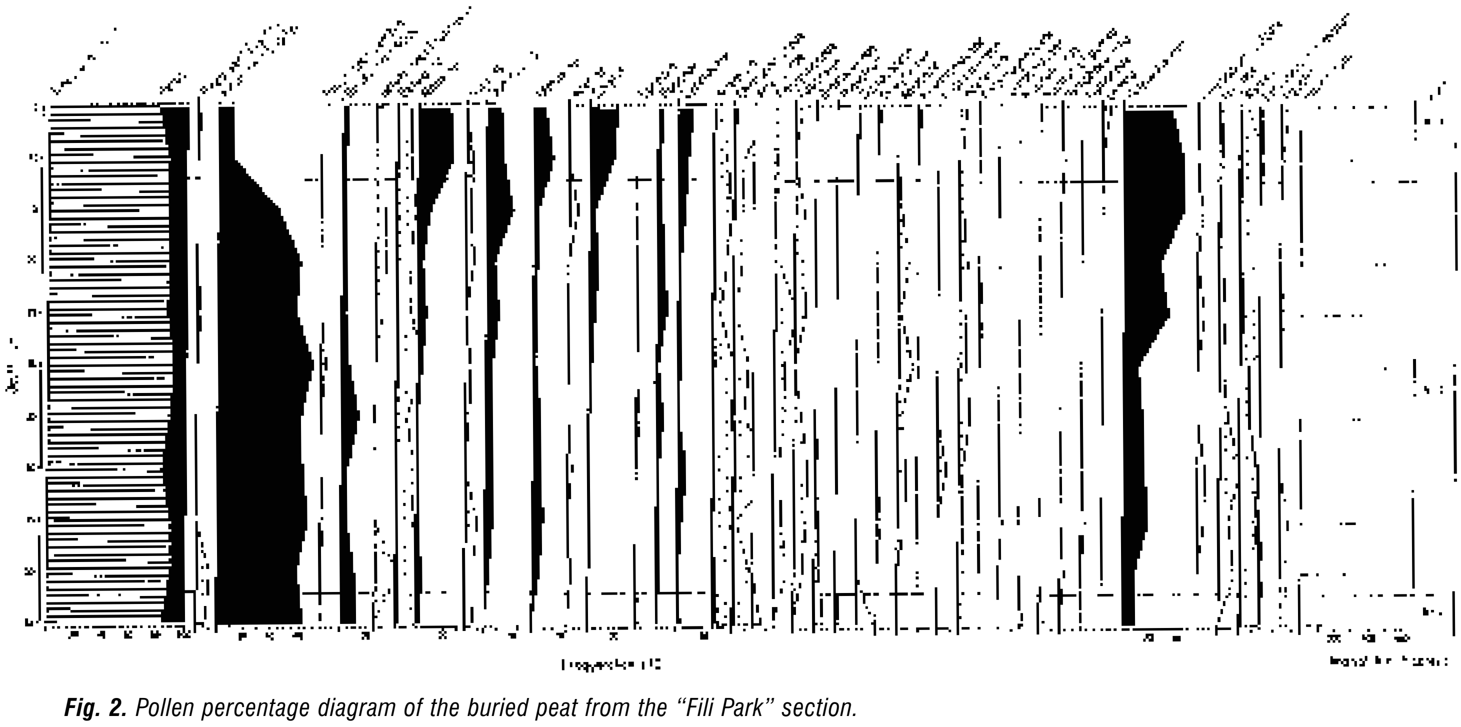

Fig. 2. *Pollen percentage diagram of the buried peat from the "Fili Park" section.*

- the first zone correlated with palynozone M2 of Mikulino diagrams, refers to the lower peat layer, characterized by the spectrum of sample 11. Pine dominates here with the pollen of birch and alder present in much smaller quantity. In single cases, the pollen of willow and hazel was observed. The pollen of broad-leaved species is absent. Among herbaceous and dwarf shrub plants, *Artemisia* and *Chenopodiaceae* predominate, with sedge and grass being more rare. The composition of meadow herbage is relatively diverse, with *Ephedra* noted. The data obtained indicate the development of floristically poor monodominant pine and birch forests (probably with small participation of spruce). Such vegetation cover based on the published data for the central areas of East Europe existed at the beginning of the Mikulino Interglacial;
- the second zone, M3, according to Grichuk (1961 and 1989) reflects the appearance of pollen of broad-leaved oak and elm species. Maple is sporadically observed. Among herbs, the role of *Poaceae* and *Cyperaceae* increases but *Ephedra* is still encountered;
- the third zone, M4, considered by Grichuk (1961 and 1989) as the initial zone of the climatic optimum of the Mikulino Interglacial, corresponds to the time of spreading of oligodominant broad-leaved forests of oak and elm with hazel in the underbush and alder.

Thus, the first half of the Mikulino Interglacial is reflected in the diagram. A similar change of forest formations is traced in numerous paleobotanical materials published for the central areas of the East European Plain ("Moscow Ice Sheet of East Europe", 1982).

The principal assumptions of using the uranium-thorium method for dating buried peat

The UTD-method has two basic assumptions: 1) the system to be dated should behave like a closed geochemical system with regard to U and Th; 2) there had to be no Th at the initial moment of peat formation. However, many of the peat sections studied earlier (Hejnis *et al.*, 1993; Heijnis, 1995) are contaminated with varying amounts of detrital material. This contributes some ^{230}Th, ^{234}U and ^{238}U to the solution/leachate prepared during chemical analysis. In such a case a mathematical correction should be done to determine the present-day ^{230}Th/^{234}U ratio in fraction to be dated.

Several methods have been proposed to make a correction for detrital Th. The first one – the so-called „leachate/residue" model for carbonate and peat samples – was studied by Ku *et al.* (1979), Ku and Liang (1984) and van der Wijk (1987). The second method is the "leachate alone" model. It was proposed and studied in detail by Schwarz and Latham (Schwarz and Latham, 1989). And the third method, the so-called „total sample dissolution" model, was represented by Bischoff and Fitzpatric (Bischoff and Fitzpatric, 1991). We use the "leachate alone" method for our work.

Distribution of U and Th in vertical profile of the section

The results of radiochemical study of peat deposits from the "Fili Park" section (Moscow) are given in **Table 1** and **Fig. 3**. The vertical distribution of uranium, thorium and the U/Th ratio in the organic fraction of samples and the ash content can be compared with the distribution of

Table 1. *Results of radiochemical analysis of peat samples from the section "Fili Park".*

Sample	Depth [cm]	Ash [%]	U [ppm]	Th [ppm]	^{238}U/^{232}Th	Layers
LU-4343	0-5	17.52	10.39±0.38	2.40±0.20	4.33±0.39	A
LU-4331	5-10	10.40	6.03±0.21	1.02±0.06	5.91±0.35	
LU-4342	10-15	9.18	5.14±0.24	0.73±0.04	7.04±0.50	
LU-4327	15-20	11.27	6.54±0.19	0.69±0.04	9.48±0.62	
LU-4341	20-25	10.78	7.94±0.21	0.45±0.02	17.64±0.91	B
LU-4329	25-30	9.68	3.71±0.13	0.53±0.02	7.00±0.35	
LU-4340	30-35	10.82	4.44±0.21	0.41±0.02	10.83±0.68	
LU-4330	35-40	10.61	6.24±0.10	0.45±0.02	13.87±0.72	
LU-4344	40-45	10.62	11.90±0.39	0.57±0.04	20.78±1.52	C
LU-4328	45-50	18.99	30.53±0.58	3.17±0.12	9.63±0.41	

Table 1 (continued)

Depth [cm]	^{238}U [dpm/g]	^{234}U [dpm/g]	^{230}Th [dpm/g]	^{232}Th [dpm/g]	^{234}U/^{238}U [dpm/g]	^{230}Th/^{234}U [dpm/g]	^{230}Th/^{232}Th [dpm/g]	Age [yrs]	Layers
0-5	7.48±0.27	9.12±0.33	5.09±0.14	0.59±0.05	1.22±0.06	0.56±0.03	8.63±0.77	88700±6200	A
5-10	4.34±0.15	5.40±0.18	3.25±0.05	0.25±0.01	1.24±0.06	0.60±0.02	13.00±0.56	99700±6000	
10-15	3.70±0.17	4.77±0.21	2.95±0.06	0.18±0.01	1.29±0.08	0.62±0.03	16.39±0.97	105000±8400	
15-20	4.71±0.14	6.05±0.18	3.22±0.03	0.17±0.01	1.28±0.05	0.53±0.02	18.94±1.13	82500±3900	
20-25	5.72±0.15	7.84±0.19	4.52±0.08	0.11±0.01	1.37±0.05	0.58±0.02	41.09±3.81	93300±4400	B
25-30	2.67±0.09	3.54±0.11	1.95±0.04	0.13±0.01	1.33±0.06	0.55±0.02	15.00±1.19	86400±5000	
30-35	3.20±0.15	3.92±0.18	2.03±0.05	0.10±0.01	1.23±0.08	0.52±0.02	20.30±2.09	78900±6000	
35-40	4.49±0.15	5.82±0.19	2.40±0.06	0.11±0.01	1.30±0.06	0.41±0.02	21.82±2.06	57600±3000	
40-45	8.57±0.28	10.23±0.34	2.44±0.05	0.14±0.01	1.19±0.06	0.24±0.01	17.43±1.30	29500±1300	C
45-50	21.98±0.42	24.16±0.46	12.10±0.11	0.78±0.03	1.10±0.03	0.50±0.01	15.51±0.61	75300±2300	

the same data by the depth of the earlier investigated stratotypical section of the Mikulino Interglacial sediments in the territory of the Russian Plain (Mikulino village, Smolensk province). As can be seen from the plots in **Fig. 3**, the general tendency in the distribution of U, Th, U/Th and ash contents is in general preserved for both sections. Similar dynamics of changes of these values by the "Mikulino" section depth, on the one hand, and the constant and least values of U, Th, U/Th and ash content in the central layer B, on the other hand, allowed a reliable identification of the inner "Mikulino" section portion suitable for UTD. The corrected age of layer B, calculated by the method of isochrones (Schwarz and Latham, 1989; Heinis *et al.*, 1993) comprised 113±11 ka (Kuznetsov *et al.*, in press). Good correlation is observed in the "Fili Park" section in respect of the distribution of uranium, thorium and ash content whereas the change of U/Th values by the depth of deposits has a more complicated character (**Fig. 3**). Based on the first three distributions, one can note that two upper and low layers are enriched with uranium and thorium (at increased ash content) compared to the internal layers. This can probably testify to a relative closeness of groundwater in whose composition the dissolved uranium and the detrital forms of uranium and thorium could be supplied to the buried peat deposits. Then the upper and lower layers could be considered as peculiar filters concentrating these radionuclides of different genesis and preventing penetration

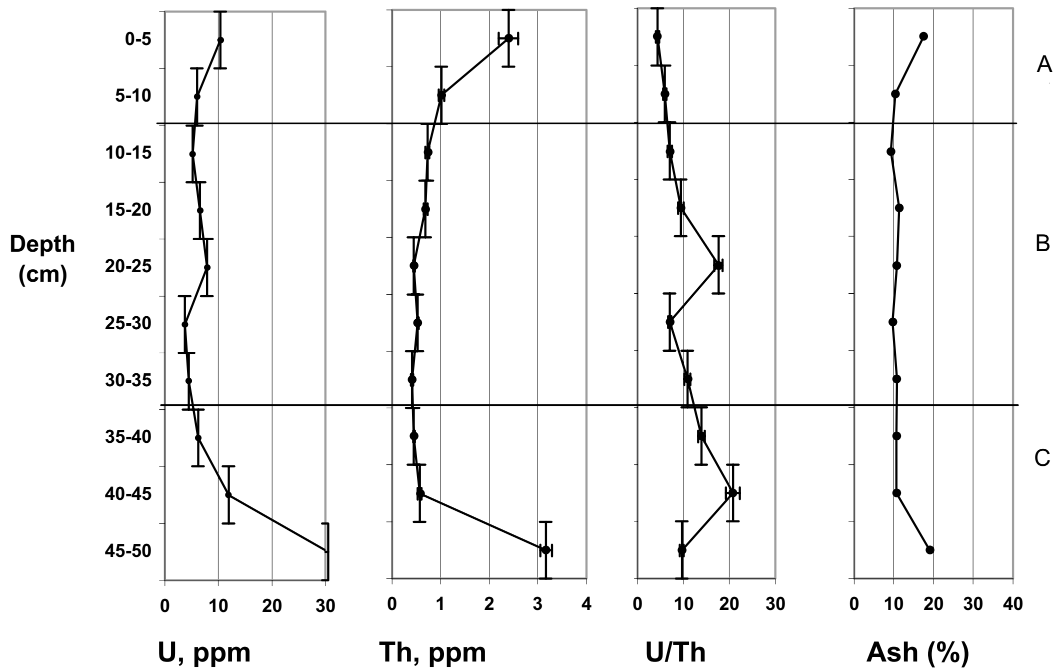

Fig. 3a. *Distribution of ^{238}U, ^{232}Th contents, $^{238}U/^{232}Th$ ratios and ash values of peat samples in the vertical profile of the section "Fili Park".*

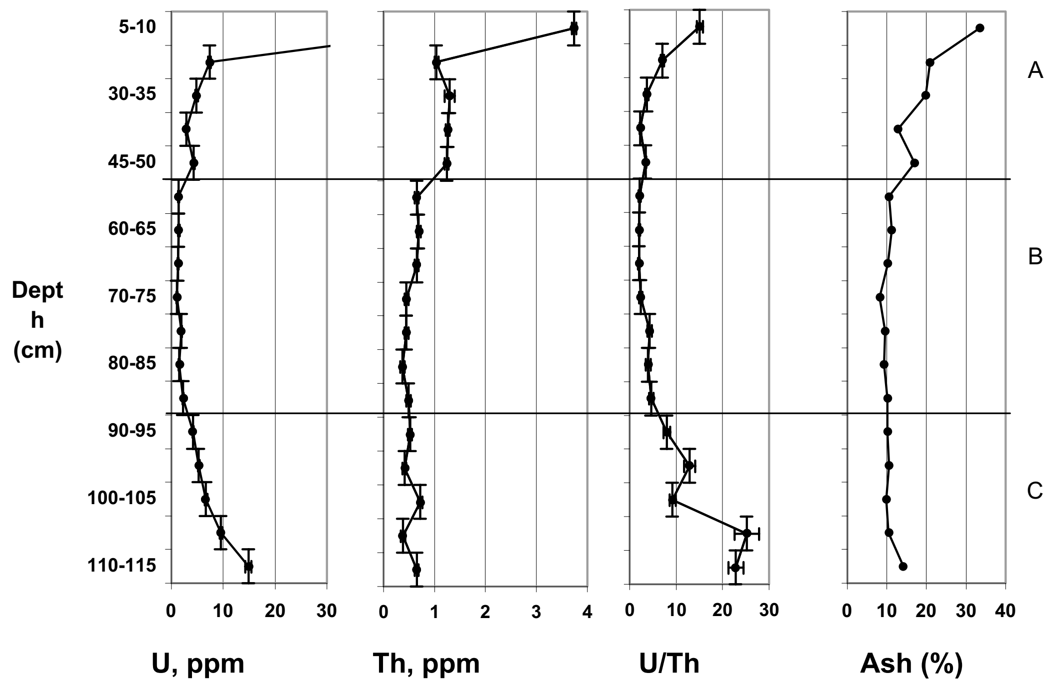

Fig. 3b. *Distribution of ^{238}U, ^{232}Th contents, $^{238}U/^{232}Th$ ratios and ash values of peat samples in the vertical profile of the section "Mikulino".*

of uranium and thorium inside the sedimentary strata. It follows from the description of the "Fili Park" outcrop and spore-pollen diagram that the section investigated in this work was washed out in its upper portion either quite recently or at the glacial time. Due to this, the upper layers of deposits (5-10 cm) accumulated the transported uranium and thorium in smaller quantities than the lowest layers (40-50 cm). Hence, one can assume that the geochemical barrier thickness in respect of uranium and thorium should be greater in the lower section portion than in the upper and comprise at least about 15 cm (in the interval of layers between 35 to 50 cm). In other words, all samples from peat layers A and C are suspected to be in the zone of open geochemical system in respect to U and Th. Correlation of the uranium and thorium concentrations with ash contents are remarkable in the inner peat layer B. Besides, U, Th and ash contents are practically constant and least in the layer B. The data obtained enabled to consider the inner part (layer B) of the peat as a more or less closed system with regard to U and Th and the uranium-thorium dating was applied.

Age results

The results of direct UTD measurements of all studied buried peat samples are summarised in **Table 1**. The dating by the uranium/thorium method of the middle section part (layer B) shows that individual uncorrected sample ages are in the range of 78,9-105 ka. However, the $^{230}Th/^{232}Th$ ratio indicates a presence of varying amounts of thorium in the organogenic fractions, and therefore a correction was applied. It is known that in the process of peat dissolving, some quantities of ^{230}Th, ^{232}Th, ^{238}U and ^{234}U can transfer from a clay component (detritus) in a leachate/solution. This causes a distortion of the $^{230}Th/^{234}U$ and $^{234}U/^{238}U$ ratio values in the sample organic fraction dated. The fact of the detrital uranium and thorium addition is established by the presence of ^{232}Th in a sample organic fraction because this long-lived isotope can be present in peat sediments only in detritus. So, in order to determine the „true" age of buried peat it is necessary to know the value of $^{230}Th/^{234}U$ (for today) in the organic fraction under dating. The mathematical correction of the direct uranium-thorium dates is used with application of the isochrones method. The essence of the method is that when dissolving the coeval peat samples, the uranium and thorium isotopes enter in a leachate/solution in the same proportions (under the same conditions of an experiment). In this case, the isotope ratio values obtained shape a straight line on the $^{234}U/^{232}Th$-$^{238}U/^{232}Th$ and $^{230}Th/^{232}Th$-$^{234}U/^{232}Th$ graphs. The inclinations of the isochrones constructed in such a way correspond to the $^{234}U/^{238}U$ and $^{230}Th/^{234}U$ ratios corrected to the detritus supply and are used then when calculating the „true" absolute age of the buried peat samples under study. Thus, using the „leaching alone" method (Schwarz and Latham, 1989; Hejnis *et al.*, 1993), the results of the direct UTD measurements were plotted on the isochrone plots. Five inner layers that were interpreted to be in the more or less closed-system were used to construct the isochron plots (**Fig. 4**). From the isochron plots, the corrected age of 89±11 ka was calculated. This age coincides with the ^{18}O deep-sea stage 5b (Morley and Hays, 1981). However, the data of the spore-pollen analysis mentioned above testify that buried peat from the section under study dates back to the first half of the Mikulino (Eem) Interglacial and correlates with the ^{18}O deep-sea stage 5e. Probably, the corrected uranium-thorium age obtained for the deposits is likely to be a little younger. It can be a result of the probable post-depositional insignificant supply of uranium with ground water into internal parts of the section (i.e., layer B cannot be considered as a completely-closed geochemical system). In fact, the differences of uranium/thorium ratios along the length of the section (**Fig. 3**) might be due to an additional uranium supply and correspondingly to a little younger age as a whole.

5. CONCLUSIONS

The internal part of the "Fili Park" section cannot be considered as a completely-closed geochemical system with regard to uranium. There was probably an additional post-deposition uranium uptake in the internal section

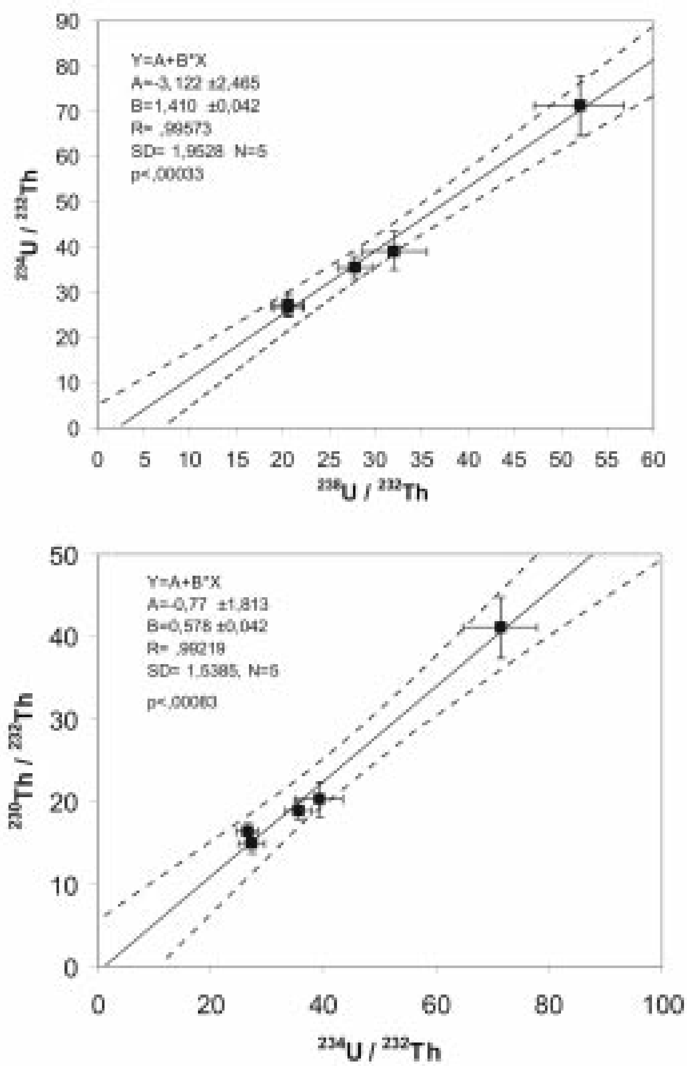

Fig. 4. Plots of $^{230}Th/^{232}Th$ vs $^{234}U/^{232}Th$ and $^{234}U/^{232}Th$ vs $^{238}U/^{232}Th$ for leachates of the „Fili Park" samples; $^{230}Th/^{234}U$ and $^{234}U/^{238}U$ as determinated from the slopes of the respective lines give an apparent age of 89±11 ka.

layers that in general have led to an underestimated age value. Nevertheless, the corrected uranium-thorium date of 89±11 ka of the buried peat was much of an age with the currently adopted boundaries of the last Interglacial (116-128 ka).

The results of palynological analysis were in accordance with the adopted subdivision scheme of the Mikulino (Eem) Interglacial.

The geochronological and palynological studies of the buried peat layer from the "Fili Park" section located in the Filevsky Park in Moscow allowed us to refer these questionable in chronostratigraphic respect deposits to the Mikulino (Eem) Interlacial.

The uranium-thorium dating of the closed geochemical samples from the inner part of the stratotypical "Mikulino" section (Russian Plain) yielded the reliable corrected age of 113±11 ka. This date corresponds to the Mikulino (Eem) Interglacial and correlates with the ^{18}O deep-sea stage 5e.

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