GEOLOGIJA. 2005. Nr. 51. P. 39–49

TL dates of aquatic sandy sediments of Middle-Upper Pleistocene in Lithuania

Algirdas Gaigalas,

Stanisùaw Fedorowicz,

Monika Meleðytë

Gaigalas A., Fedorowicz St., Meleðytë M. TL dates of aquatic sandy sediments of Middle-Upper Pleistocene in Lithuania. *Geologija.* Vilnius. 2005. No 51. P. 39–49. ISSN 1392-11OX.

Based on thermoluminescence (TL) dating, Middle and Upper Pleistocene fine-grained sands of aquatic origin have been attributed to the Butënai (Holsteinian) Interglacial (Tartokai outcrop), Snaigupëlë (Drenthe-Wartha) Interglacial (Tartokai and Valakampiai (Valakupiai) outcrops), Merkinë (Eemian) Interglacial (Tartokai and Netiesos outcrops) and Nemunas (Vistulian) Glacial (Tartokai, Netiesos and Rokai outcrops). The dating of samples from the outcrops studied show the Butënai Interglacial age of 430.2 to 280.3 ka years BP, Snaigupëlë Interglacial 239.4 to 179.3 ka years BP and Merkinë Interglacial 135.9 to 103.2 ka years BP. The Early Nemunas and Middle Nemunas non-glacial sediments accumulated between 67.2–30.6 ka years BP. Tills in the upper part of the Tartokai and Rokai outcrops are younger than 30,000 BP and belong to the Late Nemunas glacial maximum in Lithuania.

Key words: thermoluminescence, dating, Pleistocene, aquatic sedimentation, Lithuania

Received 26 May 2004, accepted 01 March 2005

Algirdas Gaigalas, Department of Geology and Mineralogy, Vilnius University, M. K. Èiurlionio 21/27, LT-03101, Vilnius, Lithuania. E-mail: Algirdas.Gaigalas@gf.vu.lt
Fedorowicz Stanisùaw, Department of Geomorphology and Quaternary Geology, Gdansk University, Dmowskiego 16 A, 80-462 Gdansk, Poland. E-mail:geosf@univ.gda.pl

1. INTRODUCTION

The thermoluminescence (TL) method of dating has been shown to be potentially a valuable tool for the geochronostratigraphical research of Pleistocene aquatic sandy sediments in Lithuania. TL and OSL dating results of the Middle and Upper Pleistocene in Lithuania have been published (Gaigalas et al., 1994, Gaigalas, Hütt, 1995, Gaigalas, Fedorowicz, 2002 and others).

TL dating of aquatic (lacustrine and glaciolacustrine) sandy sediments in Tartokai and Valakupiai (Valakampiai) outcrops of the Neris River, Netiesos outcrop of the Nemunas River and Rokai outcrop (two sections) of the Jiesia River was carried out in 2003 by one of the authors (S. F.) at Gdansk University laboratory (Fig. 1).

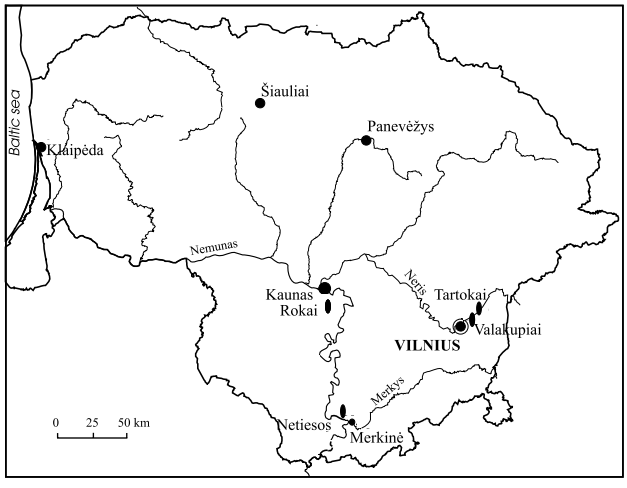


Fig. 1. Location of the study sections
1 pav. Tirtø pjûviø vietos

2. TL METHOD

The TL dating was carried out at the TL Laboratory of the Department of Geomorphology and Quaternary Geology, Gdansk University, by the method of Stanisław Fedorowicz (1994). The samples were about 1 kg in weight and 0.5 dm^3 in volume each.

The annual radiation doses (Dr) were determined by taking the potassium, radium and thorium counts with a gamma spectrometer. A preliminary procedure preceded determination of the equivalent dose (ED) and involved the removal of the external shells of quartz grains (grain size 88–102 micrometers).

The purified fraction was then treated with 10% HCl for 60 minutes. ED was assessed using the reproduction method. The fraction under test was exposed to UV radiation for 24 hours, after which the residual TL level was measured. The sample was then exposed to radiation from a Co-60 cobalt bulb of such an intensity that the values of the TL induced by this dose would be between the residual and natural TL levels. The increase in TL was found to be linearly dependent on the size of the dose and ED was then obtained by extrapolation. The occurrence of TL saturation was noted. The accuracy of dating, taking into account laboratory factors, was estimated at around 15% of the assigned age values.

3. TL DATES OF SEDIMENTS AND THEIR INTERPRETATION

The introduction of TL dating provided a more accurate chronology for the aquatic and aeolian sediments of the sections studied.

The Tartokai outcrop is a natural exposure on the right side of the Neris River valley at the Vilnius city.

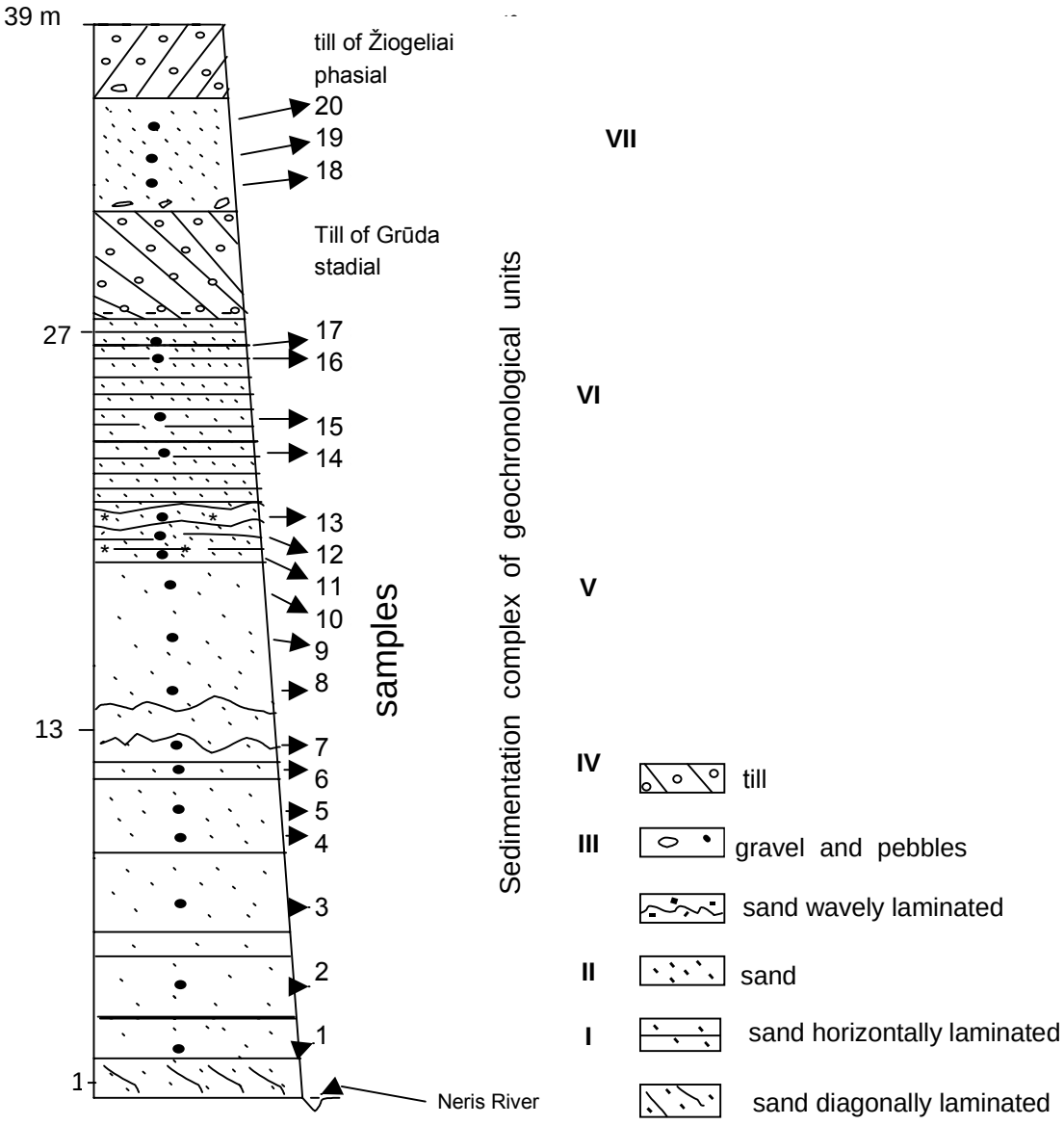


Fig. 2. Tartokai section with TL dates
Coordinates (longitude, latitude) 50°02'20"; 24°05'02"
2 pav. Tartokø pjûvio TL datos

Twenty samples of fine-grained and silty sands were dated by TL (Fig. 2). The TL age was obtained for Butënai (Holsteinian) Interglacial (430.2 ka and 280.3 ka years BP), Snaigupëlë (Drenthe-Wartha) Interglacial (188.8 ka and 183.3 ka years BP for Late interstadial, 239.4 ka, 246.3 ka and 223.8 ka years BP for Early stadial), Merkinë (Eemian) Interglacial (130.1 ka, 129.8 ka, >126.3 ka, 107.2 ka, 112.9 ka and 109.7 ka years BP), Nemunas (Vistulian) Glacial Early time (67 ka years BP), Nemunas (Vistulian) Middle time (47.8 ka, 58.2 ka and 34.9 ka years BP), Nemunas (Vistulian) Glacial Late time (>44.2 ka, 18.9 ka and 17.6 ka years BP) (Table 1). TL dating provided a more accurate geochronology of Late Nemunas (Vistulian) Glaciation. The cover till of Grûda Stadial of Nemunas (Vistulian) Glaciation was found to be younger than 30,000 BP and to belong to the Nemunas Glaciation maximum. The age of Þiogeliai Phasial of Grûda Stadial of Last Glaciation is younger than 17,000–19,000 year BP.

Seven sedimentation complexes of sandy deposits of chronostratigraphic units were distinguished in the section of Tartokai outcrop (Fig. 2).

In the Tartokai outcrop at the Neris River, Middle and Upper Pleistocene sediments accumulated in an aquatic environment under different climatic conditions are exposed. In the upper part of the outcrop they are overlain by Grûda Stage tills of the Last Nemunas Glaciation (Fig. 2). In the outcrop, we singled out seven geochronological sedimentary complexes of aquatic sediments, related to the climate change cycles. Earlier, Tartokai outcrop sediments had been studied lithologically (Bardþiuvienë et. al., 2000). The authors that studied them had singled out several lithocomplexes which they related to Merkinë and Butënai Interglacials.

The TL data obtained in the current study (Table 1) allow a detailed analysis of the sedimentary geochronological complexes formed by the climate. In the lower part of the outcrop, about 2.8 m above the Neris River water level, arises horizontally stratified fine-grained sand of lacustrine origin with oblique lamination; its age reaches 430.2 thous. years. We attributed this sand to the first sedimentary geochronological complex, most probably related to the early Butënai Interglacial complex.

The second sedimentary geochronological complex is expressed by fine-grained sand, with its particles becoming finer upwards. The sand is of a light colour with a slight yellowish shade. Its composition is feldspar-quartz. It is also of lacustrine origin; according to its age it could be ascribed to the late Butënai Interglacial. This supposition was confirmed by TL dating (280.3 thous. years).

Table 1. **TL dates of sand from Tartokai section at Neris River**
1 lentelë. **Tartokø pjûvio prie Neries smëlio TL datos**

Sample No	Above the water line	No lab. UG	dα	dβ	dγ	Dr	ED	TL age, years (ka)	Complexes
T-1	2	5578	0	0.41	0.14	0.55	236.6	430.2±68	I
T-2	5	5579	0.04	0.86	0.45	1.35	378.4	280.3±32	II
T-3	7.5	5580	0.01	0.61	0.24	0.86	205.9	239.4±36.6	
T-4	9.5	5581	0.01	0.68	0.25	0.94	231.5	246.3±36.2	III
T-5	10.5	5582	0.02	0.8	0.32	1.14	255.2	223.8±36.4	
T-6	11.75	5583	0.02	0.51	0.23	0.74	139.7	188.8±27.1	IV
T-7	12.5	5584	0	0.4	0.14	0.54	99	183.3±27.4	
T-8	14.1	5585	0.02	0.73	0.31	1.06	138	130.1±18.1	
T-9	15.9	5586	0	0.74	0.25	0.99	128.6	129.8±18.4	
T-10	17.5	5587	0	0.7	0.25	0.95	>120.0	>126.3	V
T-11	18.45	5588	0.01	0.7	0.26	0.97	104	107.2±17.4	
T-12	19	5589	0.04	0.53	0.3	0.92	103.9	112.9±13.4	
T-13	19.8	5590	0.02	0.53	0.25	0.8	87.8	109.7±15.4	
T-14	21.6	5591	0.02	0.81	0.32	1.15	77	67±9	
T-15	23.6	5592	0.03	1.17	0.48	1.68	80.3	47.8±7	VI
T-16	25.5	5593	0.03	0.9	0.39	1.22	71	58.2±8.5	
T-17	27.1	5594	0.11	1.61	1.02	2.74	95.6	34.9±6.1	
T-18	33	5595	0.03	0.75	0.35	1.13	>50	>44.2	
T-19	33.9	5596	0.03	0.93	0.41	1.37	26	18.9±3.1	VII
T-20	34.9	5597	0.02	0.94	0.37	1.33	23.5	16.7±2.5	

Three samples for TL dating were taken from the third sedimentary geochronological complex. The data of these samples are very close: 239.4 thous. years (the lowest sample), 246.3 thous. years (the middle sample) and 223.8 thous. years (the upper sample). The dated samples were taken from three layers of sand. The lowermost layer (3.4 m thick) consists of horizontally laminated fine-grained feldspar-quartz sand of a whitish colour. It is separated from the underlying sand by an interlayer of a brown colour; its thickness hardly reaches 2 cm. In the top, the middle and the bottom sand layers are separated by an aleuritic (silty) interlayer up to 4 cm thick.

The middle layer, about 0.6 m thick, is represented by fine whitish sand. The upper contact is distinct. The upper layer of the second sedimentary geochronological complex (about 1.7 cm thick) is composed of horizontally stratified finest sand interlaminated by layers of brownish silt. The sand is feldspar-quartz. According to the obtained TL data, it was formed after the Butënai Interglacial in a quiet aquatic environment in the conditions of moderate climate, possibly early in the Snaigupëlë Interglacial.

The fourth sedimentary geochronological complex can be attributed to the Middle Pleistocene Snaigupëlë Interglacial. Interestingly, this fine-grained sand complex, up to 1.7 m thick, is limonitized, horizontally stratified, in the upper part containing orange stripes, which could have been formed by pedogenesis. The complex consists of two parts separated by a more distinct sedimentary interruption; this intercomplex interruption is rather short. It overlies the lower fine sand layer, about 0.5 m thick, separating it from the overlying fine-grained quartz sand layer about 1.2 m thick. The age of these two sand layers was determined by TL as 188.8 thous. year (the lower) and 183.3 thous. (the upper). We would like to ascribe them to the Snaigupëlë Interglacial and a more recent and stormy climate.

The fifth complex is sedimentationally more complicated, however, geochronologically it is rather consistent. It could be ascribed to the Merkinë Interglacial climatic conditions. From this complex, by the TL method six samples were dated; their age becomes younger upwards, reaching 130.1 thous. years (the lowermost) through 129.8, then >126.3, 107.2, 112.9 and at the top 109.7 thous. years.

The fourth and fifth sedimentary geochronological complexes are separated by a 0.3-m layer of white finely horizontally stratified fine-grained sand; its age was not TL-dated. This sand is overlain by a 0.4-m layer of silty clay. Its colour is grey. The first (lower) dated layer of sand (130.1 thous. years) is about 0.5 m thick. The sand is extremely fine, greenish-grey because of an admixture of organic dispersed matter; it had accumulated in a bogging-up lake. The second, overlying layer was about 2.9 m thick. It is composed of very fine sand, slightly stratified horizontally (an obliqueness was noted in its upper part). The sand is yellowish, somewhat ochreous. Its TL-dated age reaches 129.8 thous. years.

The above – described thin layer is overlain by fine sand containing ferritized brown stripes. The sand is finely stratified horizontally, of lacustrine origin. The thickness of this layer is 0.5 m. Its TL age exceeds 126.3 thous. years. Its precise dating was impeded by a limonite coating on quartz grains.

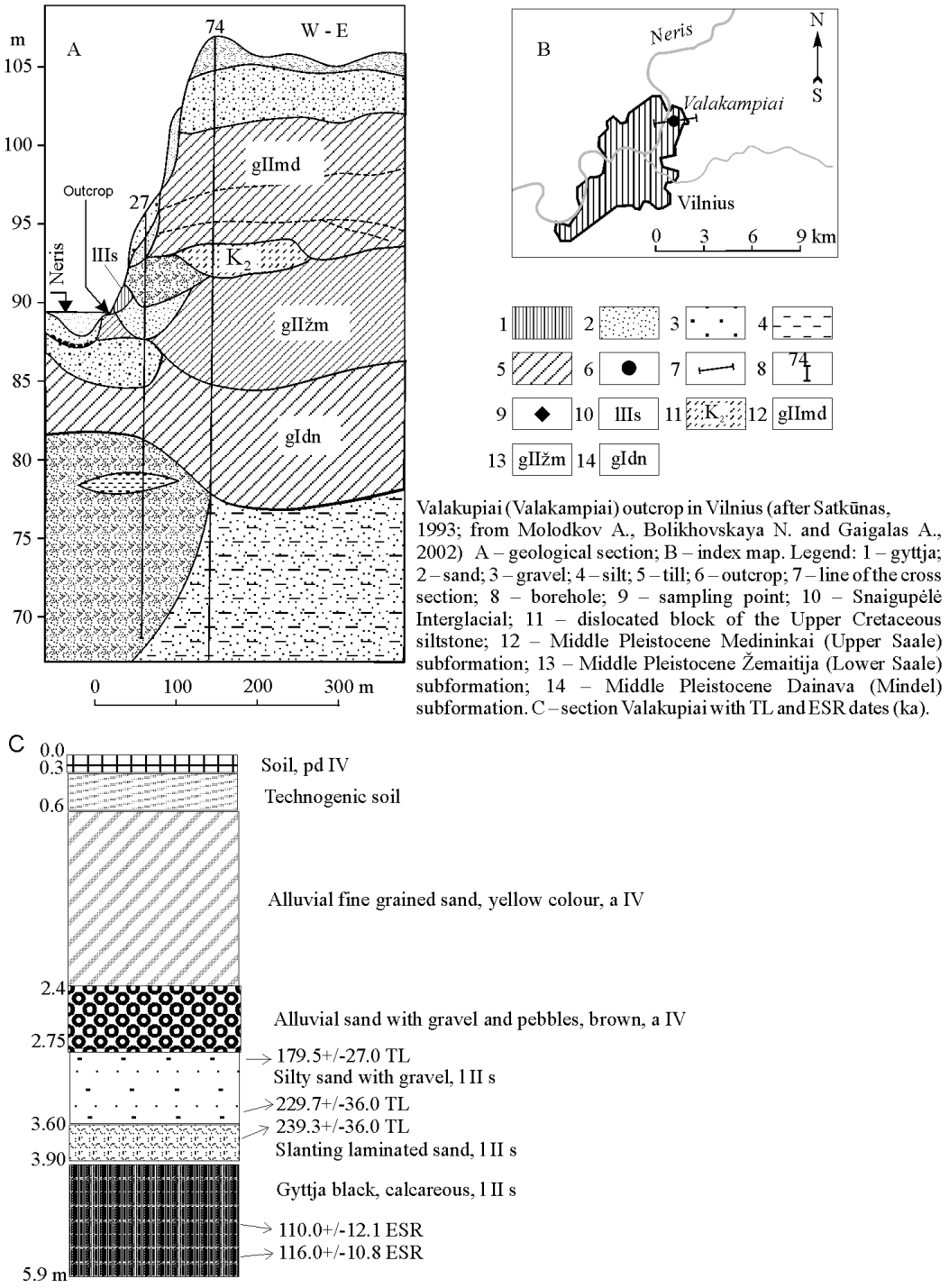
The other sand sublayer of the fifth complex is 2.4 m thick. It is wavily striped horizontally and was probably formed under lacustrine conditions. The sand contains ferritized brown stripes. Its colour is mostly whitish, and it consists of feldspar-quartz. Three samples from this layer showed a similar age: 107.2 thous. years (the lowest), 112.9 thous. years (the middle), and 109.7 thous years (the upper).

The TL dating of the sixth sedimentary geochronological complex allowed to ascribe it to the early Nemunas Glaciation (sample 14), the Varduva Periglacial, and to its middle part, *i.e.* to Rokai Megainterstadial (samples 15–17).

The complex consists of two sand layers, 6 m (the lower) and 3.7 m (the upper) thick. The lower layer shows a distinct fine wavy stratification, which resulted from sand accumulation under lacustrine conditions. The sand is very fine, of a cocoa-and-milk colour. The TL dating of sand from this layer showed an age of 67 thous. years. The age of three consecutive samples was TL-dated as 47.8 thous. (the lowest), 58.2 thous. (the middle) and 34.9 thous. years (the upper).

The sixth sedimentary geochronological complex of sands is overlain by a till loam. It is of a reddish-brown colour, carbonaceous, containing pebble and gravel of sedimentary and crystalline rocks. The loam is finely shaly. The layer thickness is about 4.3 m. The top of the layer is washed out. On its surface, pebble and coarse gravel are accumulated. On evaluating the TL dates and the bedding conditions we can maintain that this till loam was sedimented by the Grûda Stadial glacier of the Nemunas Glaciation. The till loam was not TL-dated. It coresponds to a bottom till facies. The TL method is usually not applicable to till facies deposits. The zero effect cannot be reached. Therefore the obtained dates are older and do not reflect the period of their formation because of the relict residual energy in quartz grains. The process of sedimentation proceeded in the dark.

This Grûda Stadial till of Nemunas Glaciation is overlain by a complex designated by us as the seventh sedimentary geochronological sand complex. The sand layer ascribed to the seventh complex reaches 3.5 m in thickness. It is formed by a yellowish-grey very fine sand, sligtly stratified horizontally, consisting of feldspar-quartz, here and there somewhat ferritized, particularly at the bottom of the layer.



Valakupiai (Valakampiai) outcrop in Vilnius (after Satkūnas, 1993; from Molodkov A., Bolikhovskaya N. and Gaigalas A., 2002) A – geological section; B – index map. Legend: 1 – gyttja; 2 – sand; 3 – gravel; 4 – silt; 5 – till; 6 – outcrop; 7 – line of the cross section; 8 – borehole; 9 – sampling point; 10 – Snaigupėlė Interglacial; 11 – dislocated block of the Upper Cretaceous siltstone; 12 – Middle Pleistocene Medininkai (Upper Saale) subformation; 13 – Middle Pleistocene Žemaitija (Lower Saale) subformation; 14 – Middle Pleistocene Dainava (Mindel) subformation. C – section Valakupiai with TL and ESR dates (ka).

Fig. 3. Section of Snaigupėlė Interglacial sediments in Valakupiai with TL and ESR dates (ka). Coordinates (longitude, latitude) 54°45'10"; 25°15'30"

3 pav. Snaigupėlės tarpledynmeèio nuogulø Valakupiø atodangoje TL ir ESR datos

We think that this sand complex was formed by flooded water after the Grûda Stadial glacier of Nemunas Glaciation had slightly retreated northwards. The age of the lowermost sample from this layer exceeds 44.2 thous. years. The precise dating was most probably impeded by a limonite shell on quartz grains. Also, the sample matter could have been redeposited from the underlying till whose energy survived from the time of deposition. The age of two samples taken from the higher levels was rather similar (18.9 thous. years of the lower and 17.6 thous. years of the higher samples).

The Tartokai outcrop is crowned by a till layer 4.3 m thick, which has been attributed by us to the Grûda Stadial Þiogeliai Phasial glacier of Nemunas Glaciation. The till layer covering the outcrop con-

sists of pebbly loam of a red colour with up to 13% of pebble and gravel of sedimentary and crystalline rocks. The loam is finely cracked and formed in the bottom part of the glacier (basal till).

In this outcrop, geochronologically most interesting are sand deposits from the Snaigupėlė Interglacial (the third and fourth sedimentary geochronological complexes). We encountered them in 2002 while implementing the project in Vilkiðkės outcrop, financed by the Lithuanian State Science and Studies Foundation (Gaigalas, Fedorowicz, 2002). The Snaigupėlė Interglacial sand deposits were dated in the Antaviliai outcrop (Satkûnas, Hütt, 1999). We took sand samples from this outcrop for a re-dating by the TL method in order to confirm their Snaigupėlė Interglacial age.

The Snaigupėlė Interglacial fixed in Middle Pleistocene sediment sections is troublesome not only in Lithuania but also in Europe in general. Therefore we give more attention to it. The necessity of such studies has also been confirmed by our datings of Snaigupėlė Interglacial sediments in a parastratotypical section of the Valakupiai (Valakampiai) outcrop.

The Valakupiai (Valakampiai) outcrop is situated at the Neris River in the city of Vilnius. This section is parastratotypical of the problematic Snaigupėlė (Drenthe-Warthe) Interglacial. The section consists of a lowest layer of gyttja with mollusk shells, dated by ESR at Tallinn Institute of Geology (Molodkov et al., 2002). The gyttja is overlain by a 0.8 m thick layer of lacustrine sand. The uppermost part of the section is represented by alluvial sand of the first terrace of the present Neris River. Three samples of fine-grained sand of lacustrine origin were dated by the TL method at the Gdansk University Laboratory by St. Fedorowicz. This sand was accumulated during the Snaigupėlė (Drenthe-Warthe) Interglacial (239.3 ± 36 ka, 229.7 ± 36 ka and 179.5 ± 27 ka years BP). A correlation of the Snaigupėlė Interglacial with OIS7 was supported by TL dates. Two freshwater mollusk shells collected from the lowest gyttja layer gave the mutually consistent ESR dates of 116 ± 10.8 and 110.0 ± 12.1 ka years BP with an average age about 113.3 ka (Molodkov et al., 2002). A reliable age control is needed for the Snaigupėlė (Drenthe-Warthe) Interglacial.

Earlier, freshwater mollusk shell samples had been dated at the laboratory of the Estonian Institute of Geology, headed by Dr. A. Molodkov, by the method of electron spin resonance (Fig. 3). The dates showed not the Snaigupėlė but the Merkinė Interglacial age (Molodkov et al., 2002). This outcrop, with a lacustrine gyttja from which samples for election spin resonance dating were taken, is ascribed to the Snaigupėlė Interglacial of the Middle Pleistocene. It is considered to be a parastratotypical section of this interglacial (Lietuvos..., 1999). O. Kondratienė (Кондратене, 1996) in the Snaigupėlė Interglacial sediment section distinguished seven (S_1–S_7) spore–pollen zones containing *Caulina lithuanica* Rišk., *Caulina tenuissima* D. Benn., *C. goretskyj* Dorof., *Brassenia cf borysthenica* Wieliczk. (Ришкене, 1979, Величкевич, 1974, 1979). Based on palaeobotanical distinctive features, the Valakupiai outcrop gyttja has been ascribed also to the Snaigupėlė Interglacial. This conclusion is supported by the stratigrafical position of the gyttja between two tills from the Þemaitija and Medininkai glaciations (Satkûnas, 1993). Thus, the data obtained at the Tallinn Laboratory were incongruent with the geological interpretation of the Valakupiai organogenic sediments. To elucidate the situation, three sand samples from over the Valakupiai gyttja were dated by the method of thermoluminescence at the Geochronological Laboratory of Gdansk University (Poland) (Table 2). Sedimentological analysis showed these sands to be of lacustrine origin and sedimented in a palaeolake that existed here in the Snaigupėlė Interglacial; in this lake accumulated the primary sapropel sediments of the underlying gyttja (Fig. 3).

The dates obtained in 2004 by the TL method (179.5 ± 27, 229.7 ± 36 and 239.3 ± 36 thous. years) confirm the Snaigupėlė Interglacial age of sand in the Valakupiai outcrop. To confirm the belonging of the Valakupiai outcrop sediments, repeated dating by the ESR, TL OSL (optically stimulated luminescence), U/Th (uranium-thorium) and other methods must be employed.

The issue of the existence of the Snaigupėlė Interglacial in the Middle Pleistocene is problematic both in East and West Europe. Its solution requires the absolute age datings in other geological sections by accessible methods.

The Netiesos outcrop is located on the right bank of the Nemunas River about 6 km downstream from the Merkinė town. The Merkinė (Eemian) continental deposits are composed mostly of peat and gyttja with rare mollusk shells and sandy sediments

Table 2. **TL dates of sand from Valakupiai outcrop (Valakampiai) at Neris River**
2 lentelė. **Valakupiø (Valakampiø) atodangos prie Neries smėlio TL datos**

Sample No	No lab. UG	dα (Gy/ka)	dβ (Gy/ka)	d βγ (Gy/ka)	Dr (Gy/ka)	ED (Gy)	TL age, years (ka BP)
V-1	5598	0.01	0.86	0.36	1.17	280	239 ± 36
V-2	5599	0.03	0.82	0.37	1.22	280.3	229.7 ± 36
V-3	5600	0.03	1.01	0.43	1.47	26.9	179.5 ± 27

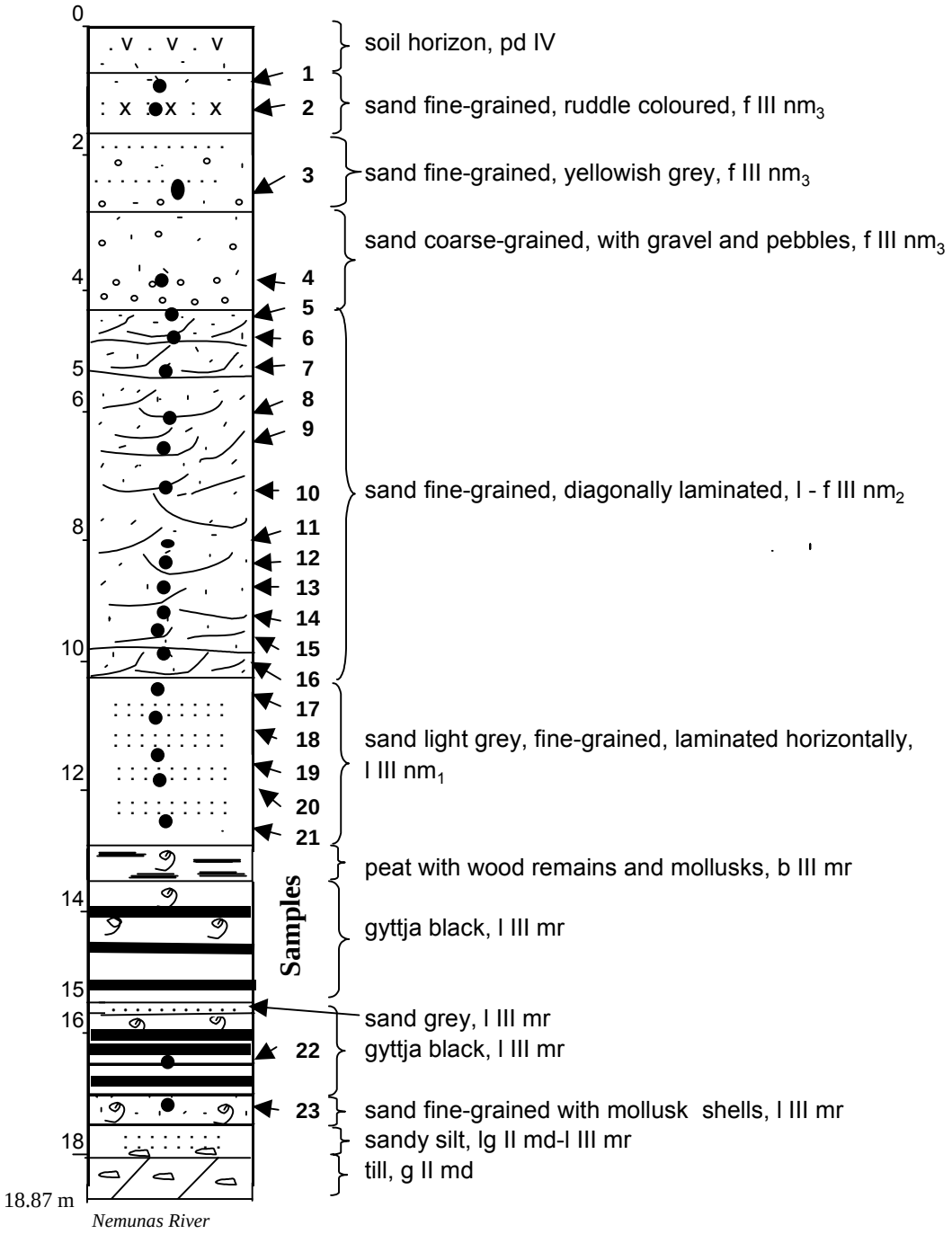


Fig. 4. Section of Netiesos outcrop at the Nemunas River with location of samples in vertical profile Coordinates (longitude, latitude) 54°02'20"; 24°05'02"

4 pav. Netiesø atodangos pjûvis prie Nemuno su pavyzdþiø paëmimo vietomis vertikaliame profilyje

of lacustrine origin on the top (Fig. 4). The age of freshwater mollusk shells from lake-and-bog deposits of the Merkinë (Eemian) Interglacial parastratotype in the Netiesos exposure had been determined as 112.1 ± 25.9 and 101.5 ± 11.5 ka years BP (for samples from the lower and upper units, respectively) by the ESR method earlier (Gaigalas, Molodkov, 2002). The new TL age for sand under the gyttja was determined to be 196.9 ± 27.5 ka years BP and for the interlayer in the lower part of gyttja as 145.9 ± 20.3 ka years BP in the present research (Table 3). Four samples of lake sand deposits which covered the organogenic sediments of Merkinë Interglacial (pollen zone M_1–M_4 in the Netiesos outcrop) were dated by OSL (Gaigalas, Hütt, 1997). These dates correlate well with our new TL results obtained in 2003 for the Netiesos outcrop for the same lake sand (118.4 ± 14.2 ka, 104 ± 13.5 ka, >113.6 ka, 135.9 ± 17.7 ka, 103.2 ± 13.4 ka years BP) (Table 3).

The Nemunas (Vistulian) glacial sandy sediments were dated by TL in the Netiesos exposure: Early

Table 3. **TL dates of sediments of Netiesos outcrop**
3 lentelë. **Netiesø atodangos nuogulø TL datos**

Sample No	Depth (m)	Lab. No. UG	dα (Gy/ka)	dβ (Gy/ka)	dγ (Gy/ka)	dc (Gy/ka)	Dr (Gy/ka)	ED (Gy)	Age TL years (ka BP)
N-1	1.30	5781	0.01	1.07	0.36	0.14	1.58	29.7	18.8 ± 2.3
N-2	1.80	5782	0.01	1.45	0.52	0.13	2.11	168.3	79.7 ± 11.9
N-3	2.80	5783	0.01	1.10	0.38	0.10	1.59	28.8	18.2 ± 2.3
N-4	3.80	5784	0.01	1.17	0.48	0.08	1.74	40.2	23.1 ± 2.8
N-5	4.40	5785	0.02	1.18	0.48	0.06	1.74	35.9	34.2 ± 4.4
N-6	5.00	5786	0.02	1.16	0.49	0.05	1.72	60.5	35.2 ± 4.2
N-7	5.55	5787	0.02	1.19	0.44	0.05	1.70	54.2	31.9 ± 4.4
N-8	6.10	5788	0.01	1.18	0.44	0.04	1.67	64.8	38.8 ± 4.6
N-9	6.75	5789	0.00	1.26	0.37	0.03	1.66	62.9	37.9 ± 4.5
N-10	7.38	5790	0.01	1.20	0.53	0.02	1.76	71.5	40.6 ± 4.9
N-11	8.08	5791	0.00	1.44	0.50	0.01	1.95	80.4	41.2 ± 5.0
N-12	8.40	5792	0.01	1.70	0.63	0.01	1.35	65.0	48.2 ± 7.4
N-13	8.77	5793	0.01	1.23	0.41	0.00	1.65	116.2	70.4 ± 8.5
N-14	9.12	5794	0.01	1.33	0.38	0.00	1.83	134.1	73.3 ± 9.5
N-15	9.50	5795	0.01	1.41	0.49	0.00	1.90	155.8	82.0 ± 10.7
N-16	9.90	5796	0.01	1.40	0.48	0.00	1.89	136.8	72.4 ± 8.7
N-17	10.40	5797	0.01	1.41	0.51	0.00	1.93	199.2	103.2 ± 13.4
N-18	10.83	5798	0.00	1.36	0.50	0.00	1.86	252.9	135.9 ± 17.7
N-19	11.50	5799	0.00	0.65	0.23	0.00	0.88	> 100.0	> 113.6
N-20	11.93	5800	0.01	1.09	0.31	0.00	1.41	146.7	104.3 ± 13.5
N-21	12.45	5801	0.00	1.04	0.38	0.00	1.42	168.0	118.4 ± 14.2
N-22	16.55	5802	0.01	1.16	0.60	0.00	1.77	258.3	145.9 ± 20.3
N-23	17.15	5803	0.01	0.91	0.37	0.00	1.29	254.0	196.9 ± 27.5

Table 4. **TL dating results of sand from Rokai outcrop**
4 lentelë. **Rokø atodangos smëlio TL datos**

Samples	Nr. lab. UG	dα (Gy/ka)	dβ (Gy/ka)	dγ (Gy/ka)	Dr (Gy/ka)	ED (Gy/ka)	TL age, years (ka BP)
R-1	5556	0.01	1.08	0.41	1.50	94.5	63.0 ± 9.0
R-2	5557	0.03	1.01	0.43	1.47	95.0	64.6 ± 9.0
R-3	5558	0.00	0.37	0.11	0.48	88.1	183.5 ± 28.0
R-4	5559	0.02	0.80	0.32	1.14	57.5	50.4 ± 7.5
R-5	5560	0.00	0.88	0.25	1.13	59.0	52.2 ± 8.0
R-6	5561	0.00	0.48	0.16	0.64	28.8	45.0 ± 7.0
R-7	5562	0.01	0.68	0.25	0.94	35.7	38.0 ± 5.0
R-8	5563	0.02	0.74	0.35	1.11	36.0	32.4 ± 4.8
R-9	5564	0.00	0.55	0.20	0.75	23.0	30.6 ± 4.8
R-10	5565	0.00	0.71	0.18	0.89	31.0	34.8 ± 5.0
R-11	5566	0.01	0.99	0.35	1.35	85.0	62.9 ± 9.0
R-12	5567	0.02	0.89	0.36	1.27	85.4	67.2 ± 9.0
R-13	5568	0.03	0.95	0.45	1.43	96.1	67.2 ± 9.0
R-14	5569	0.03	0.96	0.46	1.45	95.0	64.8 ± 9.0
R-15	5570	0.02	1.07	0.39	1.48	58.0	39.2 ± 6.0
R-16	5571	0.01	0.82	0.31	1.14	57.5	50.4 ± 7.5
R-17	5572	0.00	0.62	0.19	0.81	31.6	39.0 ± 6.0
R-18	5573	0.00	0.66	0.20	0.86	31.0	36.0 ± 5.4
R-19	5574	0.01	0.67	0.23	0.91	36.0	39.5 ± 6.0
R-20	5575	0.00	0.57	0.17	0.74	23.5	31.7 ± 4.8
R-21	5576	0.01	0.69	0.24	0.94	36.0	38.2 ± 5.7
R-22	5577	0.00	0.66	0.20	0.86	30.3	35.4 ± 5.5

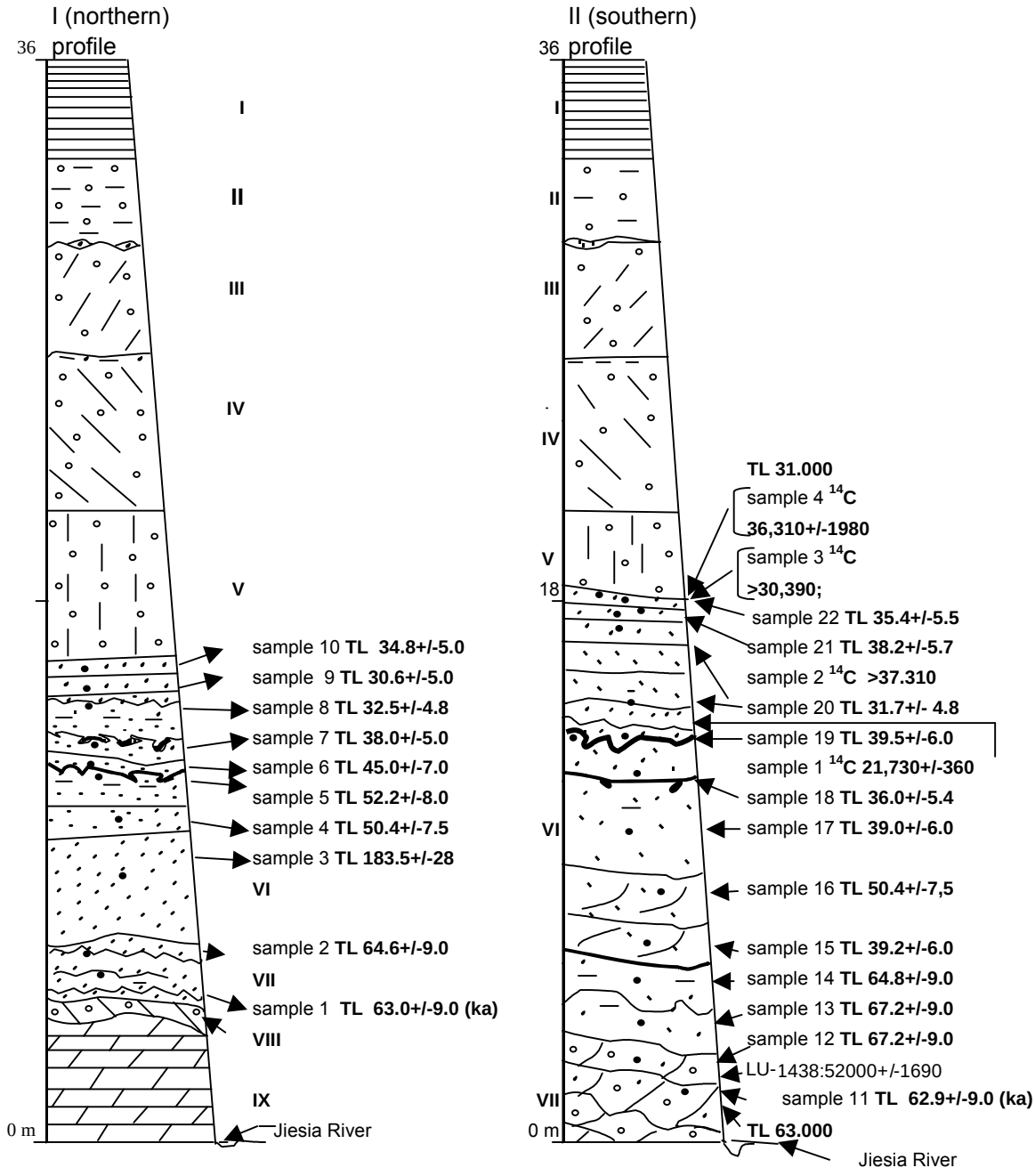


Fig. 5. TL (ka) and ^{14}C dates of sediments from Rokai section
Coordinates (longitude, latitude): 54°50'57"; 23°46'20"
Layers: I – glaciolacustrine varved clay, II – till of South Lithuanian phasial of Baltija stadial, III – till of East Lithuanian phasial of Baltija stadial, IV – till of Þiogeliai phasial of Grûda stadial, V – till of Grûda stadial of Nemunas glaciation, VI – silt and gravel of Rokai mega-interstadial, VII – sand, gravel and pebble of Lower Nemunas periglacial, VIII – till of Medininkai glaciation, IX – chalk marls in glaciodislocation
5 pav. Rokø atodangos nuogulø TL (tûkst. metø) ir ^{14}C datos

Nemunas periglacial (72.4 ± 8.7 ka, 82.0 ± 10.7 ka, 73.3 ± 9.5 ka, 70.4 ± 8.5 ka years BP), Middle Nemunas Interstadial (48.2 ± 7.5 ka, 41.2 ± 5.0 ka, 40.6 ± 4.9 ka, 37.9 ± 4.5 ka, 38.8 ± 4.6 ka, 31.9 ± 4.4 ka, 35.2 ± 4.2 ka, 34.2 ± 4.4 ka years BP) and Late Nemunas glacial time (23.1 ± 2.8 ka, 18.2 ± 2.3 ka, 79.7 ± 11.9 ka, 18.8 ± 2.3 ka years BP). The upper part of the Netiesos outcrop represents the glaciofluvial sediments of the Grûda (Brandenburgian) stadial of Nemunas (Vistulian) Glaciation. Twenty three new TL dates for sediments of different genesis from the Netiesos outcrop characterized the Last Interglacial/Glacial macroclimatic cycle of the Pleistocene in Lithuania.

The Rokai outcrop is situated on the eastern bank of the Jiesia River (a tributary of the Nemunas Ri-

ver) in the environments of the Kaunas city. Stratigraphical sandy units of Early and Late Nemunas (Vistulian) Glacial have been dated in two profiles (southern and northern) by 22 determinations of TL age by St. Fedorowicz at the Laboratory of Gdansk University (Fig. 5). The data obtained from the Rokai section confirm the absence of an ice sheet during the Early and Middle time of Nemunas Glacial (Table 4). The Early Nemunas deposits accumulated in the lake-river basin 70–55 thousand years ago (63.0 ± 9.0 ka, 64.6 ± 9.0 ka, 183.5 ± 28 ka years BP northern profile, 62.9 ± 9 ka, 67.2 ± 9.0 ka, 67.2 ± 9.0 ka, 64.8 ± 9.0 ka years BP southern profile). The Middle Nemunas deposits in interglacial lake-river conditions were accumulated before 55–30 thousand years (50.4 ± 7.5 ka, 52.2 ± 8.0 ka, 45.0 ± 7.0 ka, 38.0 ± 5.0 ka, 32.4 ± 4.8 ka, 30.6 ± 4.8 ka, 34.8 ± 5.0 ka years BP northern profile, 39.2 ± 6.0 ka, 50.4 ± 7.5 ka, 39.0 ± 6.0 ka, 31.7 ± 4.8 ka, 38.2 ± 5.7 ka, 35.4 ± 5.5 ka years BP southern profile).

The layers of both sections correlate well according to the obtained thermoluminescence dates. Only two samples (R-3 and R-10) showed an anomalous age (183.5 ± 28.0 and 62.9 ± 5.0 thous. years), probably because of an admixture of older matter from the glaciation sediments.

The obtained TL data allow to attribute the lower layers (VII) of the Rokai outcrop to the Varduva Periglacial of Nemunas Glaciation of the Upper Pleistocene.

In this period, when the glaciers had not yet reached Lithuania, flows of running water spread the coarser sediments. They are characterized by a slanting stratification. Their TL age varies within 62.9 ± 9.0 thous. to 67.2 ± 9.0 thous. years and corresponds to the early Nemunas Glaciation in Lithuania.

The overlying sandy sediments (VI) from a flooded water environment are younger. Their age becomes consistently younger upwards in sediments of both sections from 52.2 ± 8.0 thous. to 30.6 ± 5.0 thous. years. They can be attributed to the middle period of Nemunas Glaciation.

In the upper part of sandy sediments (VI) of the second section of the Rokai outcrop, interlayers rich in organic matter were found. By their composition these interlayers equal the peaty soil. Genetically, they can be ascribed to hypdromorphic soils exposed to congelation processes. Four samples of this peaty soil were dated by the radiocarbon (^{14}C) method in collabration with Prof. Habil. Dr. Anna Pazdur, Head of Radiocarbon Laboratory of Gliwice University (Gaigalas, Pazdur, 2004). The dates obtained by the method of radiocarbon dating showed a good agreement with the age determined by TL dating. They revealed the late middle period of Nemunas Glaciation.

Thus, the sandy layers (VI) with silt and peaty soil interlayers in the Rokai outcrop, which overlie the Varduva periglacial sediments (VII) of the early Nemunas Glaciation, should be attributed to the Rokai Mega-interstadial of the Middle Nemunas Glaciation.

The till layers on the top the outcrop (Fig. 5, V–II), which overlie the sandy sediments of the middle Nemunas Glaciation, according to the data of the current study and thermoluminescence and radiocarbon dating, belong to the Late Nemunas Glaciation. Hence follows an obvious conclusion that the Upper Pleistocene glaciers reached Lithuania in the Late Nemunas Glaciation. They left till layers of the Grûda and Baltija stadials, which lie over the upper part of the Rokai outcrop.

4. CONCLUSIONS

The new TL dates of aquatic sandy sediments provided a more accurate chronology of Middle-Upper Pleistocene in Lithuania.

The TL age obtained for Butënai (Holsteinian) Interglacial from 430.2 ka to 280.3 ka years BP, Snaigupëlë (Drenthe-Wartha) Interglacial from 246.3 ka to 179.5 ka years BP, Merkinë (Eemian) Interglacial from 135.9 ka to 103.2 ka years BP, Nemunas (Vistulian) Glacial Early time from 72.4 ka to 64.6 ka years BP, Nemunas (Vistulian) Middle time from 58.2 ka to 31.9 ka years BP, Nemunas (Vistulian) Glacial Late time from 23.1 ka to 17.6 ka years BP.

The tills of the Late Nemunas (Vistulian) glaciation maximum accumulated about 18.9 ka – 17.6 ka years BP.

ACKNOWLEDGEMENT

This research was supported by Lithuanian State Science and Studies Foundation.

References

Barzdþiuvienë V., Ðinkûnas P., Jurgaitis A., Satkûnas J. 2000. Pleistocene sedimentation features in Middle Neris palaeobasins. *Litosfera*. ***4***. Vilnius: 36–45.

Gaigalas A., Hütt G., Meleðytë M. 1994. The OSL age of the Merkinë (Mikulino) interglacial period in Lithuania. *Conference on geochronology and dendrochronology of old town's and radiocarbon dating of archaeological findings. Abstracts and papers.* Vilnius: 16.

Gaigalas A. 1994. On palaeogeography of Late Pleistocene in the Lithuania. *Geografia XXVII – Nauki Matematyczno-Przyrodnicze*. Zeszyt ***92***. 183–194.

Gaigalas A. 2000. Correlation of ^{14}C and OSL dating of Late Pleistocene deposits in Lithuania. *Geochronometria*. ***19***. 7–11.

Gaigalas A. Hütt G. 1995. OSL dating of the Merkinë (Eem) interglacial (in Jonionys) and the Nemunas Glaciation (Rokai section) in Lithuania. *PACT.* ***50***. 59–69.

Gaigalas A., Fedorowicz. St. 2002. Thermoluminescence dates of Mid- and Late Pleistocene sediments in Vilkiðkës exposure, Eastern Lithuania. *Geologija.* ***38***. 31–40.

Gaigalas A., Pazdur A., Pawlyta J. 2001. Radiocarbon age of Late Pleistocene glacigenic sediments in Jonionys section of Merkinë (Eemian) interglacial. *Geochronometria*. **20**. 75–80.

Gaigalas A., Molodkov A. 2002. ESR ages of three Lithuanian Mid-Late Pleistocene interglacials: methodical and stratigraphical approach. *Geochronometria*. **21**. 57–64.

Gaigalas A., Fedorowicz St. 2002. Thermoluminescence dates of Mid- and Late Pleistocene sediments in Vilkiðkës exposure, Eastern Lithuania. *Geology*. **38**. Vilnius. 31–40.

Gaigalas A. and Pazdur A. 2004. Radiocarbon dating of Late Quaternary in Lithuania. *Book of Abstracts 8th International conference "Methods of absolute chronology"*. 17–19th May 2004, Ustroñ, Poland. 51–53.

Fedorowicz St., 1994. Wyniki badañ laboratoryjnych glin zwa‰owych w laboratorium Gdañskim. *Zesz. Nauk., Politech. Sl., seria Mat.-Fiz. Z. H. Geochronometria*. **10**. 253–262.

Molodkov A., Bolikhovskaya N., Gaigalas A. 2002. The last Middle Pleistocene interglacial in Lithuania: insights from ESR-dating of deposits at Valakampiai, and from stratigraphic and palaeoenvironmental data. *Geological Quarterly*. **46**(*4*). Warszawa. 363–374.

Satkûnas J. 1993. Valakampiai outcrop in Vilnius. *Pleistocene stratigraphy, ice marginal formations and deglaciation of Baltic States*. Excursion Guide (June 14–19, 1993). Site 18. 39–40.

Velichkevich F., Kondratienë O., Kisielienë D. 1999. Palaeocarpologic complexes of the Merkinë (Eemian) interglacial deposits in Netiesos outcrop (South Lithuania). *Geologija*. **29**. 40–56.

Âåëè÷êåâè÷ Ô. Þ., 1979: Èñòîðèÿ ïëåéñòîöåíîâîé ôëîðû ñðåäíåé ïîëîñû Âîñòî÷íî-Åâðîïåéñêîé ðàâíèíû. *Ñîâåòñêàÿ ïàëåîáîòàíèêà*. Ì îñêâà: Íàóêà. 76–121.

Êîíäðàòüåâ Î. 1996. Ñòðàòèãðàôèÿ è ïàëåîãåîãðàôèÿ êâàðòåðà Ëèòâû. 210 ñòð.

Ðèøêåíå Ì. À. 1979. Àíòðîïîãåíîâàÿ ôëîðà Ëèòâû. *Ñîâåòñêàÿ ïàëåîáîòàíèêà*. Ì îñêâà: Íàóêà. 122–131.

Algirdas Gaigalas, Stanisùawas Fedorowiczius, Monika Meleðytë

LIETUVOS VIDURINIO–VIRÐUTINIO PLEISTOCENO AKVATINIØ SMËLIO NUOGULØ TL DATOS

Santrauka

Termoliuminescencijos (TL) metodu buvo datuotas smulkiagrûdis smëlis, susiklojæs vandens aplinkoje, kurio mëginiai paimti ið Butënø (Holðteino) tarpledynmeèio (Tartokø atodanga), Snaigupëlës (Drente-Varta) tarpledynmeèio (Tartokø ir Valakupiø atodanga), Merkinës (Eemio) tarpledynmeèio (Tartokø ir Netiesø atodangos) ir Nemuno (Vislos) ledynmeèio nuogulø (Tartokø, Netiesø ir Rokø atodangos). Mëginiø ið minëtø atodangø TL datavimo rezultatai rodo, kad Butënø tarpledynmeèio nuogulø amþiaus datos yra pasiskirsèiusios laiko intervale prieð 430,2 iki 280,3 tûkst. metø, Snaigupëlës tarpledynmeèio – nuo 239,4 iki 179,3 tûkst. metø ir Merkinës tarpledynmeèio – nuo 135,9 iki 103,2 tûkst. metø. Ankstyvojo Nemuno ir vidurinio Nemuno akvatinës smëlio nuogulos kaupësi prieð 67,2–30,6 tûkst. metø. Morenos, slûgsanèios Tartokø ir Rokø atodangø virðutinëse dalyse, yra jaunesnës negu 30000 metø ir priskirtinos vëlyvojo Nemuno ledynmeèio ledyno paplitimo maksimumui Lietuvoje.

Àëüãèðäàñ Ãàéãàëàñ, Ñòàíèñëàâ Ôåäîðîâè÷, Ì îíèêà Ì åëåøèòå

ÒË ÄÀÒÛ ÀÊÂÀËÜÍÛÕ ÏÅÑ×ÀÍÛÕ ÎÒËÎÆÅÍÈÉ ÑÐÅÄÍÅÃÎ-ÂÅÐÕÍÅÃÎ ÏËÅÉÑÒÎÖÅÍÀ ËÈÒÂÛ

Ð å ç þ ì å

Òåðìîëþìèíåñöåíòíûì (ÒË) ìåòîäîì äàòèðîâàíû ìåëêîçåðíèñòûå ïåñêè, îáðàçîâàâøèåñÿ â âîäíîì ñðåäå. Ïðîáû áûëè ñîáðàíû èç ñëåäóþùèõ îáíàæåíèé: Òàðòîêàé áóòàíèêîãî (ëèõâèíñêîãî, ãîëüøòåéíñêîãî) ìåæëåäíèêîâüÿ, Òàðòîêàé è Âàëàêóïÿé ñíàéãóïåüñêîãî (äíåïðîâñêîãî-ìîñêîâñêîãî, äðíòà-âàðòà) ìåæëåäíèêîâüÿ, Òàðòîêàé è Íÿòåñîñ ìÿðêèíñêîãî (ìèêóëèíñêîãî, ýåìñêîãî) ìåæëåäíèêîâüÿ è Òàðòîêàé, Íÿòåñîñ è Ðîêàé íÿìíñêîãî (âàëäàéñêîãî, âèñëèíñêîãî) ëåäíèêîâüÿ. Ïîëó÷åíû äàòû âîçðàñò áóòàíèêîãî ìåæëåäíèêîâüÿ ðàñïðåäåëÿåòñÿ âðåìåíè îò 430,2 äî 280,3 òûñ. ëåò, ñíàéãóïåüñêîãî ìåæëåäíèêîâüÿ – îò 239,4 äî 179,3 òûñ. ëåò è ìÿðêèíñêîãî ìåæëåäíèêîâüÿ – îò 135,9 äî 103,2 òûñ. ëåò. Ðàííå- è ñðåäíåíÿìíñêèå àêâàëüíûå ïåñ÷àíûå îòëîæåíèÿ íàêàïëèâàëèñü îò 67,2 äî 30,6 òûñ. ëåò òî ìó íàçàä. Ì îðåíû, çàëåãàþùèå íà âåðõíåé ÷àñòè ðàçðåçîâ Òàðòîêàé è Ðîêàé, ìîëîæå íà 30 òûñ. ëåò. Îíè, âèäèìî, îòëîæåíû âî âðåìÿ ìàêñèìàëüíîãî ðàñïðîñòðàíåíèÿ ëåäíèêà ïîçäíåíÿìíñêîãî ëåäíèêîâüÿ â Ëèòâå.