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# CORRELATION OF $^{14}C$ AND OSL DATING OF LATE PLEISTOCENE DEPOSITS IN LITHUANIA

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**Abstract.** Optically stimulated luminescence (OSL) studies on the $^{14}C$ dated Rokai section of the Middle Nemunas (Middle Vistulian) limno-alluvial deposits of the Jiesia river were made. The most deposits from palaeolake with broad, low-gradient floors of Middle Nemunas interstadial in Central Lithuania are inferred to be more favourable to accurate OSL dating. OSL procedures and sedimentation processes critically affected the accuracy of OSL ages.

## 1. INTRODUCTION

Advances in many areas of Quaternary research have been impeded because most sedimentary sequences had not been satisfactorily dated. Radiocarbon dating, the most widely used procedure for determining ages of Quaternary deposits, is limited to organic material younger than about 50 ka. Unfortunately most glacial sediments, which are the dominant Quaternary deposits in Lithuania, are barren of datable organic matter. Most stratigraphic units of Pleistocene are older than 50 ka. Berger (1984) applied the technique of thermoluminescence (TL) for direct dating of glacially related silts. The thermoluminescence ages for the glaciolacustrine sediments agree with the radiocarbon control dates. Such sediments can be dated by TL.

Thermoluminescence studies on $^{14}C$ dated marine core were made by G. Berger, D. J. Huntley and J. J. Stipp (1984). In an attempt to develop an absolute dating tool for such sediments, G. Berger, J. J. Claque and D. J. Huntley (1987) applied the partial bleach TL dating technique to glaciolacustrine sediments of known age from central British Columbia, Canada. A TL age of Holocene control sample, similar to the radiocarbon age, was also attained using the partial bleach method (Forman *et al.,* 1987). The same method yielded the TL age for Pleistocene raised marine sediments from Hudson Bay Lowland, Canada, in agreement with the age estimates from the amino acid epimerization method. Berger and Nielsen (1990) used the TL method for dating Middle Wisconsin non-glacial river sediments. The younger direct dates imply a significant climatic warming and deglaciation in the centre of the Laurentide Ice sheet during the Middle Wisconsin time. Thermoluminescence systematics of known-age sediments from Fraser River delta (Canada) and fluvial environments have been determined to test the hypothesis of "zeroing" the TL mineral clocks (Berger *et al.,* 1990). The exact TL dating requires a small zero-point signal, which remains in most deposits.

## 2. OSL, $^{14}C$ AND ESR DATES AND PALAENVIRONMENTAL INTERPRETATION

In the environs of Kaunas, Middle Lithuania, in an outcrop on the right bank of the River Jiesia, limno-alluvial sandy-gravel and sandy deposits with interbeds of soils and silts of Late Pleistocene (Middle Nemunas =Vistulian time) are found **(Fig.1)**. We have studied the OSL of limno-alluvial deposits (Gaigalas and Hütt, 1996), that has a rich set of $^{14}C$ dates. Our objective

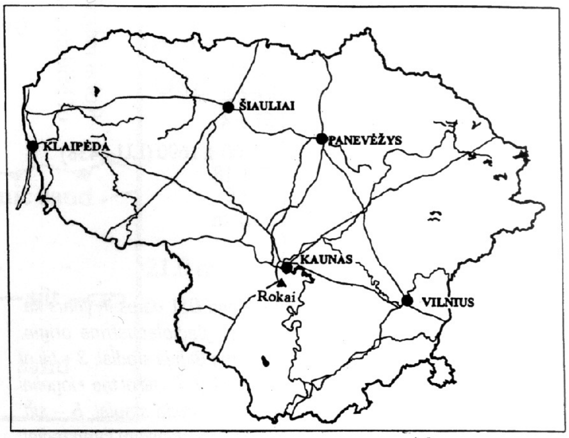


***Fig.1.** Location map of Rokai section.*

was to investigate the OSL properties of sediments from this outcrop, and to devise procedures to obtain OSL ages consistent with the $^{14}C$ dates (**Fig. 2**).

In general, the optically stimulated luminescence (OSL) dates of 19 samples from the Middle Nemunas limno-alluvial deposits in the Rokai section on the Jiesia river, obtained in the Estonian Institute of Geology by G. Hütt range from 63±6 to 32±4 ka (Gaigalas *et al.,* 1994).These OSL dating agree well with radiocarbon dating obtained by Kh. Arslanov in the St. Petersburg University (LU-), Russia, by A. Pazdur in the Silesian Technical University (Gd-), Gliwice, Poland and by J. Banys in the Institute of Geology (Vs-), Vilnius, Lithuania.

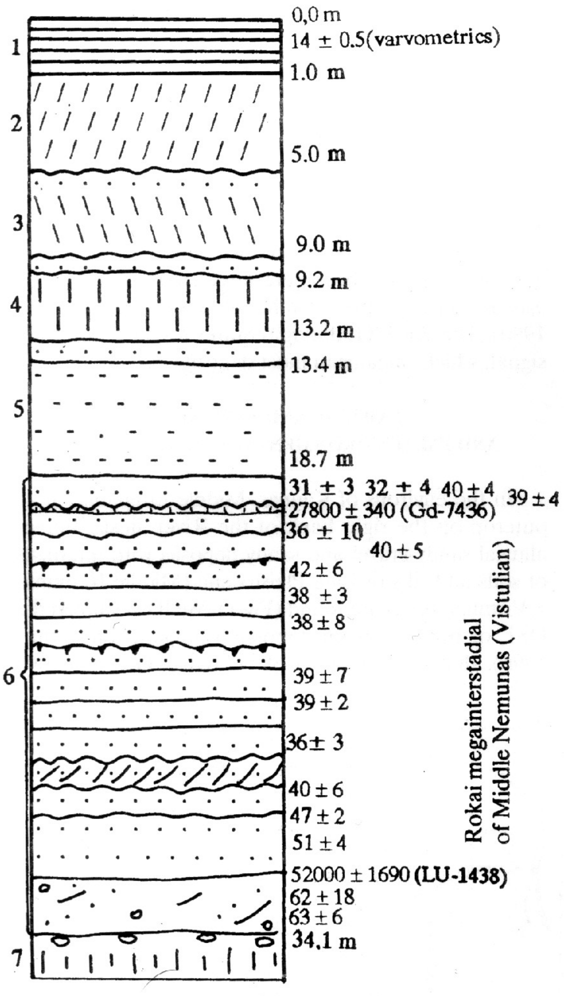


***Fig. 2.*** *Rokai section with radiocarbon and OSL dates in years ka. Stratigraphic units: 1 – varved clay of glaciolacustrine origin, 2 – till of the South Lithuanian phase of the Baltija stadial, 3 – till of the East Lithuanian phase of the Baltija stadial, 4 – till of the •iogeliai phase of the Gruda stadial, 5 – till of the Gruda stadial, 6 – silt, sand and gravel of the Middle Numunas (Weichselian) interstadial, 7 – till of Medininkai (Warthe) glaciation.*

The radiocarbon (LU-1432, 52,000±1690 BP) date of branches and arboreal mass from a lens in the lowermost part (above 2.5 m of water level) interstadial limno-alluvial sandy-gravel and sand strata with interbeds of silts confirms its Middle Nemunas (Middle Valdaian, Middle Vistulian) age. Large and small fractions of Rokai samples give approximately the same find age, i.e. correspond to the earlier part of the Middle Nemunas not glacial interval (Gaigalas *et al.,* 1986).

In the upper part of sandy limno-alluvial strata of the Rokai section, 1.5 m lower than Late Nemunas till, there lies an interlayer of sandy peat soil and chemogenic white carbonate tuff (Gaigalas *et al.,* 1994). Samples of wood remains, terrestrial peat and carbonates were selected from the depth of 1.50-1.70 m under the till and then dated in different radiocarbon laboratories (LU-3165, 37,590±820; LU-3155, 34,930±510; Gd-7436, 27,800±340; Gd-6991, 24,430±280; Vs-400, 29,800±1120 BP; **Fig. 3**).

We selected samples of known $^{14}C$ age from the Rokai outcrop with the objective of determining the influence of distance and mode of transport on the accuracy of OSL age. Accurate OSL apparent ages can be obtained for soil, limnic and alluvial sediments provided special precautions are taken in sample collection and OSL analysis (Gaigalas and Hütt, 1996). The results show clearly that both sedimentation processes and OSL procedures, as reflected in the particle size and sedimentary structure of the samples, critically affected the accuracy of OSL ages. Conditions of sedimentation in deep, steep-walled lakes with high sediment inputs generally would not favour accurate TL dating (Berger *et al.,* 1987). The reasons for this are that transport distances in such water bodies are commonly short, and sediment gravity flows are important agents of sedimentation. The TL of modern deposits is not reduced to zero but to a certain low level. The non-zero TL age of such deposits is called the residual or relict age (Berger *et al.,* 1984).

The relict age effect depends from the sedimentation environments: frequency of sunny and cloudy days, relation between seasons (winter-summer), occurrence of clean or muddy water in the lake basin etc. There are several warm-cool-climate nonglacial sedimentary units in the Rokai environments in Middle Nemunas time.

Most deposits from palaeolakes with broad, low-gradient floors of Middle Nemunas interstadial in Central Lithuania are inferred to be more favourable to accurate OSL dating. In such lakes and rivers in area of low relief, rain-out from suspension is an important sedimentation process and transport distance is long. The most satisfactory deposits are clay and silty clay interlayers less than a few centimetres thick. Fine-grained water laid sediments, deposited at rates less than a few millimetres per year, should be datable by the OSL method. The suspended silt and surface mud yield minimum relict OSL ages.

Optically stimulated luminescence applied for known age sediments from the Rokai section have been determined to test the hypothesis that "zeroing" of OSL mineral clocks occurs in fluvial and shallow lake environments.

The residual OSL level retained by sediments is a function of the light spectrum and duration of exposure of minerals during their transportation and sedimentation. Mineral grains are bleached by light prior to deposition and yield near-zero ages. Sediments deposited in the Middle Nemunas time were transported by rivers and suspended, and possibly resuspended in a shallow lake. Thus they had an ample opportunity to be exposed to light prior to deposition.

The observation of an anomaly high OSL age (from 39±4 to 40±2 ka) for sands, which covered the peat layer with $^{14}C$ dates 24,430±210 of organic detritus, 27,800±340 of carbonate tuff, 34,910±510 of organic detritus and 37,590±820 BP of carbonate tuff strongly suggests that these sands were exposed only for a short time. The date for sand cover does not apply, strictly, to the Middle Nemunas stratigraphy and further sampling is required to date the sand units. The other OSL ages of 31±3 ka, 32±4 ka and 36±10 ka years agree with a calendar-converted radiocarbon age of organic detritus (35±0.5 ka) and carbonate tuff (38±0.8 ka BP).

This OSL dating focused on limno-alluvial and soil depositional environments. Gaigalas and Hütt (1996) began a study of the OSL of suspended grains and known $^{14}C$ age sediments from Middle Nemunas mega-interstadial in Rokai outcrop near Kaunas town, Central Lithuania. The results of our OSL dating of underwater sediments are reported separately (Gaigalas and Hütt, 1996) as a part of study of water-borne and eolian sediments. I report here OSL results for suspended grains of lake, river, run-fall and soil sediments. The OSL in fine-grained (0.1-0.01 mm) bimineral sediments is generally dominated by that of detrital feldspar.

The ability to date limno-alluvial sediments and soils accurately by the OSL provides the opportunity to establish reliable absolute chronologies beyond the of range radiocarbon method (**Table 1**), to correlate widely separated stratigraphic sequences in glaciated region of Baltic countries and Poland, and to date better the glaciations from Scandinavian ice center.

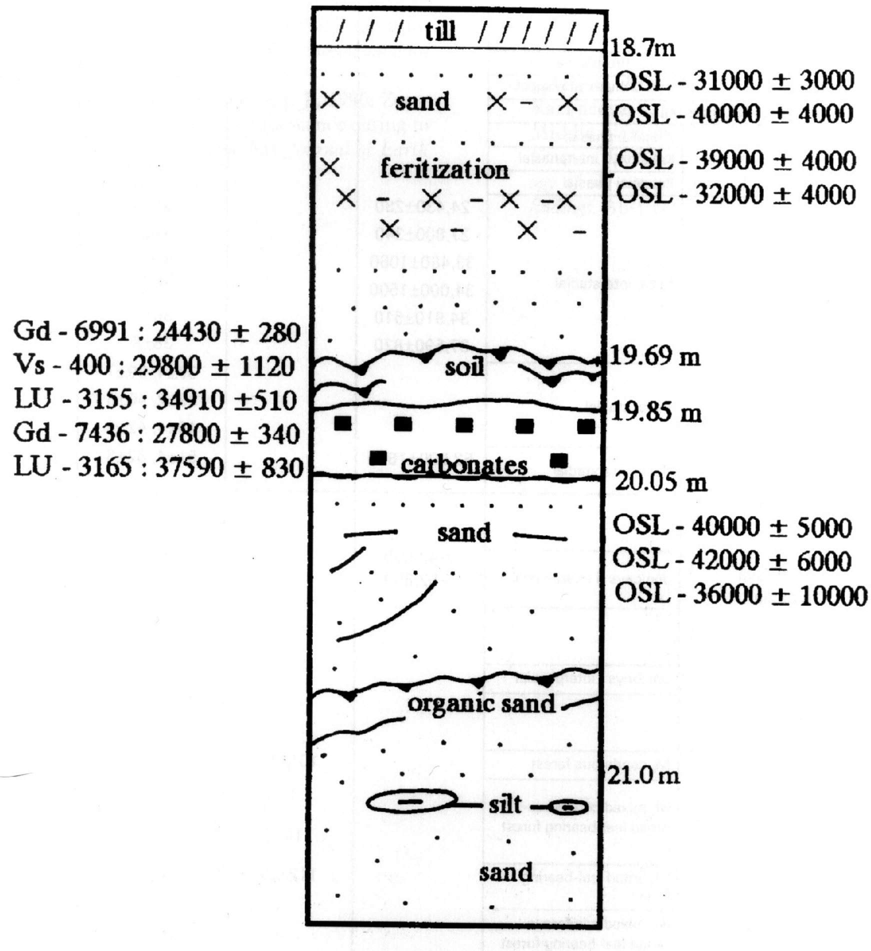


*Fig. 3. Correlation of OSL and $^{14}C$ dates of Middle Nemunas sediments in upper part of Rokai section.*

An OSL age from 31±3 ka to 63±6 ka BP for the lake, fluvial and surficial sediments of the Rokai megainterstadial agrees with the radiocarbon control dates and implies that such sediments can be dated by OSL. The three major factors affecting the accuracy of palaeodoses for these sediments were anomalous fading, nonlinearity in the OSL growth curves (both long recognised as problems) and overbleaching of the residual OSL remaining after deposition.

### 3. CONCLUSIONS

The exact OSL dating belong from zero point signal. The residual OSL level is a function of the spectrum and duration of light exposure during sediment transport and accumulation. The relict effect depends on: climate fluctuation and sedimentary environment (frequency of sunny and cloudy days, relation between winter and summer seasons, occurrence of sedimentation in the ice-covered basin etc.).

***Table 1.*** *Stratigraphy and geochronology of the Upper Pleistocene in Lithuania (Gaigalas, 1997).*

| Interglaciation and glaciation | | Interstadial and stadial | Interphasial and phasial | Ages: $^{14}C$ Age [BP] | Ages: ESR [ka], (Molodkov) | Ages: OSL [ka] | The age of boundary [years] |
|---|---|---|---|---|---|---|---|
| Nemunas glaciation | Upper (glacial) | Žiemgala last glacial (gotiglacial) | Upper Dryas phasial | | | | |
| | | | Alleröd interphasial | 11,970±180<br>11,500±430 | | | 11,900 |
| | | | Middle Dryas phasial | | | | 12,300 |
| | | | Bölling interphasial | 12,160±120<br>12,700±80 | | | 12,800 |
| | | | North Lithuanian phasial | | | | |
| | | | Linkuva interphasial | | | | 14,500 |
| | | Baltija Stadial (daniglacial) | Middle Lithuanian | 14,040±240 | | | |
| | | | Šušvė interphasial | | | | |
| | | | South Lithuanian | | | | 15,900 |
| | | | Punia interphasial | | | | |
| | | | East Lithuanian phasial | | | | 16,500 |
| | | Pavyte interstadial | | | | | 18,000 |
| | | Gruda stadial | Žiogeliai phasial | | | | |
| | | | Krikštonys interphasial | | | | |
| | | | Puvočiai phasial | | | | 22,000 |
| | Middle (mega-inter-stadial) | Rokai | Biržai interstadial | 24,430±280<br>27,800±340<br>33,460±1060<br>34,000±1500<br>34,910±510<br>37,590±820 | | 31±3<br>32±4<br>36±10<br>38±3<br>36±3<br>38±8 | 37,000 |
| | | | Bičiai stadial | | | 39±4, 39±7<br>39±2, 40±6<br>40±4, 42±6 | 42,000 |
| | | | Rokai interstadial | 52,000±1690 | | 51±4, 62±8 | 55,000 |
| | Lover (peri-glacial) | Varduva stadial | | | | 61±9<br>41±3 | |
| | | | Jonionys II interphasial | >42,000<br>>52,800 | | 62±7<br>62±18 | |
| | | | | | | 63±6<br>70±3 | |
| | | | Jonionys I interphasial | | | 70±8 | |
| | | | | | | 95±12<br>86±7 | 70,000 |
| Merkinė interglaciation | | | $M_5$ coniferous forest | | 101±11 | | |
| | | | $M_4$ mixed coniferous-broad leaf-bearing forest | | 110±2 | 70±10<br>85±8<br>90±12 | |
| | | | $M_3$ broad leaf-bearing forest | | 112±25 | 114±11 | |
| | | | $M_2$ mixed coniferous-broad leaf-bearing forest | | | | |
| | | | $M_1$ coniferous forest | | | | 120,000 |

Deep sedimentation basin, muddy water column, short transport distance, steep-walls of the lake and high input of sediments do not favour accurate OSL dating, as well as coarse grain size of minerals and coverage by iron oxides or other plates.

Long transport distance and low relief, clean water column, silty clay and clay interlayers, a few centimetres thick, low deposition rate a few millimetre per year, redeposition, suspension of silt and mud, fine-grained waterlaid sediments, soil and occurrence of eolian, rain-out processes provides the opportunity of accurate OSL dating.

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