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The age of loess deposits at Dybawka, Tarnawce and Zarzecze (SE Poland) based on luminescence dating

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The article presents results of luminescence examination of three profiles with Carpathian and Pericarpathian loess, located in SE Poland. The authors review the current state of knowledge about the profiles. Deposits from the last two glacial cycles, the Warta and Vistula glaciations, were analysed. Samples of mineral and soil deposits were dated. Fifty-two results of TL dating were presented. Comparative dating (TL and OSL) was conducted for 9 samples. The results showed a possible interrelation between the luminescence methods, specified by the formula used. This formula results from the interpolation curve. With a larger number of results, such interpolation will be possible.

Key words: Carpathian and Pericarpathian loesses, TL dating, OSL dating, chronostratigraphy

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INTRODUCTION

The age of Quaternary deposits can be determined by luminescence methods. Dated deposits must have been exposed to solar radiation for a sufficient time to reduce the energy stored in grains of the deposit under examination (Fedorowicz, 2003).

Physical luminescence measurements for geological purposes are at present based on two methods: thermoluminescence (TL) and optically stimulated luminescence (OSL). The former (TL) enables the researcher to measure the energy stored in deposit grains by heating them to the temperature of approx. 500 °C. In the latter (OSL) the energy stored in grains is released by grain exposure to the light of a suitable wavelength.

What differentiates the two methods is how the so-called equivalent dose (ED) stored in grains is measured. It involves a different measurement methodology and apparatus. The measurement of the so-called dose rate (Dr) may be identical (spectrometric) in the two methods (Fedorowicz, 2003). The age of a deposit measured by luminescence methods is the quotient of equivalent dose and dose rate. It specifies the moment when a given deposit was last exposed to solar radiation.

Deposit exposure to solar radiation, hence also the reduction of energy stored in grains, limits method application due to the impossibility to date all types of deposits. This limitation is met by Aeolian deposits (loess and dune sands) and sand deposits, such as beach sands and fluvial sands (Bluszcz, 2000, Fedorowicz, 2003, Maruszczak et al. 1992), which are suitable for luminescence dating.

The time of past grain exposure to solar radiation is of crucial importance for measurements. If it was too short, the energy stored in the deposit might have only been decreased, and not reduced. This may falsify results in luminescence dating. In this case, the age of deposit will be made older. The energy reduction process (the so-called zeroing process) may be faster or slower. It takes less time to zero OSL than TL signals. The short time of deposit exposure to solar radiation may lead to total zeroing of OSL signal, but the TL signal may be only reduced in that time.

The time of deposit exposure to solar radiation may but does not have to cause discrepancies in data obtained via TL and OSL methods for the same sample. If the time of solar radiation was long and intensive in the past, the age of deposit should be approximately the same according to the both methods. If the time of exposure to solar radiation was short and less intensive, the TL age will be longer than OSL. The application of both TL and OSL methods may provide additional information about deposition conditions.

TL AND OSL METHODS

TL dating was carried out by S. Fedorowicz. The dried deposit 0.5 cu. dm in volume was subjected to spectrometric measurement ^{40}K, ^{226}Ra, ^{228}Th. Twenty measurements were made, each of them lasting 2,000 s. Nuclide values were converted into α, β, γ radiation doses and adjustments were made for deposit humidity (Aitken, 1983). The dose rate is a sum of alpha, beta and gamma radiation, and cosmic radiation. The dose rate was measured with the MAZAR spectrometer.

The equivalent dose was measured on the 80–100 μm fraction of grains sifted earlier from the entire sample mass. Grains were treated first with 10% HCl and than with HF for 1 hour. After the samples had been rinsed with distilled water and dried, extracted grains were divided into 7 portions. The first portion was used for natural thermoluminescence measurements. The remaining portions were treated with the ultraviolet lamp to reduce the energy stored in grains. After the grain energy had been zeroed, residues of energy in grains were measured (the so-called residual thermoluminescence). The remaining 5 portions were irradiated with gamma rays from the cobalt bomb, and ray values were selected in such a way as to regenerate the energy originally accumulated by the grains. The equivalent dose was measured by the regeneration method with the use of a reader-analyser, model RA'94. Samples were heated to 500 °C at the heating rate of 8 grades/s. Several glow curve charts were prepared for each portion. The plateau test was also carried out to check for sample saturation.

OSL dating was carried out by A. Bluszcz from the Silesian Technical University in Gliwice under the co-author's university research grant (BW 1230–5–0125–3). The dose rate was measured spectrometrically; U, Th and K measurements were made with adjustments for deposit humidity, cosmic radiation, grain size and HF etching. The equivalent dose was measured with the SAR method for grains of 125–200 μm granulation (Bluszcz, 2000).

GEOLOGICAL SETTING

For extra- and periglacial areas, loess formations are the most important carriers of information about the course of events in the Quaternary period. They provide a comprehensive information, starting from data on the accumulation environment and climatic changes up to a detailed information about local palaeoenvironmental conditions (Mojski 1981).

One of the most characteristic features of these formations is the occurrence of fossil soils in loess. The loess sequence, of the last glacial period in particular, reveals short-term climatic oscillations recognized by examining deep marine deposits and ice cores (Bond et al. 1993, Johnsen et al. 1992, Dansgaard et al. 1993). For these reasons it is of crucial importance to determine the loess stratigraphy and chronology.

Polish loess researchers mainly focus on loess covers in Southern Poland Uplands where loesses build extensive and thick covers. As a result, loesses of the Carpathian area, where they occur irregularly, fell slightly beyond the scope of interest. It was not until recently that interest in Carpathian loess has increased and a large progress of research was achieved (Łanczont 1997). This article is another contribution to this trend: we present the latest results of luminescence dating of two Carpathian loess profiles located in the close vicinity and related to the Pleistocene terraces of the San River (Dybawka, Tarnawce). The study also covered one of the peri-Carpathian plateau loess profiles (Zarzecze) whose state of examination is more advanced, but materials for the determination of their chronology are not sufficient and unambiguous enough from the palaeogeographic point of view (Laskowska-Wysoczańska 1991, Butrym, Maruszczak 1992, Łanczont et al. 2000). The determination of loess age should enable a more precise correlation of loess deposition cycles and warming phases, when dust covers were fixated by the vegetation and soils were formed, with the climatic phenomena registered in deep marine deposits and ice cores as oxygen-isotope stages distinguished on a global scale. In the end it should enable the determination of their chronostratigraphy. Loess-soil deposits, which may be correlated with OIS 6–2, were taken into consideration in the profiles analysed; older loess sequences in the Tarnawka and Zarzecze profiles were not taken into account. We wish to emphasize that all stratigraphic units of a lower rank distinguished in the relevant loess stratigraphy scheme are represented in the Vistulian part of the profiles (Maruszczak, 1991).

The profiles under consideration are situated in the SE part of Poland in the Przemyśl-Dynów Foodhills (The Outer Carpathians) and the Kańczuga Plateau, which belongs to the Sandomierz Basin. The main morphological elements of the Carpathian Foothills include relicts of three surfaces of partial planation forming a step-like relief. The remains of the oldest level are preserved at an altitude of *ca*. 500 m a.s.l. on the watershed of the main rivers, *i.e*. the San and the Wiar. The middle and bottom levels are situated at the altitudes of 380–410 m a.s.l. and 290–320 m a.s.l., respectively. The morphological axis of this area is the extensive and deep San valley. Its slopes, as well as valley slopes of other bigger rivers, contain a number of benches and flattenings that belong to the set of Pleistocene terraces.

The Carpathian Foreland has flat, quite monotonous hummocks. The area of this plateau reaches the altitude of 240–300 m a.s.l. It is quite intensively dissected, and the height differences are up to 40–80 m. The Kańczuga Plateau steeply descends to the 20 m high Pleistocene terrace of the San.

The distribution of loess in the Carpathian Foothills is uneven. Some bigger patches can be found in the marginal zone of the Carpathians. In the interior part of the Foothills there are loess islands. They can be found mainly in the San river valley, where the largest loess areas are connected with high and middle Pleistocene terraces; the thickness of such loess is sometimes more than 20 m. The upper border of the loess extent lies at an altitude of 280–320 m a.s.l. In the Kańczuga Plateau, the cover of loess and various loess formations occupies nearly its entire area, except for valley-floors. For this reason, the region is also known as the peri-Carpathian loess plateau.

Figure 1 presents all the results of deposit dating obtained by the TL and OSL methods. It should be stressed that the correlation of loess and soil horizons with stratigraphic units within the younger Quaternary period and the correlation with oxygen-isotope stages, as presented in Fig. 1 and the profile description, were based on a wide range of geological and palaeogeographic criteria. Results of deposit dating were not of a decisive nature; therefore, there are sometimes discrepancies between the stratigraphic position adopted for a given stratum and the TL (OSL) age of the deposit building such a stratum.

THE PROFILE OF LOESS DEPOSITS IN TARNAWCE NEAR PRZEMYŚL

The profile is situated on the northern side of the valley of a nameless San tributary, which cuts into a flattening genetically related to the high terrace of the San river. The top of exposure is at 248 m a.s.l. The age of the high terrace is indirectly specified as the period after the retreat of the San 2 ice-sheet, which, in its maximum extent, covered the margin of the Carpathians and entered the San valley. The evidence for this terrace age may be the lack of till within its limits and the sporadic presence of Scandinavian rock gravel in the secondary deposit in the alluvial cover of the terrace (Łanczont 1991a, 1993). The rock socle of the terrace is situated at approx. 35–37 m above the San riverbed and is covered by a thin layer of alluvial deposits. Two main complexes of silt deposits, which correspond to the older loess representing the Odra (=Drenthe) and Warta (=Warthe) Glacials and the younger loess from Vistula (=Weichselian) Glacial were distinguished in the profile (Fig. 1). The lower loess series is represented by loess-like bog-alluvial deposits 3.5 m thick, with erosion hiatuses in the middle and upper strata. Redeposited remains of Lublin (=Rügen) (?) paleosol occur on the denudation surface. The series of deluvial loess-like deposits representing Warta Glacial contains a rich inventory of deposition structures, which reflect the variability of sedimentation processes. The top part of the older loess bed comprises a pedocomplex consisting of forest soil and superimposed turf soil correlated with the Eemian Interglacial and Early Glacial on the basis of soil typology, and in particular on palaeobotanical analysis (Komar, Łanczont 2002). Thin strata of deluvial loess from the Early Vistulian and Lower-Middle Pleniglacial are to a large degree weathered and pedogenically transformed; at a depth of 3.15–4.15 m there are two interstadial soils partially destroyed by erosion processes and separated by a thin stratum of strongly weathered loess. It is only Upper Pleniglacial loess in this profile that has a nature of typical/proper aeolian loess and is relatively thick (>3 m).

THE PROFILE OF LOESS DEPOSITS IN DYBAWKA DOLNA NEAR PRZEMYŚL

It is a loess profile on the medium San terrace, the relative altitude of which is approx. 20–25 m. The top of exposure is 223 m a.s.l.; the San riverbed is situated at 196.7 m a.s.l. and the terrace height abo-

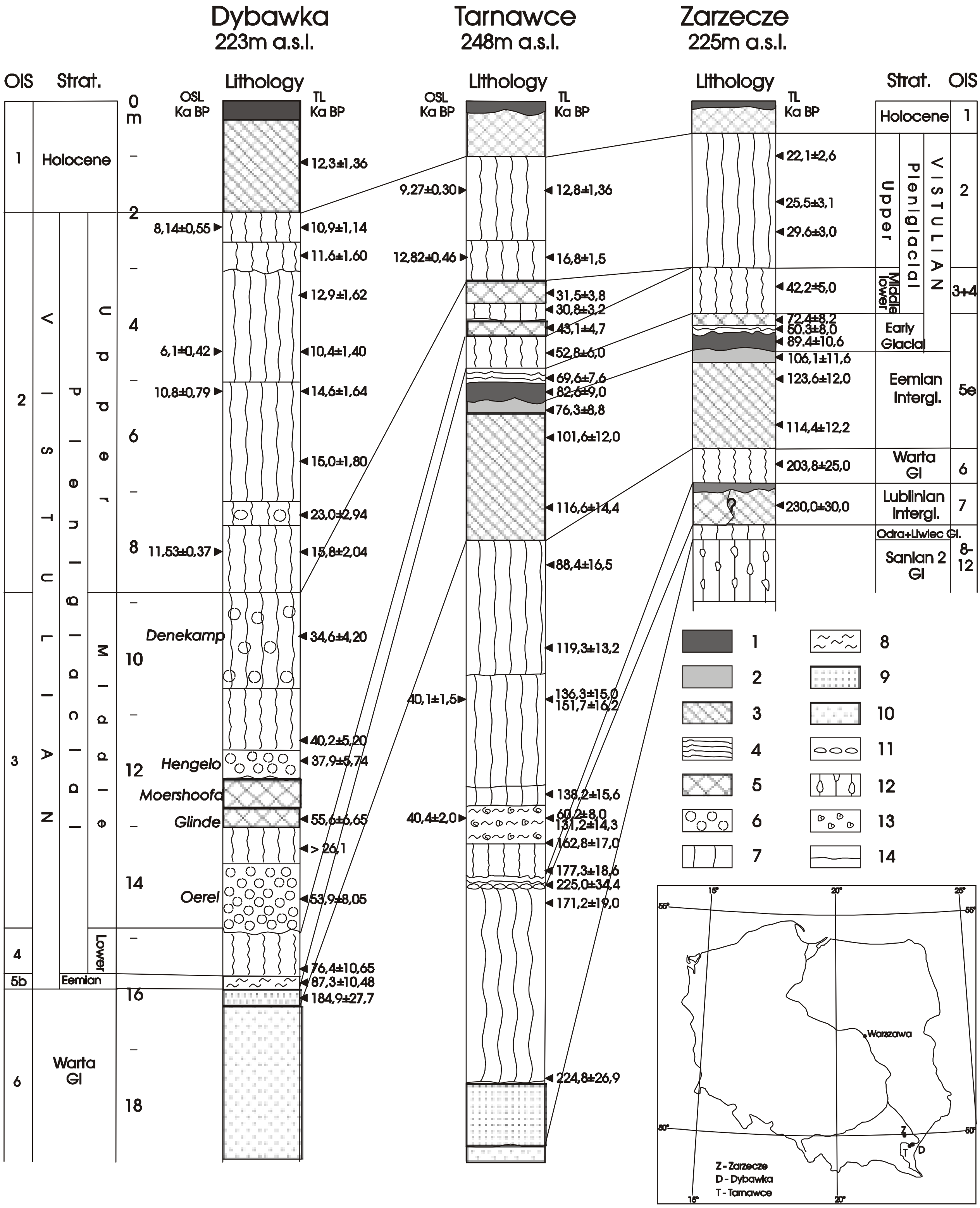

Fig. 1. Loess profiles at Dybawka, Tarnawce and Zarzecze.
Holocene soil and interglacial paleosol: *1* – humus horizon, *2* – eluvial horizon, *3* – illuvial horizon, *4* – soil deluvia, *5* – interstadial paleosols, *6* – gley signs, *7* – loess, *8* – muddy sand, *9* – sand, *10* – sand with gravel, *11* – debris cover, *12* – glacial till, *13* – molluscan shells, *14* – erosion boundary
1 pav. Liosų profiliai prie Dybavkos, Tarnavce ir Zarzeče

ve the riverbed is 26 m in the profile under examination. It is a new unpublished profile; however, the loess that covers this terrace was identified earlier (Łanczont, 1991) in the exposure located at a distance of approx. 0.3 km downriver. The two profiles are similar in many respects, but the one examined earlier includes loess deposits of Early Vistulian together with the boggy soil topping them, and the loess thickness is lower in this profile.

The stratigraphic interpretation of the newly discovered profile was based on the lithologic features, analysis of paleosols and in correlation with the adjacent loess profiles, which are described in detail (Łanczont 1994, 1997). In our profile loess is separated from the Flysch rock socle located at an altitude of *ca*. 4 m above the San level, with alluvia in the form of a thick gravel series and a thin sand stratum – the deposits most probably from the period of Warta Glacial. There are no deposits from the Eemian Interglacial (stratigraphic hiatus), which may be explained as a result of the active deep and lateral erosion that took place in the final phase of the Eemian Interglacial (Łanczont 1994). Thin alluvial muds lying on Warta sands belong to the Early Vistulian. In the lower part of the silt series there are several weakly developed tundra gley paleosols, which most probably represent interstadials of the Middle Vistulian. Above it there is an 8-meter loess layer from the Upper Pleniglacial; it is internally differentiated as regards structural loess features. These are very typical carbonate loesses, which contain 40–50% of the 0.05–0.02 mm fraction. At a depth of 7.5 m there is a horizon of initial pedogenesis, which points to the poor tundra vegetation and provides a basis for the separation of two stratigraphic subunits of the Upper Pleniglacial loess. In light of the foregoing facts and dating results, it may be supposed that the highest intensity of loess accumulation took place at the end of this period. Furthermore, from simple calculations we conclude may that the maximum accumulation rate might have reached even 2 mm/year; hence, it was twice as high as in the case of loess in Central Poland Uplands (Maruszczak 1991).

THE PROFILE OF QUATERNARY DEPOSITS IN ZARZECZE NEAR PRZEWORSK

It is located next to the active brickyard situated in the northern outskirts of this village by the road to Przeworsk. It is the central part of the Kańczuga Plateau.

The profile is built of two basic deposit components: loess and glacigenic sediments. The loess part of the profile was presented by Laskowska-Wysoczańska (1991). The TL dating results provided in her publication and conducted in the Warsaw laboratory are controversial, also for the author herself. In 1999 Malata and Wójcik discussed the sub-loess part of the profile, and Łanczont et al. (2000) made an attempt to date the deposits in the entire profile by the TL method; under- and overmoraine deposits were dated by J. Kusiak at the laboratory of the Department of Physical Geography and Palaeogeography at the Maria Curie-Skłodowska University in Lublin.

At present, luminescence examination covered the upper, loess part of the profile, nearly 8 meters thick. The key horizon is the Eemian – Early Glacial pedocomplex at a depth of 4.1–6.15 m. The most important element of this soil is a well-developed illuvial horizon 1.5 m thick, an evidence of interglacial forest soil. The humus horizon, which is above illuvium, is most probably a superimposed layer and related to pedogenesis, which took place in woodless, steppe conditions in the Earliest Vistulian. Under this soil there is a stratum of loess-like deposit, *ca*. 1.5 m thick, separated by two-horizon brown earth soil. It is either weakly developed interglacial soil or interstadial soil. It is very difficult to specify the stratigraphic position for this soil, especially that TL dates obtained for sub-Eemian deposits in the Lublin and Gdańsk laboratory are discrepant. Previously this soil was interpreted as a result of interstadial pedogenesis (?) from the San 2 (=Elstera 2) Glacial, although it was not possible to rule out that it is related to the younger or older part of the so-called Great Interglacial (=Holstein) (Łanczont et al. 2000). The current results suggest that the soil is related to the Lublin Interglacial.

The loess that covers the Eemian-Early Glacial pedocomplex, is not very thick and signs of stratigraphic differentiation are not very visible. However, it is worth noting that the paleosol at a depth of 3.75–3.95 m, which is considerably destroyed by slope processes, may be most probably linked to the younger interstadial within the Early Vistulian. Above it there is clayey loess; its features point to an accumulation in tundra conditions of a cold but not extremely dry climate, which was predominant in the first phases of the Upper Pleniglacial. No youngest layers were identified in the profile. It is very likely that they were removed during the increased erosion and denudation phase in the Late Vistulian, caused by permafrost degradation. Loess covers were cut in areas of a high relief, even before they were fixated by the vegetation (Maruszczak 1991).

DISCUSSION

TL and OSL dating results may be analysed from two points of view. The first issue is how the previous geological surveys and basic studies verify the luminescences dates. Which analyses confirm the current knowledge about the profile examined? Which test results are erroneous in light of our current knowledge?

The second issue concerns the answer to the question what information was provided by simultaneous TL and OSL measurements.

The literature contains very few examples of interlaboratory comparisons of dating results. There are few comparisons of radiometric dating and very few comparisons regarding luminescence measurements (Bluszcz 2000). It should be borne in mind that TL dating results have been available in the literature for 30 years. There are several dozen thousands of these results. Results of the newer method (OSL) started to appear in the literature slowly. Up till now there is a lack of relation between these luminescence methods.

The comparative results of TL and OSL methods apply to the Dybawka (DA) and Tarnawce (TA) profiles. Nine samples were collected from the profiles. The same material was dated by both methods (first TL, next OSL). Comparative results are shown in Table, which served as a basis for the preparation of the figure TL = f(OSL) (Fig. 2).

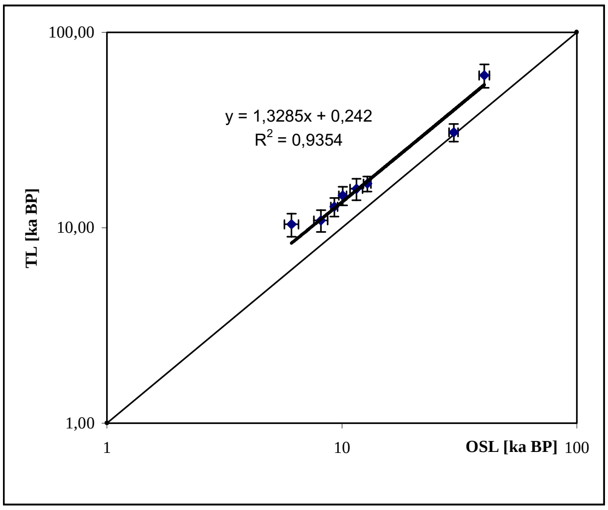

Fig. 2. Methodical intercomparison of TL and OSL dates
2 pav. TL ir OSL datų metodinė koreliacija

Table. **Results of TL and OSL dating**
Lentelė. **TL ir OSL datavimo rezultatai**

Sample	Lab. No UG	TL age (ka BP)	Lab.no GD TL	OSL age (ka BP)
TA–1	5666	12.6 ± 1.40	727	9.27 ± 0.30
TA–2	5667	16.6 ± 1.50	728	12.82 ± 0.46
TA–4	5669	30.8 ± 3.20	729	29.9 ± 1.5
TA–14	5679	136.3 ± 15.00	725	40.1 ± 1.5
TA–16	5681	60.2 ± 8.20	726	40.4 ± 2.0
DA–2	5688	10.9 ± 1.14	719	8.14 ± 0.55
DA–5	5691	10.4 ± 1.40	744	6.10 ± 0.42
DA–6	5692	14.6 ± 1.64	723	10.08 ± 0.39
DA–9	5695	15.6 ± 2.04	724	11.53 ± 0.37

Figure 2 does not include TA–14 and TA–16 results due to the insufficient protection of samples against light. These samples were collected again in the field and dated only by the TL method.

The following observations may be made from Fig. 2:

– All TL dates are older than OSL dates

– TL and OSL dating results of the oldest samples differ significantly (results of the oldest sample were not even presented in Fig.)

– seven dating results of the youngest samples are very similar for both methods

– comparative results of the 7 youngest samples clearly go parallel to the straight line. With the larger number of results, this fact may lead to the determination of the correlative coefficient between the methods for loess samples and perhaps for all types of deposits

– the age when a given stratum was formed should be determined by the youngest TL and OSL dates, since they indicate the moment of the last exposure to light.

Examinations of single portions with the OSL methods often show grain heterogeneity due to the energy accumulated in such grains. For this reason individual portions sometimes give a large dispersion of results. The laboratory that has conducted OSL dating considers the age of the youngest portions to be the final result and this result is reflected in Fig. 2. The OSL laboratory also specifies the age of the remaining older portions. In the case of Dybawka and Tarnawce profile samples, it was also noted that the portions examined showed an older age than Table did.

CONCLUSIONS

All samples measured by the OSL method and showing a younger age than TL also included older samples that gave identical results in both methods. In the Tarnawce profile the TL age of the Warta deposits was younger than expected by more than 100 ka. Warta deposits were represented in the profile by seven samples. Two floor samples of Warta deposits had a lower TL age than Eemian soil samples, which were situated higher. It is likely that soil processes had an impact on the younger age of these samples. The younger age of the samples may be also explained by addition of a younger material, which might have been provided by the activity of underground animals; however, sample collectors did not notice any such traces, possibly because of the wrong collection or inappropriate protection of samples. As already noted, the latter required re-collection of TA–14 and TA–16 samples and their new TL dating.

It should be noted that the TL method is less precise and the technique of a large number of portions usually gives an averaged result for all grains examined. Thus, in most cases the TL age is older than the OSL age.

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LIOSŲ AMŽIUS PRIE DYBAVKOS, TARNAVCE IR ZAŽEČE (PR LENKIJA), NUSTATYTAS TERMOLIUMINESCENCIJOS METODU

S a n t r a u k a

Straipsnyje pateikti rezultatai trijų Karpatų ir Perikarpatų liosų pjūvių, esančių PR Lenkijoje. Apžvelgus ankstesnių tyrimų medžiagą, analizuojami liosai, susiję su dviem glacialiniais ciklais – Vartos ir Vyslos apledėjimais. Termoliuminescijos metodu buvo datuoti 52 mineralogeninių ir dirvožemio nuogulų mėginiai. Devyniems mėginiams atliktas palyginamasis datavimas termoliuminescencijos ir optiškai stimuliuotos liuminescencijos metodais. Galima spėti, kad skirtingais metodais gauti rezultatai priklauso nuo panaudotos formulės, kuri nustatoma iš interpoliacinės kreivės. Tam tikslui reikalingas didesnis rezultatų skaičius.

Мария Ланчонт, Станислав Федорович

ВОЗРАСТ ЛЕССОВЫХ ОТЛОЖЕНИЙ В РАЗРЕЗАХ ДЫБАВКА, ТАРНАВЦЕ И ЗАРЖЕЧЕ (ЮВ ПОЛЬША) ПО ТЕРМОЛЮМИНЕСЦЕНТНОМУ ДАТИРОВАНИЮ

Р е з ю м е

Представлены результаты исследований трёх профилей с карпатскими и перыкарпатскими лёссами, расположенными в Юго-Восточной Польше. Обобщены имеющиеся сведения по изученным отложениям. Учтены отложения двух последних гляциальных циклов, т. е. оледенений Варты и Вислы. Датированы образцы минералогенных и почвенных отложений. Представлены 52 даты по TL. Для 9 образцов проведено сравнительное датирование (TL и OSL). Полученные данные позволяют предположить, что существует зависимость, которую можно выразить формулой, используемой при датировании разными люминесцентными методами. Формула эта будет вытекать из интерполяции кривой. Достоверная интерполяция возможна при большем количестве результатов датирования разными методами.