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TL DATING OF YOUNG AEOLIAN DEPOSITS FROM KĘPA KUJAWSKA

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Abstract—We report the results of thermoluminescence (TL) dating applied to sand samples from the dune in Kępa Kujawska, Poland. The emphasis is on the estimation of the residual TL. The tests for bleaching of natural TL with the use of daylight and a bleach simulator were carried out. From the results it follows that the residual TL is a significant part of the natural TL. The equivalent doses were determined by the regeneration method with the residual TL assumed as a starting level. The annual doses were calculated by means of gamma spectrometry. The ages of the bottom and top layers of the dune are 10.6 ka ± 2.4 ka and 2.1 ka ± 0.6 ka, respectively.

1. INTRODUCTION

In the thermoluminescence (TL) method of absolute dating natural radioactivity acts as a pacemaker while the TL signal serves as a counter. The age determined this way is counted from the time of the last erasure of the accumulated TL (Aitken, 1985). In case of geological deposits, daylight bleaching can play a part in resetting TL acquired prior to the deposition (Singhvi *et al.*, 1982; Jungner, 1988). Optical bleaching is a rather complicated process, especially in quartz (Bøtter-Jensen *et al.*, 1995; Bailey *et al.*, 1997; Franklin, 1997). The assumption of absolute reset of natural TL can lead to an overestimation of the actual age if any part of natural TL, the so-called residual TL, remains. In an attempt to involve specific bleach-ability of minerals and incomplete reset of natural TL several methods have been developed (Wintle and Huntley, 1980; Mejdahl, 1985; Morris and McKeever, 1993). However, the influence of bleaching on natural TL by daylight illumination at the time of deposition still remains one of the most serious sources of uncertainty in the TL dating of sediments.

2. EXPERIMENTAL PROCEDURE

The dune in Kępa Kujawska near Toruń was chosen for investigations. The petrographical analysis performed for all sedimentation layers indicates that the percentage of quartz is unusually high, always exceeding 90% (Lankauf *et al.*, 1996). The grains of dimensions between 100 and 120 μm were extracted. Further separation procedure was applied depending on feldspar content. In particular, the sample from 1.1 m deep layer was first washed in 40% H_2O_2 for 24 h, 4% HF for 48 h and than washed in 5% HCl and distilled water. The material from a 7.0 m deep layer was additionally separated in heavy liquids and etched in 40% HF for 40 min to remove the outer layer of grains.

The stimulated luminescence from quartz prevails over feldspar in the material selected for the study. The trap distribution, measured by FGT (see Pietkun and Oczkowski, 1994; Chruścińska *et al.*, 1996) and the very low value of IR/green OSL ratio support this. Every glow curve presented in this paper is the average of at least four independent measurements on 15 mg sample aliquots each. All TL measurements were made on an automated RISØ System (model TL/OSL-DA-12) filtering the emission with a 2.5 mm U-340 filter (Bøtter-Jensen and Duller, 1992). Before read-out of every glow curve the temperature of 240°C was kept for 20 s. The Sr-90/Y-90 β source from the System was applied for regenerative and additive dose irradiation.

The annual dose rates were determined on the basis of high-resolution gamma spectra obtained with the use of Canberra System 100 spectrometer with shielded HPGe detector (type XtRa—GX1520) and Sampo 90 software. The specific activity of isotopes in investigated samples (of about 0.5 kg) allows one to calculate the partial matrix doses for α, β and γ radiation. On the strength of that, the specific dose rate responsible for the natural TL of quartz can be finally calculated. This procedure, which will be published separately, takes account of moisture effects, the depth of sedimentation layer and etching procedure applied.

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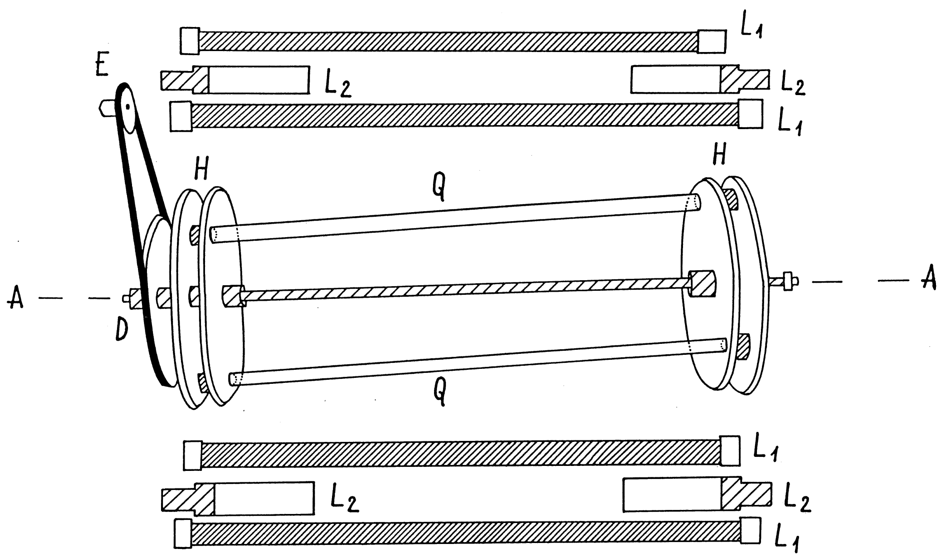

Fig. 1. The bleach simulator: E—electric motor, D—driven wheel, A—axis of rotation, Q—quartz tube, H—tube holder, L_1—UV lamp, L_2—"white" lamp.

The bleach simulator was constructed to imitate the conditions of deposition in laboratory. It provides not only exposure to light for the purpose of bleaching, but at the same time, it forces sample grains to roll, similarly as natural agents (e.g. the wind) do with dune sand. The whole device, seen in Fig. 1, is kept inside a white box. The light source consists of four Philips "white" lamps (type PL-electronic/c, 23 W) and four TLD 18 W/08 UV lamps.

The samples are put into 1.5 mm thick quartz tubes of diameter 21 mm. Two ends of such tubes are fixed into holes situated on the opposite solid wheels. The holes are shifted a little, hence the tube is tilted in relation to the axis "A" in Fig. 1. While the tubes are revolving around this axis, the grains of a sample inside roll back and forth. The lamps are fixed symmetrically above and below the tube holder.

The spatial averaging spectrum of the simulator is shown in Fig. 2. It was measured in the range of 350–850 nm with S1000 Fibre Optic Spectrometer (Ocean Optics Inc.) and the absorption due to the quartz tube is included. The comparison of the simulator output to the daylight standards of The American Society for Testing and Materials (ASTM E892) is presented in the form of a histogram in Fig. 3. As it can be derived from the histogram, our

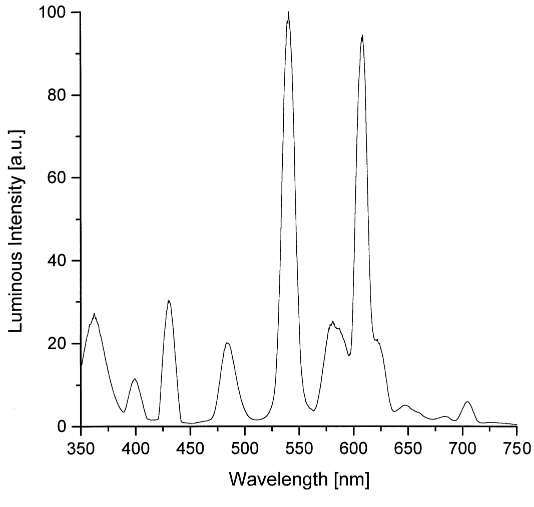

Fig. 2. The spectrum of the bleach simulator.

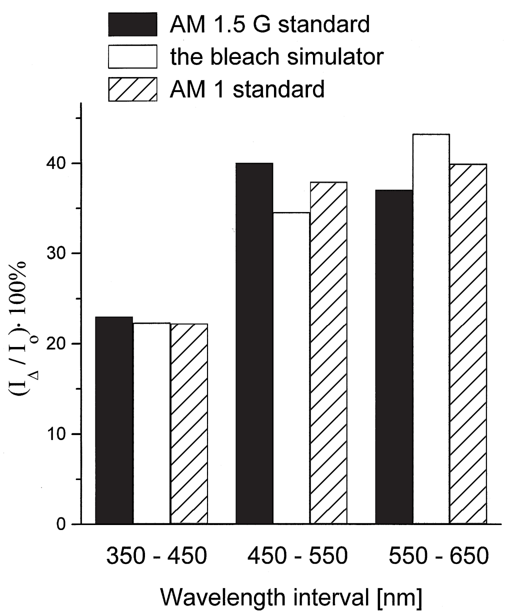

Fig. 3. The ratio of the irradiance in wavelength intervals (I_Δ) to the total irradiance in 350–650 nm region (I_o) for the bleach simulator and daylight ASTM standards: AM 1.5 G—global and AM 1—direct solar radiation.

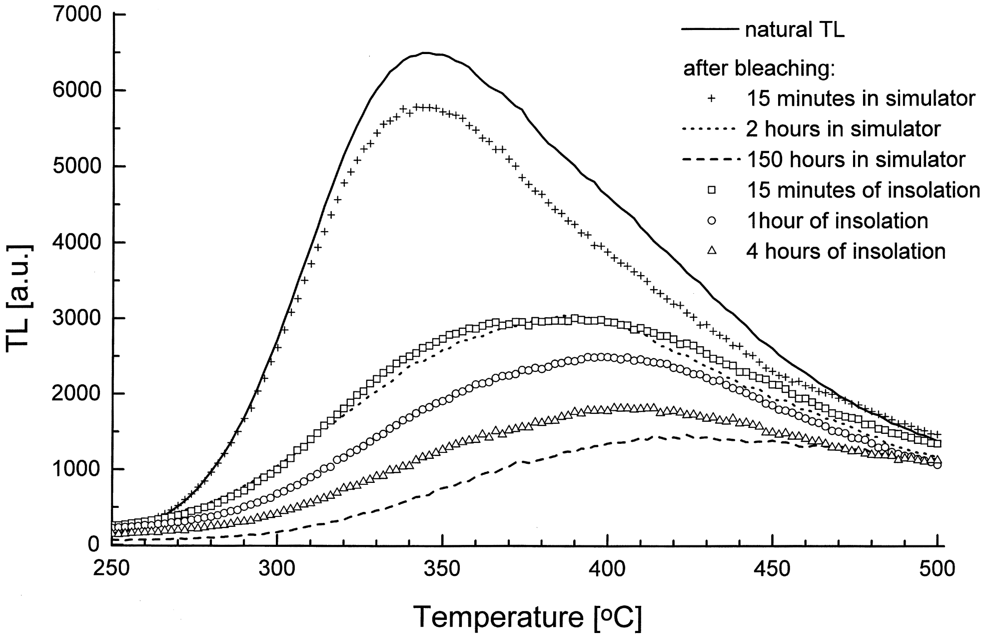

Fig. 4. The glow curves related to the natural TL and TL remaining after optical bleaching. The experiments were performed on the material from the top layer of the dune (1.1 m). The heating rate was 10°C/s.

simulator gives quite satisfactory imitation of the daylight in the range of 350–650 nm. Most of the power density of global radiation (including direct solar radiation, diffuse and reflected) at the Earth's surface is contained in this range.

For absolute irradiance measurements a Radiant Flux Meter with multijunction thermopile (Hewlett-Packard, model 8330A/8334A) was applied. It is characterised by a flat (±3%) spectral response from 300 to 3000 nm and 0.1 srd solid angle. Inside the bleach simulator the value of 1.3 W/m^2 was obtained. The irradiation due to direct solar light measured in Toruń on a sunny day close to autumnal equinox reached 130 W/m^2 at noon. At the

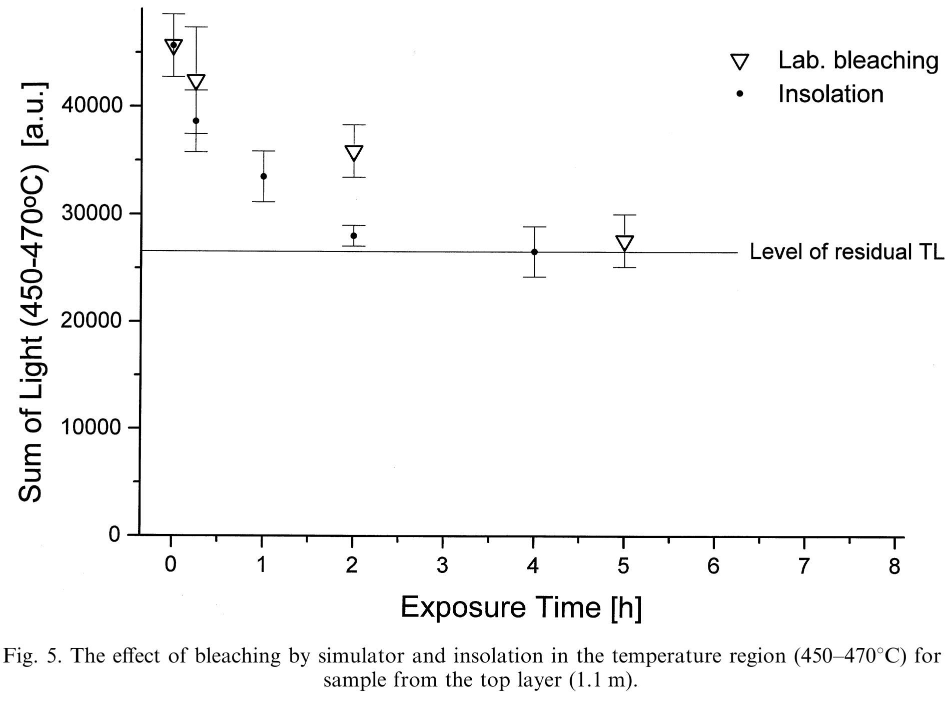

Fig. 5. The effect of bleaching by simulator and insolation in the temperature region (450–470°C) for a sample from the top layer (1.1 m).

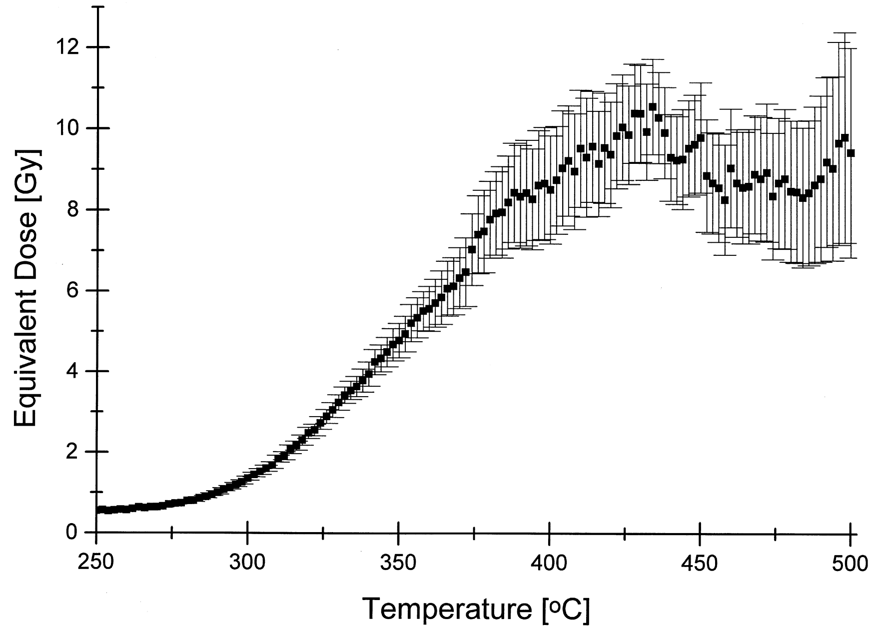

Fig. 6. The plateau test for a sample from the top layer (1.1 m).

same time, the irradiation related to the diffuse part of solar light was 1.2 W/m^2. Hence, the output of the simulator approximates the diffused solar radiation.

3. RESULTS AND CONCLUSIONS

In a previous paper (Lankauf *et al.*, 1996) we mentioned the problem of absolute dating of aeolian deposit from Kępa Kujawska. The residual TL was one of the reasons suspected for a surprisingly high level of estimated equivalent doses. Therefore, the bleaching properties of the material were the main subject of our investigation.

The samples were insolated during sunny summer days, about noon, by exposing them to direct solar radiation. The prolonged bleaching with the simulator was also performed. Figure 4 gives the comparison of the laboratory and natural bleaching effects on the natural TL. The sum of light was determined by the integration of glow curve in the temperature region of interest. Figure 5 presents the

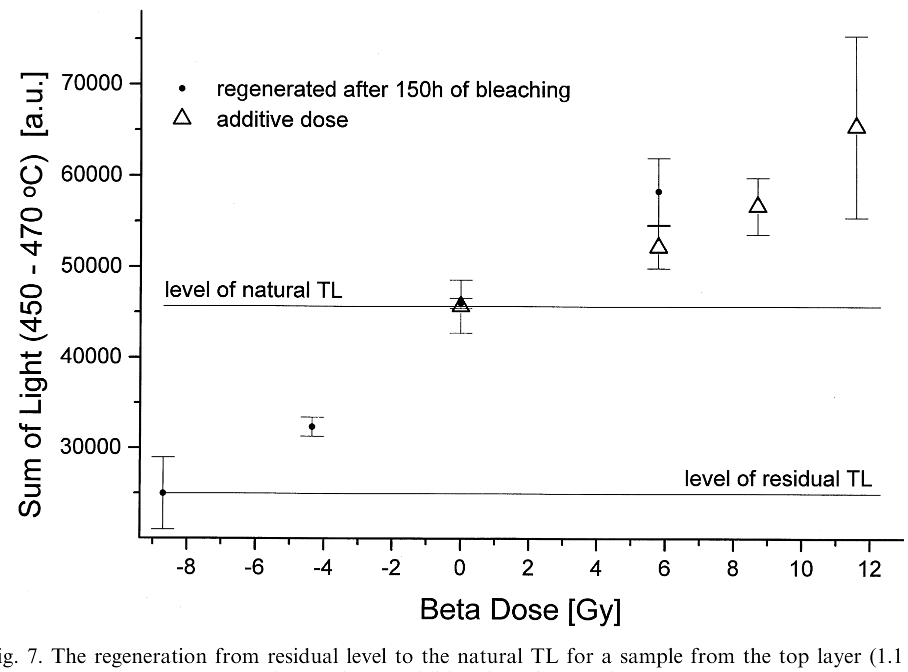

Fig. 7. The regeneration from residual level to the natural TL for a sample from the top layer (1.1 m). The TL due to additive doses is also shown.

Table 1. Results obtained for investigated samples

Sample depth (m)	Temperature range (°C)	Integrated TL (a.u.) natural	residual	Equivalent dose (Gy)	Dose rate (mGy/a)	Age (ka)
1.1	450–470	45,700	26,600	8.7 ± 1.5	4.2 ± 0.5	2.1 ± 0.6
7.0	370–426	94,400	40,300	18 ± 2	1.7 ± 0.2	10.6 ± 2.4

dependence of the sum of light calculated for 450–470°C range on the time of bleaching. As it is seen, the bleaching due to direct solar radiation is more rapid, but both solar and laboratory bleaching seem to approach the same level. Henceforth, the TL remaining after 150 h of bleaching in the simulator was assumed to be the residual TL. This value was fixed as the starting level for the regeneration method. The plateau test is presented in Fig. 6. On this basis, the temperature region for further analysis was chosen.

The growth curve due to regeneration from residual TL is presented in Fig. 7. The equivalent dose is determined by linear regression applied to this dependence. More precisely, the equivalent dose is equal to the absolute value of abscissa at which the regression line intersects the level of residual TL. As it follows from Fig. 7, the equivalent dose is that dose which rebuilds the natural TL. Table 1 presents levels of natural and residual TL obtained for the shallow (1.1 m) and for the deep (7.0 m) layer of the dune. After the determination of equivalent dose and radioactivity dose rate the age was calculated. The overall error in the data given in the last column of Table 1 includes the uncertainty in radioactivity measurements. The dates are consistent with geographical knowledge about the dune and, moreover, the result obtained here for the top layer is supported by C-14 dating (Pazdur, 1997).

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