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BETA SOURCE CALIBRATION FOR THERMOLUMINESCENCE DATING

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Abstract. The results of calibration of the dose rate from the beta source, incorporated in the RISØ TL/OSL SYSTEM TL-DA-12, are presented. The quartz grains, separated from sediments by a typical procedure applied for thermoluminescence (TL) dating were used as a dosymetric material. The stability of thermoluminescence sensitivity of the material was achieved by the sequence of irradiating and the subsequent annealing of the grains. The calibrated ^{60}Co and ^{137}Cs sources were applied for irradiation with reference gamma doses. The calibration performed in January 1998 confirms the result obtained in 1996 with respect to the decay of activity of the beta source in the meantime.

1. INTRODUCTION

The $^{90}Sr/^{90}Y$ beta radiation source (Amersham) is incorporated in Risø TL/OSL reader system, model TL/OSL-DA-12 (Bøtter-Jensen and Duller, 1992). The source is covered by a lead shield. The irradiation of the sample is controlled by the mean of a pneumatic mechanism, which turns the source to the position directly above the sample. The delay time is ca. 0.04 s. The allowed irradiation time excess from 1 s to 10,000 s. The diameter of sample holders, made from nickel, equals 8 mm. On 13 August 1995 the nominal activity of the source was 1.48 GBq.

The beta dose rate of the source, corresponding to the used material and appropriate method: thermoluminescence (TL) or optically stimulated luminescence (OSL), have to be determined for dating purposes (Murray and Wintle, 1979; Bluszcz and Bøtter-Jensen, 1993; Göksu *et al.,* 1995). The dose rate is the ionising radiation energy absorbed per unit mass of the sample in a period of time. Hence TL reader accompanied by a calibrated source enables to obtain the paleodose of a given sample.

2. EXPERIMENT

Altogether six independent measurement series were carried out to calibrate the dose rate of the source for quartz grains. Glow curves were recorded in argon atmosphere with the heating rate of 10 °C/s. The optical filter U-340, with thickness of 5 mm, was used (Bøtter-Jensen and Duller, 1992). The TL intensity, corresponding to established beta dose, was averaged from at least four single glow curve measurements. For each series the plateau test was performed and on this base the temperature region was chosen. The TL sensitivity was stable in the range of ±5%.

The regeneration method was applied for determining the Sr-90 dose rate. At the beginning, the beta dose was established as a time (in seconds) of irradiating the sample. The dose D_β, which was equivalent to the known gamma dose D_γ, was derived from the TL growth curve. The ^{90}Sr dose rate $\check{D}$ was calculated according to the formula (1):

$$\check{D}\,[\mathrm{mGy/s}] = D_\gamma\,[\mathrm{mGy}] \,/\, D_\beta\,[\mathrm{s}] \qquad (1)$$

The first calibration measurements were carried out in 1996. The quartz grains, in size from the range of 100-200 mm, separated from geological deposits were used. The material, from now on denoted as R1, was supplied by the Risø National Laboratory in Roskilde (Denmark) as two samples. The first one was quartz just only heated in the temperature of 500°C. The other sample was additionally irradiated by a gamma Co-60 source, with absorbed dose equal to 17,2 Gy. From two separate measurement series following values of the ^{90}Sr dose rate were determined: (59.1±4.1) mGy/s and (56.4 ± 5.2) mGy/s (Przegiętka, 1996).

Next calibration with the use of the same material, R1 – provided by the RISØ – was performed in January 1998. Two sets of experimental data were obtained. On the base of linear regression, applied to the growth curve in each case separately, two values of the beta dose rate were calculated: (55.5±5.4) mGy/s and (59.3±5.1) mGy/s.

Since 1996 above 30 geological samples collected from quaternary fluvio-glacial sediments and dune (Oczkowski and Przegiętka, 1998) were dated by our Laboratory. The routine procedure was applied for separate quartz grains from geological deposits. Two grain fractions of diameters: 125-150 mm and 150-300 mm were extracted. Then, they were cleaned in 10% solution of HCl and 30% H_2O_2. The floating method was applied to select grains of density between 2.62 g·cm^{-3} and 2.70 g·cm^{-3}. Finally, the material was etched for 40 minutes in 40% solution of HF. Hence, the remaining part of plagioclases was removed and the outer layer of quartz grains (in thickens of ca. 30 mm) was etched.

In January 1998 the collected quartz, henceforth denoted as D1, was used for calibration of the beta source. Firstly, the TL sensitivity of quartz D1 was stabilised using method proposed by Correcher and Delgado (1998). The grains in amount of (20±1) mg were put on the sample holders and irradiated with beta source for 2000 s, corresponding to the dose of ca. 100 Gy. Then, the quartz was heated in oven (in the air) in the temperature of 550°C for 30 minutes. It was checked, that heating completely erased the TL energy from the quartz.

After that, the material was divided into three parts. The first one of 700 mg was reserved for beta irradiation. Two other portions, each of 350 mg, were assigned to get two reference gamma doses. These samples were exposed to the calibrated ^{137}Cs gamma source (with activity of 130 GBq) at Institute of Nuclear Physics in Cracow. The quartz grains were regularly distributed in black, rectangular boxes, made of Plexiglas, with 3 mm thick faces. Estimated thickness of quartz layer was ca. 0.25 mm, which is equivalent to 2-3 monolayers of grains. The doses were measured by applying the ionising chamber and expressed as KERMA in the air: 0.534 Gy and 1.583 Gy. Taking into account the mass energy-absorption coefficients related to gamma lines from ^{137}Cs source: 0.0293 cm^2·g^{-1} and 0.0300 cm^2·g^{-1} respectively for quartz (Aitken, 1985) and the air (Turner, 1996) the factor 0.97 was obtained for calculating doses absorbed in the grains. Hence, the reference gamma doses were: 0.518 Gy and 1.536 Gy respectively.

The TL measurements, as well as irradiation with beta regenerative doses, were performed on amount of (15±0.2) mg quartz grains, uniformly scattered on the sample holders. For average grain diameter of 0.1 mm, it corresponds to at least one monolayer. The dose rate of the beta source was (51.8±5.1) mGy/s and (46.6±2.8) mGy/s, calculated respectively for lower and higher gamma reference doses.

3. RESULTS AND CONCLUSIONS

The results of all calibration measurements are summarised in **Table 1**. The data obtained in 1996 were recalculated, due to decay of the ^{90}Sr activity in 18 month period, using following formula:

$$\check{D} = 0.964 \cdot \check{D}_o \qquad (2)$$

where:
$\check{D}$ is the dose rate in January 1998,
$\check{D}_o$ corresponds to the dose rate in August1996.

The average gives the final dose rate value for January 1998 equal to (54.1±4.6) mGy/a. The data from **Table 1** are presented on the plot in **Figure 1.** If one presumes 2 mGy/a as the common value of annual dose for quartz fine grains separated from geological deposits, then the beta dose rate of ^{90}Sr source corresponds to increase of the sample TL age of 27 years per 1 second of the irradiation (ca. 100 ka in one hour).

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Table 1. *Results of ^{90}Sr dose rate calibration, derived from TL regeneration method for quartz grains extracted from sediments. Samples are denoted as: R1-quartz obtained from Riso, D1-quartz separated for dating purposes in Toruń Laboratory.*
**) The decay of the beta source activity (since August 1996 to January 1998) was taken into account (Przegiętka, 1996).*

No.	Date	Sample/ dose/ [Gy]/ radiation source	Preheat [°C/s] range [°C]	Temperature	Aliquots [mg]	Dose rate [mGy/s]
1	Aug.1996	R1/17.2/^{60}Co	220/40+290/10	385-421	7±0.3	57.0±4.1
2	Aug.1996	R1/17.2/^{60} Co	220/40 run-one	458-489	10±0.3	54.4±5.2
3	Jan.1998	R1/17.2/^{60}Co	220/40	264-284	15±0.3	55.5±5.4
4	Jan.1998	R1/17.2/^{60}Co	220/40	330-360	15±0.3	59.3±5.1
5	Jan.1998	D1/0.518/^{137}Cs	220/40	376-400	15±0.3	51.8±5.1
6	Jan.1998	D1/1.536/^{137}Cs	220/40	376-400	15±0.3	46.6±2.8

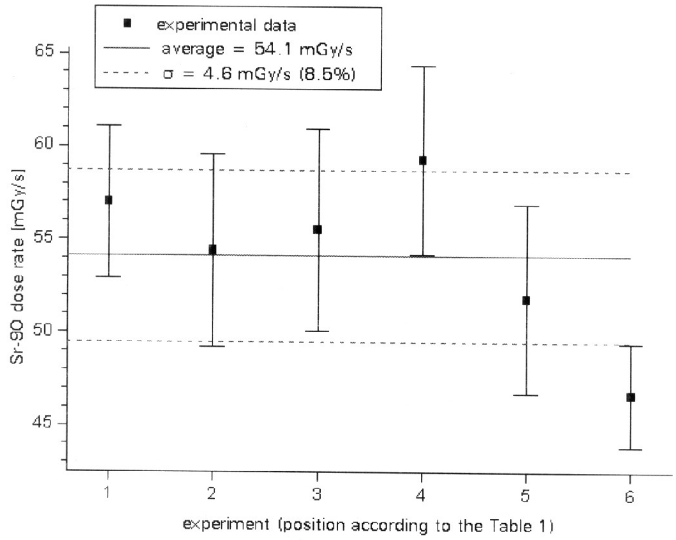

Fig. 1. *Presentation of the data set from the Table 1 and the average value of dose rate.*

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