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Dose-rate comparisons of sands for thermoluminescence dating

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Introduction

One of the important factors in thermoluminescence dating of sediments is the evaluation of the environmental dose-rate. However, it is not always possible either to carry out gamma spectrometry measurements in the field or to leave behind dosemeter capsules for collection at a later date. This is particularly true in remote areas or inaccessible regions where samples can only be obtained by taking cores. The latter can be caused by lack of natural sections in a flat terrain with high groundwater tables. Both these sampling situations also preclude the collection of large samples which are sufficient for gamma spectrometric measurements in the laboratory. Accurate knowledge of the gamma dose-rate is especially important for the dating of sand-sized quartz grains, because of low internal dose-rates. As a precursor to future sampling in regions where such difficulties are foreseen, we embarked upon a TL study of eolian sand from the Lutterzand region in the eastern part of The Netherlands, where natural sections on the banks of the river Dinkel enabled sampling of ample material. This was undertaken as part of a collaborative EEC funded project.

One of the aims of this paper is to compare the β dose rate, as measured by Thick Source Beta Counting (TSBC) developed by Sanderson (1988) with the β dose measured by β counting using the GM Multicounter Systems (GMC) developed by Bøtter-Jensen and Mejdahl (1985, 1988). These dose rates can then be compared with those predicted as a result of laboratory gamma spectrometer measurements (GSPEC) made on larger samples.

A second aim of this study is to compare the infinite-matrix gamma/beta dose-rate ratios, obtained by direct measurement of the dose rates using GSPEC and TSBC, for samples from one profile which spanned a time range of about 12 ka. A third aim is to compare these data with those obtained by thick source alpha counting (TSAC) and atomic absorption spectrometry (AAS) on subsamples.

Experimental Method

TSBC and TSAC were carried out in Cambridge, GMMC and GSPEC in Risø and AAS in Amsterdam. TSBC measurements were carried out on 30 g of dried sample. TSAC was performed on about 5 g of dry sample; measurements were made on both finely crushed (less than 45 μm) and uncrushed sand grains. GSPEC was measured on samples of about 500 g containing their natural water content of less than 5% for all samples. GMMC measurements were made on 1 g of dry sample (Bøtter-Jensen and Mejdahl, 1988). AAS was carried out on 100 mg samples.

Results

Table 1 gives the results of the TSBC measurements with counting errors of ±0.004 and resulting β dose rates using a calibration factor of 1.949 mGy.a^{-1} /cps, a standard of Shap granite and a background MgO. The dose-rate values can be compared with those obtained by GMMC and from the GSPEC K, U and Th contents using the conversion factors from Nambi and Aitken (1986). The data is presented in stratigraphical order - sample 6 is the youngest and sample 1 is the oldest. Two sets of samples were measured and shown as OLD and NEW respectively. The NEW samples were collected at the same depth in the section as close as possible to the OLD samples.

The mean of the β dose rates, using the three methods on the NEW samples, has a standard deviation of about 6% which is probably related to sample inhomogeneity as reflected in the different subsamples for the methods used. The methods show relatively good agreement and no systematic difference between the methods.

Alpha counting was only carried out on the OLD samples. For all except two samples crushing to less than 45 μm grains resulted in a reduction of the α count.

Table 1. Results of various radioactivity measurements.

Sample	TSBC cts/s. 38.3cm²	TSBC Gy/ka	α-count cts/ks.cm²	α-count cts/ks.cm²	Ratio α-count crushed/uncrushed	%K2O
OLD L6	0.429	0.838	0.225	0.141	0.63	0.80
L5	0.454	0.884	0.154	0.155	1.01	0.86
L4	0.454	0.884	0.154	0.155	1.01	0.86
L3	0.421	0.823	0.265	0.139	0.52	1.01
L2	0.446	0.870	0.224	0.177	0.79	0.79
L1	0.557	1.086	0.477	0.273	0.56	1.19

Table 1 contd.. Results of various dose-rate measurements.

Sample	TSBC β dose-rate Gy/ka	GMMC β dose-rate Gy/ka	GSPEC β dose-rate Gy/ka	Mean β dose-rate Gy/ka
NEW L6	0.717	0.76	0.69	0.72 ±0.02
L5	0.777	0.65	0.66	0.70 ±0.04
L4	0.917	0.80	0.80	0.84 ±0.04
L3	0.927	0.75	0.73	0.80 ±0.06
L2	0.682	0.76	0.66	0.70 ±0.03
L1	0.966	1.09	0.94	1.00 ±0.05

Table 2. K_2O, U, and Th contents from GSPEC, and calculated γ dose-rate and predicted α-counts for these values

Sample	K_2O %	U ppm	Th ppm	γ dose-rate Gy/ka	Calc. α-counts cts/ks.cm²	Ratio α-counts crushed/calculated
NEW L6	0.84	0.55	1.45	0.31	0.119	1.18
L5	0.78	0.55	1.60	0.30	0.125	1.24
L4	0.95	0.70	1.75	0.34	0.149	1.19
L3	0.88	0.65	1.35	0.32	0.128	1.09
L2	0.78	0.55	1.80	0.31	0.132	1.34
L1	1.08	0.95	2.25	0.44	0.197	1.39

Table 3. γ and mean β dose-rates and their ratio.

Sample	γ-dose-rate, GSPEC	Mean β dose-rate	Dose-rate ratio
NEW L6	0.31	0.72	0.43
L5	0.30	0.70	0.43
L4	0.34	0.84	0.41
L3	0.32	0.80	0.40
L2	0.31	0.70	0.44
L2	0.44	1.00	0.44

Table 2 gives the GSPEC results for the NEW samples. This includes the isotope concentrations and the gamma dose-ratecalculated using the conversion factors of Nambi and Aitken (1986).

The mean ratio of the potassium contents obtained by ASS (in Table 1) and by GSPEC (in Table 2) is 1.06 ±0.07, which is reasonable given the factor of 500 in sample size. Table 2 also gives the α–count which is predicted by the U and Th content and this can be compared with the measured α counts given in Table 1. Even though the α counts were performed on the OLD samples, the gamma measurements should be representative of the bulk material from which they were taken. It appears that the crushed α count is more representative than the uncrushed α count, although there still is a systematic difference when compared with the predicted α count. This is represented by a mean ratio of 1.24 ±0.11 (Table 2).

Table 3 gives the ratio of the gamma dose-ratecalculated from the GSPEC (from Table 2) to the mean β dose-rate from Table 1. The mean of this ratio is 0.42 ±0.02.

Discussion and Conclusions

In spite of some scatter in the individual β dose-ratemeasurements TSBC appear to be an acceptable method of determining the β dose-rate for sand samples. Preferably three separate subsamples should be measured for each sample. Another possibility for measuring the β dose-ratewould be β TL dosimetry (Bailiff, 1982).

TSAC of either crushed or uncrushed grains does not give reliable measurements of the average U and Th contents. The fact that the crushed grains gave better results than the uncrushed material could point to the activity being concentrated on the surface of the grains. It may also be due to the presence of smaller grains containing U and Th falling to the ZnS screen. For instance some zircon grains might occur in the fine sand fraction of these sediments.

The consistency of the gamma/beta dose-rate ratio as shown in Table 3, suggests that within a limited geographical area and with homogeneous material , it would be possible to use the conversion factor to obtain the gamma dose rate. The error associated with this conversion factor is ±4% For the sands in the Lutterzand area the ratio was 0.42 ±0.02, but values of 0.33 ±0.03 may be calculated for six samples from sand dunes in Central Sweden (Lundqvist and Mejdahl, 1987) and 0.39 ±0.03 for the three sand samples from frost wedge casts in Jutland, Denmark. (Kolstrup and Mejdahl, 1986). The application of a particular dose-rate ratio is limited by the fractional contribution of ^{40}K to the natural radiation dose rate, The minimum value of the ratio is 0.30 for a sand containing no U and Th.

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