Ancient TL

www.ancienttl.org · ISSN: 2693-0935

Grün, R., 1987. *Alpha dose attenuation in thin layers.* Ancient TL 5(3): 6-8.
https://doi.org/10.26034/la.atl.1987.123

Alpha dose attenuation in thin layers

Rainer Grün*
Department of Geology, McMaster University, Hamilton, Ontario, Canada

When dating thin walled samples like foraminifera, terrestrial snails, or thin walled mollusc shells by TL or ESR it is sometimes not possible to remove the outer 20 µm in order to eliminate most of the volume being penetrated by α-rays from the matrix. Bell (1980) calculated a-dose attenuation curves for quartz grains based on formulas given by Charlton & Cormack (1962) which were tabulated by Howarth (1965).

The absorbed α-dose D_α at a depth x into a non-radioactive layer being irradiated by a radioactive infinite matrix (from one side = 2π-geometry) can be expressed by (Howarth, 1965):

$$D_\alpha = \frac{n_0 E_0}{m^s} \cdot G_\alpha \left[\frac{x}{R_0} \right]$$

where n_o is the number of α-particles with initial energy E_o and maximum range R_o. $G_\alpha(x/R_o)$ is a geometrical function which depends on the configuration of the interface of radioactive/non-radioactive bodies and the energy-range relation for α-particles; m^s is the ratio of the mass stopping powers of matrix over sample (in the following calculation = 1).

Howarth (1965) tabulated the values for P_α (the geometrical function for a plane interface) in steps of 1/100 R_0. In this paper, these values were numerically integrated for the α-decays occurring within the U- and Th-decay chains using maximum α-ranges from Aitken (1985: Tab. J1-J3) yielding average α-doses received by a volume of thickness x subjected to an α-emitter up to a thickness of 50 µm which corresponds to the maximum range occurring; that of ^{212}Po with an initial energy of about 8.8 MeV. The calculated values are shown in Table 1. For thicknesses above 50 µm a linear extrapolation can be carried out using the values for 50 µm.

However, as shown by Zimmerman (1971) although the energy loss of an α-particle increases as it slows down, the α-efficiency decreases. These effects led to the development of the *a* -value system (summarized by Aitken, 1985) in which it is assumed that the TL (and ESR) intensity along unit length of α-track is more or less constant. This system was experimentally confirmed for ESR by Lyons (1987). Therefore, it seems appropriate to apply the formulae from Aitken (1987).

Table 2 can be used to determine the average effective α-dose for TL or ESR age calculations, given a matrix with a homogeneous distribution of alpha-emitters such as clay or loess.

The values of the average α-doses in Table 2 are slightly lower than in Table 1. This raises the question about the validity of α-attenuation curves for grains as estimated by Bell (1980), who did not consider an *a* -value system.

In the case of terrestrial snails, which have typical shell thicknesses of about 45 µm the α-contribution of an average clay (3 ppm U; 9ppm Th; 1% K; k = 0.1; 4 π-geometry) is about 7.5% of the total external dose. With thicker samples it seems to be sufficient to remove the outer 20 µm in order to eliminate the influence of external α-irradiation, since this treatment removes the volume which contains 96% (^{232}Th-decay chain) to 100% (^{238}U to ^{230}Th) of the total external α-dose. As can be seen from Table 2 the α-attenuation within various the U-decay chains (^{235}U; ^{238}U to ^{230}Th; ^{230}Th to ^{206}Pb) is slightly different, which should be taken into account when considering U-series disequilibria. However, the uncertainties in the determination of the effective alpha efficiency (especially in ESR dating) and estimation of the precise thickness of a sample is normally much larger than these differences in α-attenuation.

Acknowledgements
I want to thank O. Katzenberger for checking the computer program and Dr. H. P. Schwarcz and Dr. J. M. Chadam for valuable comments on the manuscript and Prof. M. J. Aitken for a very lively discussion. Financial support was provided by NSERC.

* Now at: Subdept. of Quaternary Research, The Godwin Laboratory, University of Cambridge, Free School Lane, Cambridge CB2 3RS, England.

Table 1

Average α-doses (as percentage of the infinite matrix dose) for calcite samples with thickness x irradiated from one side (2π geometry) and infinite matrix doses (imd) for 1ppm U and Th (Nambi and Aitken, 1986). Density of calcite = 2.7 gm/cm3

Thickness x (μm)	^{232}Th-decay chain	U-series	^{235}U-decay chain	^{238}U - ^{230}Th	^{230}Th - ^{206}Pb
imd [μGy/a]	738	2781	124	555	2103
1	46.8	46.2	46.6	45.4	46.7
2	44.1	43.0	44.0	41.4	43.5
3	41.8	40.5	41.6	38.4	41.1
4	39.7	38.1	39.3	35.4	38.9
5	37.7	36.0	37.5	33.0	36.8
6	35.9	34.0	35.7	30.5	34.9
7	34.2	32.3	33.9	28.7	33.3
8	32.7	30.5	32.4	26.6	31.6
9	31.3	28.9	31.0	24.7	30.0
10	29.9	27.4	29.6	23.1	28.5
15	24.1	21.3	23.6	16.7	22.4
20	19.7	16.9	19.2	12.7	17.9
25	16.4	13.9	15.9	10.1	14.8
30	14.0	11.7	13.4	8.4	12.5
35	12.1	10.1	11.6	7.2	10.7
40	10.6	8.8	10.1	6.3	9.4
45	9.5	7.8	9.0	5.6	8.4
50	8.5	7.0	8.1	5.1	7.5

Table 2

Average effective α-doses (EAD) in a layer with thickness x , effective α-doses (ED) at depth x (as percentages of the infinite matrix dose) for calcite samples irradiated from one side (2π geometry) and percentage of total α-dose (PR) which is eliminated by removing x from a layer with thickness > maximum α-range. Density of calcite = 2.7 gm/cm3.

Thickness	^{232}Th decay chain			U-series			^{235}U-decay series			^{238}U - ^{230}Th			^{230}Th - ^{206}Pb		
x [μm]	EAD	ED	PR	EAD	ED	PR	EAD	ED	PR	EAD	ED	PR	EAD	ED	PR
1	45.1	41.3	13	44.5	40.2	16	45.2	41.3	14	43.4	38.3	21	44.9	40.8	15
2	41.7	35.4	26	40.7	33.8	30	41.7	35.5	26	38.9	30.9	38	41.3	34.7	28
3	38.8	30.7	36	37.5	28.7	41	38.9	30.9	37	35.2	25.1	52	38.2	30.0	39
4	36.3	26.7	45	34.7	24.4	51	36.4	26.9	46	32.1	20.4	63	35.6	25.7	49
5	34.0	23.2	53	32.3	20.8	59	34.1	23.5	54	29.3	16.4	72	33.2	22.1	57
6	32.0	20.3	59	30.1	17.6	66	32.1	20.4	61	26.9	13.1	79	31.1	19.0	64
7	30.1	17.7	65	28.1	14.9	72	30.2	17.8	67	24.7	10.3	85	29.2	16.3	70
8	28.4	15.3	70	26.3	12.5	77	28.5	15.4	72	22.8	7.9	89	27.4	13.9	75
9	26.8	13.3	75	24.7	10.4	82	26.9	13.3	76	21.0	6.0	93	25.8	11.8	79
10	25.4	11.5	79	23.1	8.6	85	25.5	11.5	80	19.4	4.3	95	24.3	9.9	83
15	19.6	5.3	91	17.2	3.0	95	19.6	5.0	93	13.6	0.4	100	18.3	3.7	94
20	15.6	2.1	96	13.4	1.0	98	15.5	1.9	98	10.2	0		14.3	1.2	98
25	12.7	0.8	99	10.8	0.4	99	12.6	0.5	99	8.1			11.6	0.5	99
30	10.7	0.4		9.0	0.1		10.6	0.1		6.8			9.7	0.2	
35	9.2	0.2		7.8	0		9.1	0		5.8			8.3	0	
40	8.1	0.05		6.8			7.9			5.1			7.3		
45	7.2	0		6.0			7.1			4.5			6.5		
50	6.5			5.4			6.3			4.2			5.8		

References

Aitken, M.J. (1985) *Thermoluminescence Dating* , 359p. Academic Press, London.

Aitken, M.J. (1987) Alpha dose to a thin layer, *Ancient TL* , this issue.

Bell, W.T. (1980) Alpha dose attenuation in quartz grains for thermoluminescence dating. *Ancient TL* , 12, 4-8.

Charlton, D.E. and Cormack, D.V. (1962) A method for calculation of the alpha ray dosage to soft tissue filled cavities in bone. *Brit. J. Radiology* , 35, 473-477.

Howarth, J.L. (1965) Calculation of the alpha ray absorbed dose to soft tissue cavities in bone. *Brit. J. Radiology* , 38, 51-56.

Lyons, R.G. (1988) Alpha/gamma response of calcite speleothems as determined by nuclear accelerator techniques. Proc. 5th TL and ESR Seminar, Cambridge, *Nucl. Tracks and Radn. Measts.*, in press.

Nambi, K.S.V. and Aitken, M.J. (1986) Annual dose conversion factors for TL and ESR dating. *Archaeometry* , 28, 202-205.

Zimmerman, D.W. (1971) Thermoluminescence dating using fine grains from pottery. *Archaeometry* , 13, 29-52.

PR Reviewer's Comments (M J Aitken)

We are indebted to Dr Grün for these useful reference data. Note that for material other than calcite the thickness given should be multiplied by that ratio of the densities.
