Comments on extrapolation methods of dating sediments by TL

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In the last issue of Ancient TL, Mejdahl (1985) presented a TL age for a marine sediment from Kap Kobenhavn, Greenland, of 1.07 Ma. It was calculated from an equivalent dose (ED) obtained by extrapolating the first glow growth curve to zero TL. Since this old date exceeds the limiting value of 100 ka that I have observed in a study of N.W. European sediments (Debenham, 1985) he concludes that he is observing a TL signal which is more stable than the feldspar 400 nm emissions used by myself. In this contribution, I question whether the greater age of the Greenland sediment signifies greater signal stability, or merely results from the method of ED determination employed.

The assumption made when an ED is obtained from the first glow measurements alone is that the extrapolated curve retraces the original TL growth curve in antiquity. Mejdahl presents no evidence that his extrapolation does so. In general TL practice, the usual way of testing this assumption is to additionally determine the form of the second glow growth curve. In the case of sediments, this may be done by first bleaching out the removable part of the natural TL, and giving various beta or gamma doses. The resulting TL is referred to as a 'regenerated' growth curve. Comparison of the first glow and regenerated growth curves shows whether a TL sensitivity change has occurred on bleaching. In the series of N.W. European sediments that I have studied, it appeared that little or no such change occurred. If and only if this holds true, the ED is simply equal to the natural regeneration dose (NRD), i.e. the dose that, given to the bleached material, regenerates the intensity of the natural TL. This is the basis of the regeneration method for ED determination.

Figure 1 shows a selection of regenerated growth curves obtained by beta irradiation following a laboratory bleaching of the natural TL in five sediments. It is representative of the variety of growth curve characteristics observed in over seventy sediments. In most cases, an initial non-linear portion is followed by a rising linear section, while, for a few samples, no initial non-linearity was evident. They cannot be fitted by curves of the simple saturating exponential type. Note in particular that data in the high dose regions display little or no curvature. Only these sections of the growth curves are revealed by first glow measurements on old sediments. It is clear that extrapolations, whether by straight line or poly nomial, from these higher doses cannot be relied on to reproduce the form of the curves at relatively low doses where the curvature is, in most cases, much higher.

A specific example is worked out in figure 2, which gives measurements for the oldest of the N.W. European sediments I have studied. Here an extrapolated ED based on the first glow growth curve is compared with the natural regeneration dose (NRD) found by interpolation of the regenerated growth curve. The extrapolated ED is 2.3 times greater than the NRD. The slopes of the two curves at the intensity of the natural TL are closely similar (ratio S_R/S_N = 1.11 $\pm$ 0.44), suggesting that the laboratory bleaching which preceded the regenerating irradiations did not significantly alter the TL sensitivity of the material. A TL age of 130 $\pm$ 15 ka was computed using the regeneration technique, while use of the extrapolation method would yield an age of approximately 300 ka.

It follows from the above that a TL date produced by means of first glow growth curve extrapolation may be much greater than that resulting from the regeneration method. Hence, TL ages exceeding the limiting value of 100 ka (Debenham, 1985) are to be expected when extrapolation is used, and they should not be taken as evidence of greater signal stability.

Finally, the following points regarding the regeneration technique should be emphasised. Comparison of the first glow and regenerated growth curves is considered an integral part of the method. The regenerated growth curve should be measured up to at least twice the NRD, and first glow points should be determined at various additive beta doses up to the same maximum TL intensity. This will give considerably better precision on slope ratio measurements than I have achieved so far. Any observed sensitivity change can be allowed for in the date calculation. Reproducibility of the TL measurements should be better than $\pm$ 5%, with good consistency of glow curve shapes. Anything worse than this probably indicates that the favourable feldspars 400 nm signal is suffering interference; quartz TL is usually to blame. While there can be no certainty about the validity of the regeneration method for dating sediments, it is clearly more justifiable to infer past TL acquisition from regenerated growth forms than from first glow extrapolation. A number of experiments have been carried out to further investigate the regeneration method. In these, samples recently bleached by sunlight have been irradiated to simulate an archaeological dose, artificially bleached, and then given regeneration doses. The samples were either sediments known to have been recently deposited and having very low natural TL, or were old samples bleached in sunlight while in suspension in water to low residual TL. Results show that the forms of the first glow growths were reproduced by the regenerated curves.

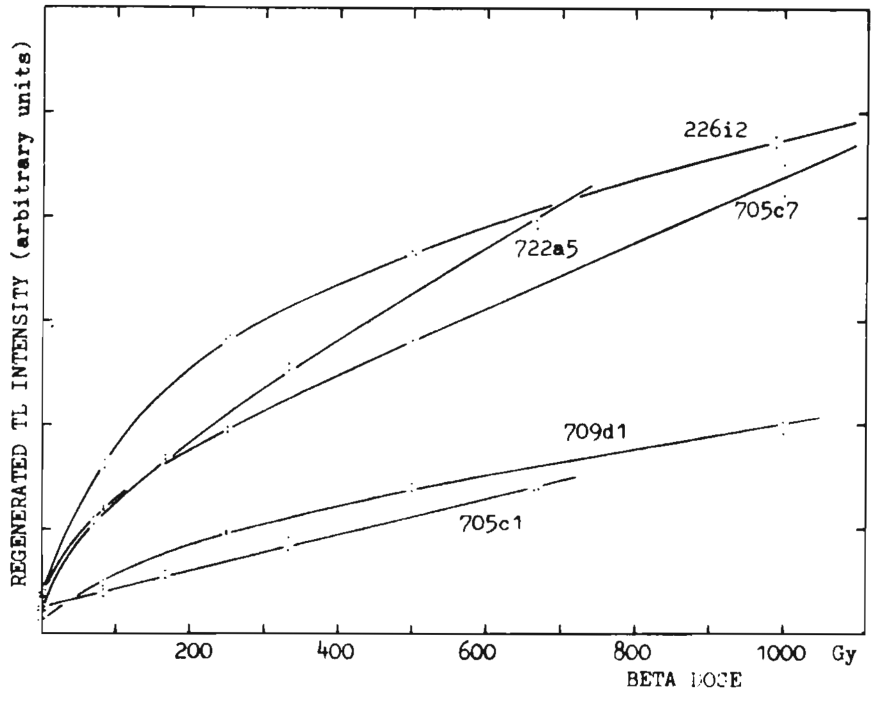

Figure 1: *Growth curves at 300-310°C regenerated by beta irradication after 16 hours bleaching under an Oriel simulated sunlight source. Polymineral fine grains samples on Al discs were observed with a quartz windowed EMI 9635 photomultiplier tube fitted with a Schott 2 mm thick UG11 filter. Heating rate was 2.5°C/s. Curves are labelled with sample identifiers (Oxford Lab. refs.); 226i2, Pontnewydd Cave, N. Wales, expected age > 200ka; 722a5, Achenheim, E. France, ~ 150ka; 705c7, Muleta Cave, Majorca, ~ 70ka; 709d1, Cagny-la-Garenne, N. France, ~ 400 ka; 705 c1, Muleta Cave, Majorca, ~ 50ka.*

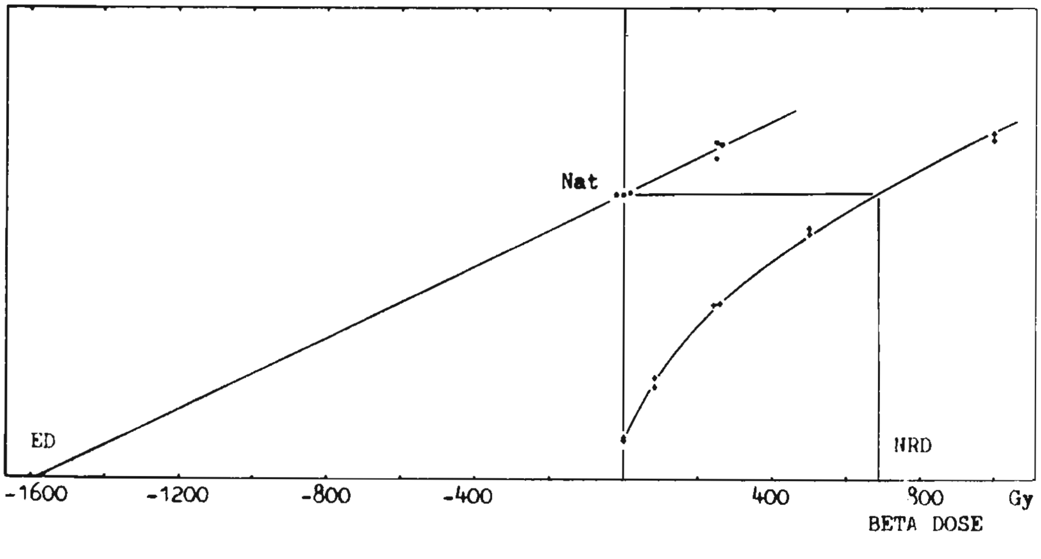

Figure 2: *Comparison of regeneration and extrapolation techniques of ED determination as applied to a sediment (Oxford Lab. ref. 713f1) from Susterseel, W. Germany. Measurements derive from the temperatue interval 300-310°C.*

References

Debenham, N. C. (1985) Use of UV emissions in TL dating of sediments. Nucl. Tracks, in press.

Mejdahl, V. (1985) Thermoluminescence dating of loess deposition in Normandy. Ancient TL, 3 (1), 14-16.

Reviewer's comments (A. G. Wintle)

The ongoing discussion concerning the method of ED determination for sediments is particularly relevant at this time since several papers containing TL dates have recently appeared. In particular, Buraczynski and Butrym (1984) have produced a series of TL dates ranging from 27,500 to 278,000 years BP for loess from Achenheim. They used the extrapolation of the additive first glow growth curve to obtain the ED. It is interesting to note that sample OxTL722a5 in Denbenham's paper is also from Achenheim and it shows considerable non-linearity in the regenerated response. Unfortunately Buraczynski and Butrym do not give any raw data, such as the ED obtained or how they converted from a LiF dose rate (from gammas only) to a SiO_2 dose rate (from alphas, betas and gammas to 50-56 micron polymineral grains). Also, lack of other age control means that their dates, and therefore their ED methodology, cannot be assessed.

The other papers of interest in this context are those from the December 1985 issue of the Canadian Journal of Earth Sciences by Berger and by Lamothe. In these the partial bleach method (R-Γ was used since the sediments being studied were waterlain and therefore likely to be 'overbleached' in the laboratory bleaching experiment. The examples given showed non-linearity for doses in excess of 400 Gy and for this reason quadratic fits were used for the extrapolation of the additive dose curve. The ages obtained were consistent with the geological evidence. However, it can be seen from their graphs that for samples older than those reported overestimation of the type described by Debenham would occur.

However, it should be stressed that it is not necessarily valid to apply the results obtained for polymineral fine grains from loess to data obtained for 100-300 micron pure potassium feldspar samples, as used by Mejdahl. On the other hand, it is clear that further studies using added doses on such feldspar samples should be attempted on sediments with greater age control in the period 100-300 ka where Debenham's proposed loss of luminescence centres should already be easily observed.

References

Berger, G. W. (1984) Thermoluminescence dating studies of glacial silts from Ontario, Canadian Journal of Earth Sciences, 21, 1393-1399.

Buraczynski, J. and Butrym, J. (1984) La datation des loess du profil d'Achenheim (Alsace) a L'aide de la methode de thermoluminescence, Bulletin de l'Association Francaise pour l'Etude du Quaternaire, 20, 201-209.

Lamothe, M. (1984) Apparent thermoluminescence ages of St. Pierre sediments at Pierreville, Quebec, and the problem of anomalous fading, Canadian Journal of Earth Sciences, 21, 1406-1409.