Comments on TL Age Underestimates of Stalagmitic Calcite

K. S. V. Nambi
Health Physics Division
Bhabha Atomic Research Centre
Bombay 400085, India

Debenham and Aitken (1984) have obtained TL age estimates on twenty seven stalagmitic calcite samples and compared them with the known U-series age estimates. Within the reproducibility/error limits specified for each estimate, these authors have concluded that no case of overestimation of the age by the TL technique is evident and there are about five cases where TL clearly gave underestimates; they have indicated that zoning effects and/or geochemical reactions during burial could be the possible causes for the TL underestimation. However, taking into account the two cases where the U-series ages have been given infinity limits and the six cases where the U-series estimations have been specified as lower limits, one can list in fact eleven cases where the TL technique can be construed to have yielded underestimates of the true ages.

I presented, during the Third Specialist Seminar on TL and ESR Dating at Helsingør (Nambi, 1983), a summary of TL age underestimates on a variety of geological samples (mostly $CaCO_3$), and brought to notice a possible correlation between the underestimation factor (= TL age/true age = t'/t) and the paleo alpha dose received by the sample ($=\int^{t} D_{\alpha}.dt$). Subsequently, I have observed that data of Reena De et al (1983) on calcitic oozes and of May (1977) on basaltic lava flows, also exhibit the same trend concerning TL age underestimates (Nambi 1984). Very recently TL dating failure on a nine year old laboratory - grown CaF_2 crystal containing 1555 ppm of natural uranium also indicated a proportionality between the extent of underestimation and the magnitude of paleo alpha dose (Nambi et al 1984). It should be stressed that if zoning effects or geochemical actions during burial - diagenesis is a good example in $CaCO_3$ - could be the cause for TL age underestimation, a systematic trend between the extent of underestimation and the paleo alpha dose is not warranted in all cases.

I am happy to find a similar trend in the Oxford data on TL dating of stalagmitic calcites (Fig. 1). In this figure the paleo alpha doses have been calculated assuming the U-series ages and using the dose rate conversion constants with corrections for isotopic disequilibrium as given by Hennig and Grun (1983). Nine cases have been indicated in this figure as having an upper limit for the underestimation factor and a lower limit for the paleo alpha dose to include the possibility of infinite age limit indicated in the U-series dating. There is lot of scatter of the data in the paleo alpha dose region of 200 - 500 Gy where the TL underestimation just sets in; some of the scatter points have been found to belong to samples where U-leaching cannot be ruled out (Debenham, 1984). Nevertheless the dependence of the extent of underestimation with the paleo alpha dose is quite evident especially for the nine cases mentioned above. As the paleo alpha doses covered by the Oxford study differ hardly by one order of magnitude - as against four orders of magnitude in the data presented in Nambi, 1984 - the pattern seen here is less dramatic in its appeal.

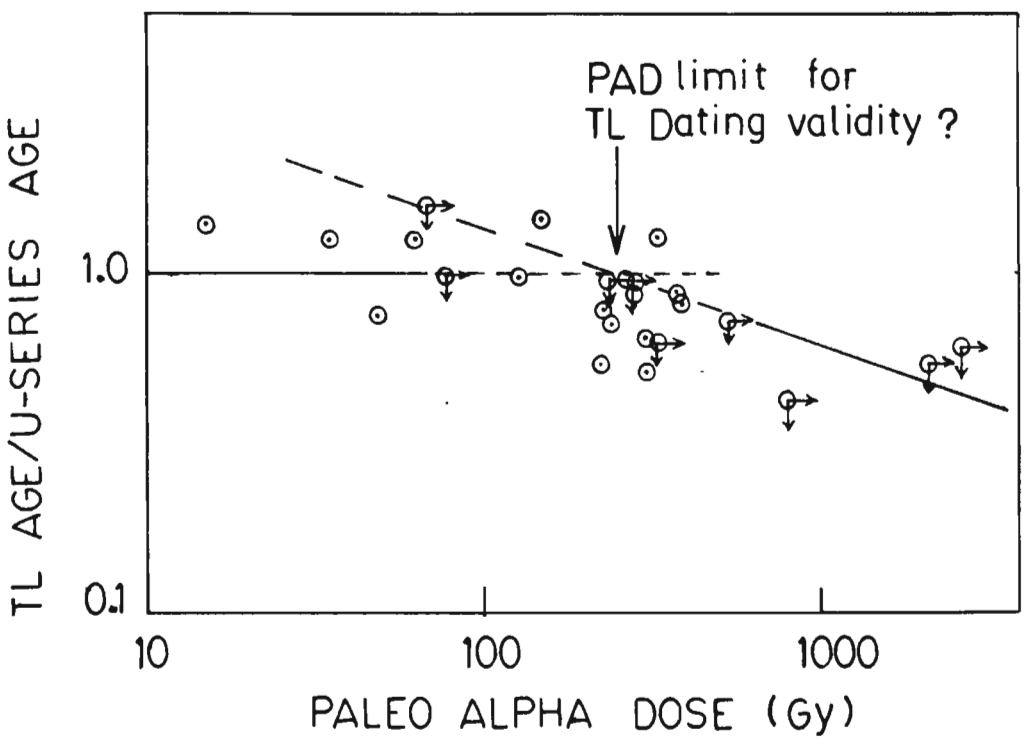

Figure 1

Deviation of TL age estimates from the U-series age estimates with progressive increase of Paleo Alpha Dose (PAD) in stalagmitic calcite samples.
(Derived from Debenham & Aitken (1984); See text for explanation on points marked with arrow-heads; the dotted indicate the dose region of uncertainty for the extensions of true and underestimation lines)

I should also point out that the "underestimation lines" have been found with different slopes and different "paleo alpha dose limits for TL dating validity" in the three groups of data so far analysed (Nambi 1984; Nambi et al 1985 and present work). In other words, in the empirical fit for the underestimation line given by $t'/t = a[\int_0^t \dot{D}_\alpha . dt]^{-b}$, the constants a and b assume different values in different materials which is quite logical to expect if one imagines an alpha-induced progressive damage effect; a dynamic equilibrium level sets in due to alpha damage and the TL saturation level depends upon not the trap life time, but the ratio of effective alpha + beta + gamma dose rate and the alpha dose rate (Nambi 1984).

Observation of the same trend in independently collected data from different sources cannot be set aside as accidental for lack of a good physical explanation at the moment. In the recently concluded Fourth Specialist Seminar on TL and ESR Dating at Worms, many new aspects of the alpha irradiation yields in various materials came to light viz., temperature dependence, dose dependence and impurity dependence (Nambi et al, 1984 and De Canniere et al, 1985). It is hoped that as more and more data encompassing a wide range of paleo alpha doses and extents of TL underestimations of the age are discovered to be mutually related and more and more of the microscopic details of the alpha irradiation effects are unearthed, a clear physical explanation of the TL age underestimation will emerge.

References

Debenham, N. C. and Aitken, M. J. (1984) Thermoluminescence dating of stalagmitic calcite, Archaeometry 26 (2), 155-170.

Debenham, N. C. (1984) Private communication.

De Canniere, P., Grun, R., Debuyst, R., Dejehet, F. and Apera, D. (1985) ESR determination of specific alpha and gamma irradiation yields in geological samples. Nucl. Tracks, in press.

Hennig, G. J. and Grun, R. (1983) ESR Dating in Quaternary Geology, Quaternary Sciences Reviews 2, 159-238.

May, R. J. (1977) Thermoluminescence dating of Hawaiian alkali basalts, J. Geophys. Research, 82, 3023-3029.

Nambi, K. S. V. (1983) The problem of low thermoluminescence age estimates in geological dating, PACT Journal 9 (II), 479-485.

Nambi, K. S. V. (1984) Alpha - radioactivity - related upper limit for thermoluminescence dating? Proc. Indian Acad. Sci. (Earth Planet Sci.) 93, 47-56.

Nambi, K. S. V., Rao, S. M. D. and Chougaonkar, M. P. (1985) TL dating of synthetic CaF_2: U crystals: Further proof of the alpha - radioactivity - related limitations. Nucl. Tracks, in press.

Reena De Rao, C. N., Kaul, I. K., Sunta, C. M., Bapat, V. N. and Nambi, K. S. V. (1984) Thermoluminescence ages of oceanic carbonate sediments - oozes and chalks, from DSDP sites 216, 217, 219 and 220 in Northern Indian Ocean, Mod. Geol. 8, 207-215.

Reviewers' comments (M. J. Aitken and N. C. Debenham)

The author's hypothesis regarding correlation of TL age underestimate with paleo alpha dose is an interesting one but there is a danger that the 'reinforcement syndrome' well known in magnetic reversal stratigraphy will lead to too ready an interpretation of data in this way, with insufficient weight being given to other possible interfering factors. In the case of stalagmitic calcite Dr Nambi takes for granted that uranium-series ages can be equated with true ages; the fallacy in this is particularly evidenced by the eight uranium series determinations made on the four samples from the South Fissure at Pontnewydd which gave a wide scatter of dates even between repeat measurements on the same sample, whereas the TL dates are consistent among themselves.

In the case of the calcium fluoride experiment an explanation readily to hand is that the heavy doping gave rise to substantial anomalous fading.