Ancient TL

www.ancienttl.org · ISSN: 2693-0935

Berger, G. and Huntley, D., 1989. *Treatment of error in plateau values - caveat emptor.* Ancient TL 7(2): 27-29. https://doi.org/10.26034/la.atl.1989.145

Treatment of error in plateau values - caveat emptor

Glenn W. Berger † and D. J. Huntley §

† Department of Geology, Western Washington University, Bellingham, WA 98225, U.S.A.
§ Department of Physics, Simon Fraser University, Burnaby, B.C. V5A 1S6, Canada

Introduction

The treatment of the estimated errors in the equivalent-dose (D_e) values in plateau plots appears to have sometimes been handled incorrectly in recent publications. We discuss here what the correct treatment should be. We raise this subject because of an earlier instance (Rendell, 1985) in which some mathematical expressions ascribed to us were incorrectly quoted, and because we suspect that there is here a new misuse of some expressions which originated with us. We wish to re-emphasize the dangers of using any programs for which one does not understand the limitations of the mathematical routines.

Discussion of different ways to assess plateau values has also been a part of the development of more mature dating methods (e.g. Berger and York 1981). Hence, this matter should be clarified now before unnecessary differences in interpretation of TL dates arise. Specifically, some results [eg Forman, 1988; Forman et al. 1988, some of the Alpha Analytic dates (private communication)] present errors in the mean D_e values (hence in the TL age estimates) that are unrealistically small, by a factor of two to ten. Most of the data of Forman et al. (1988) are reproduced (with some puzzling differences in cited errors) in Forman et al. (1989), but in the latter case the single D_e plot does not reveal any discrepancy in error assignment.

We are not singling out Forman and colleagues for mischievious reasons, but only because they have been careful enough to publish examples of growth curves and/or plots of equivalent-dose plateaus which enable us to draw inferences about their treatment of errors. We are distressed at the number of authors who do not publish such plots (and the editors and reviewers who allow this omission). Presently, statistical treatments of errors in TL data for sediments (young or old) cannot be judged objectively by independent workers without such plots. As a corollory, mere tabulation of TL dates (e.g. Drozdowski and Fedorowicz 1987, Zöller et al. 1988, Zubakov et al. 1988) has little value. In fact, few of the sediment TL dates yet published satisfy all the criteria for acceptability proposed by Wintle and Huntley (1982).

Two types of error estimate

There appear to be two kinds of error estimate in circulation. This supposition is made because one of us (GWB) wrote the early error routines for the TL laboratory at Cambridge and the now-defunct commercial Alpha Analytic laboratory in Miami, Florida. These routines contained two error estimates: the first, the average of the individual D_e error estimates; the second, the weighted error of the mean.

This second estimate is calculated using a weighting appropriate for the case in which all the individual errors are statistically uncorrelated (often referred to as the standard error of the mean, e.g. Topping 1962). This second estimate is always smaller than the first and would be appropriate only if the errors were due entirely to, for example, photon-counting statistics. The "correct" error estimate will normally lie somewhere between these two extremes, but in practice is usually closer to the larger first estimate, because the errors in the individual D_e values are highly correlated. A proper calculation requires a knowledge of the covariance terms of the errors in the individual D_e values, but these covariance terms are not known.

What is the evidence that the errors in the individual D_e values are usually highly correlated? These errors reflect the scatter of the glow curves -- their reproducibility, manifesting largely subsample variability. Almost always, when one glow curve is lower or higher than another, this difference not surprisingly persists over several channel or temperature points (as much as 50-100 °C). This shows up on a D_e vs T plot as a sequence of D_e values which have much less scatter than expected on the basis of the size of the error bars on the individual points.

Errors in individual D_e values will likely be uncorrelated only when the "noise" in each glow curve is dominated by photon- counting statistics or some instrumental characteristic. Such glow curves commonly are observed when the signal intensity is very low (less than a few hundred photon-counts per channel), such as for very young volcanic ash samples. Use of the standard-error-of-the-mean estimate is warranted only in such cases of very low photon counts.

Figure 1 shows two equivalent-dose plots of real data which illustrate the two situations described above. Part A represents a 500 year-old tephra which had low TL signals, whereas part B represents a ≈40,000 year-old lake sediment. For the former, the standard-error-of-the-mean error estimate is appropriate, whereas for the latter the average error is valid.

The use of integral D_e determinations (that is, calculated from TL data integrated over a broad region of the glow curves) might seem to be a useful way to reduce the error in the final D_e value, but a little thought and an example show that this approach provides no advantage. Consideration of fig 1a and the underlying glow curves (Berger and Huntley, 1983) shows that an integral D_e will reduce the error to the same extent as the weighted error of the mean, without having the benefit of a plateau test. Consideration of fig. 1b reveals that an integral D_e will yield the same error as the average of the individual errors in the plateau. We have done this calculation for the TL data underlying fig 1b and verified that this is so. These results are not suprising, given the main reasons for correlation (or not) of errors (discussed above). A final argument against the use of an integral calculation is that it side-steps use of a proper plateau test. Many workers use only the simplistic ratio-of-glow-curves method for a plateau test and follow this with an integral calculation. This approach is inadequate for it depends on the assumption of a linear dose response for all samples and all regions of the glow curves.

A practical example

There is also a practical way to determine which of the two error estimates is appropriate. One can simply repeat the equivalent-dose experiment several times on a given sample. Various levels of care could be used. Perhaps the most realistic approach would be to do each experiment on a separately prepared set of discs for a given sample. In this way the variability between disc sets could be factored into the estimate of error in the plateau D_e value. This approach is certainly the most realistic if one expects to compare error estimates in TL dates between different laboratories, or indeed between different samples. Of course if one has such replicate data, one can use the results with proper statistical weighting to produce a better error estimate than is represented by any individual result.

To our knowledge, this experiment has not yet been done using the partial-bleach or regeneration techniques. If anyone has done such experiments, we would be interested to hear of the results. However, such an experiment has been done using the additive-dose technique applied to the Mazama volcanic ash (Berger and Huntley, 1983). To support our arguments and to provide convenient access to these results, we reproduce in Table 1 here some of these data for the Mazama ash. These data show that the most realistic error estimate for the plateau D_e is the average error over the plateau region . The smaller weighted- error-of-the-mean estimate does not reflect the actual reproducibility of the plateau experiments.

Conclusion

In the absence of a statistically correct procedure for evaluating the error in the quoted D_e, the best estimate of this error will usually be obtained by taking the average (over the plateau) of the errors in the individual D_e values. This may be an overestimate in some cases, but that is not nearly as serious a mistake as making a large underestimate.

Table 1. Repeat equivalent-dose measurments for Mazama ash

D_e (Gy)	Ave. error (Gy)	
25.9	0.9	average = 27.9
26.9	1.0	
28.9	1.8	standard deviation = 1.7
26.4	2.6	
30.4	2.0	standard error
28.7	2.2	of the mean = 0.7

References

Berger, G. W. and York, D. (1981) Geo-thermometry from $^{40}Ar/^{39}Ar$ dating experiments. *Geochim. Cosmochim. Acta.*, **45**, 795-811.

Berger, G. W. and Huntley, D. J. (1983). Dating volcanic ash by thermoluminescence. *PACT J.*, **9**, 581-592.

Drozdowski, E. and Fedorowicz, S. (1987) Stratigraphy of Vistulian glaciogenic deposits and corresponding thermoluminescence dates in the lower Vistula region, northern Poland. *Boreas*, **16**, 139-153.

Forman, S.L. (1988) The solar resetting of thermoluminescence of sediments in a glacier-dominated fiord environment in Spitsbergen: geochronologic implications. Artic and Alpine Research, **20**, 243-253.

Forman, S. L., Jackson, M. E., McCalpin, J. and Maat, P. (1988) The potential of using thermoluminescence to date buried soils developed on colluvial and fluvial sediments from Utah and Colorado, U.S.A.: preliminary results. *Quat. Sci. Rev.*, **7**, 287-294.

Forman, S. L., Machette, M. N., Jackson, M. E. and Matt, Paula. (1989) An evaluation of thermoluminescence dating of paleoearthquakes on the American Fork segment, Wasatch Fault zone, Utah. *J. Geophys. Res.*, **94**, 1622-1630.

Rendell, H. M. (1985) Problems with linear regression as applied to TL data. *Ancient TL*, **3**, 6-9.

Topping, J. (1962) Errors of observation and their treatment. Chapman and Hall.

Wintle, A. G. and Huntley, D. J. (1982) Thermoluminescence dating of sediments. *Quat. Sci. Rev.*, **1**, 31-53.

Zöller, L., Stremme, H. and Wagner, G. A. (1988) Thermolumineszenz-datierung an löss paläo-boden-sequenzen von nieder-, mittel- und oberrhein/Bundesrepublik Deutschland. *Isotope Geology*, **73**, 39-62.

Zubakov, V. A. (1988) Climatostratigraphic schemes of the Black Sea Pleistocene and its correlation with the oxygen-isotope scale and glacial events. *Quaternary Research*, **29**, 1 - 24.

P.R. Reviewer's comments (Rainer Grün)
This is a very timely comment on error treatment in TL dating. It would be of great value if the authors also commented on the general validity of linear fits, and whether it would be more realistic to use integral ED determinations. This leads, of course, to the general discussion of whether the existence of signal and ED plateaux are sufficient criteria for the reliable evaluation of the ED.

Reply
In this paper we have attempted to address a small but significant computational aspect concerning D_e determination and not the broader issues raised by the Reviewer. However, a more detailed discussion of curve fitting may be found in Berger et al (Berger, Lockhart and Kuo, 1987); the plateau test is not a sufficient condition for the validity of D_e, but as Aitken (1985) has pointed out previously, it is certainly necessary. Part of the problem of the development of the TL dating methods has been the over-zealous interpretation of "something flat" as a chronologically meaningful parameter.

Reference
Berger, G.W., Lockhart, R.A., and Kuo, J. (1987) Regression and error analysis applied to the dose-response curves in thermoluminescence dating. *Nucl. Tracks and Radn. Measts.*, **13**,177-184.

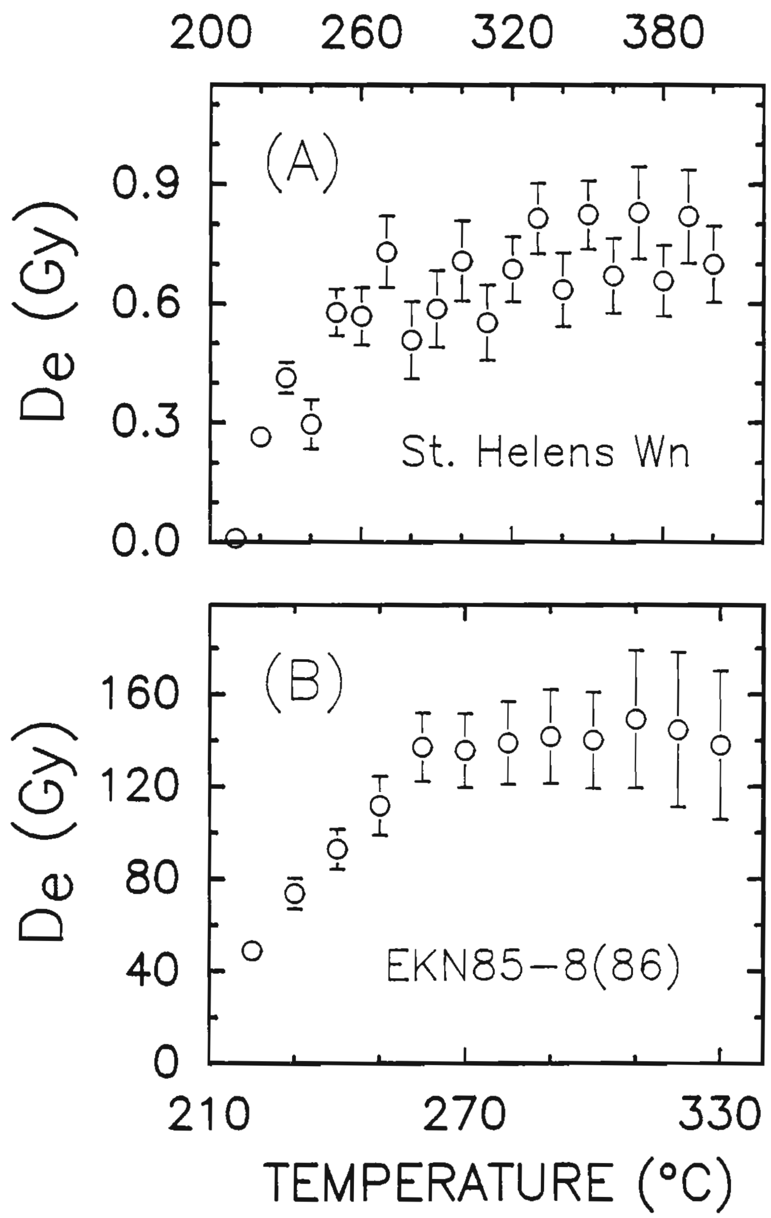

Figure 1.
Equivalent-dose plots for two sets of data, representing the situations of highly uncorrelated (A) and highly correlated (B) errors in individual D_e values. The data of part A represent additive-dose results for the Mt. St. Helens Wn tephra from Berger and Huntley (1983), whereas the data of B represent partial-bleach (R - β) results of Berger (unpublished).