TL dating of fluvial quartz sands: a comparison of ages obtained at 325°C and 375°C

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Generally the validity of the ages determined for aeolian quartz sands using the 375°C TL peak has been accepted as providing an accurate measure of the time since the last deposition of the sediment (Gardner *et al.*, 1987, Nanson *et al.*, 1992). The reason for this acceptance is that it is felt that these sediments receive sufficient solar exposure prior to deposition to reduce the stored TL to a minimum level. Over the past number of years however there has been a growing concern that water borne sediments may not receive such an exposure and that these sediments may retain a remnant of their previously acquired TL signal (Spooner *et al.* , 1988). The retention of such a remnant would lead to an overestimation of the age of the sediment.

As a result of this concern there is an increasing move towards the use of the more easily removed TL peak occurring at 325°C in the age determination of water borne sediments. This trend however is not without its drawbacks as one must ensure that the level of light exposure during and following the sample collection is kept to an absolute minimum. This requirement is a far from desirable laboratory working condition.

Because of the large number of fluvial sedimentary studies undertaken by the laboratory and the concern regarding the validity of the results of these studies a comparison between the TL ages determined at 325°C and at 375°C was carried out. As the Wollongong practice, where possible, is to analyse most samples at a temperature of 375°C this comparison entailed re-analysis at 325°C. Also reported here are the results of tests conducted upon the laboratory lighting and its effect upon the TL stored within the sample quartz grains. It should be noted that wherever possible it has long been the practice of the laboratory to perform corroborative dating exercises using independent dating methods (Nanson *et al.* , 1991, bin Hassan *et al.*, 1993).

The Wollongong laboratory in the main utilises the total bleach combined regenerative/additive method of TL analysis as described by Readhead (1984). Where necessary the polymineral fine grain (1-8 µm) assemblage, as described by Aitken (1985), is applied. Laboratory bleaching is achieved using a Philips 300MLU sunlamp, irradiations are performed by means of a strontium-90 plaque source and TL outputs are detected by an EMI 9635Q PM fitted with a Corning 7-59 filter. A heating rate of 5°C s^{-1} is used in the case of coarse grain work and 20°C s^{-1} for the fine grain experiments. All measurements are made under a high purity nitrogen atmosphere and each output is normalised using a second glow procedure. This is found preferable to weight normalisation as, unlike weight normalisation, it compensates for any slight difference in sample planchette colour or staining which has been found to have a marked effect upon TL output. There appears to be no systematic increase in TL sensitivity with increasing first radiation dose. Each sample aliquot is deposited upon an aluminium planchette using a volume technique which is described by Bell (1978). Sample aliquots are spread in a monolayer and adhered using a silicone spray found to be both stable at high temperatures and non-TL emitting.

The laboratory is illuminated by six single 36 watt fluorescent tubes. The outer fittings of these are covered with Cinemoid No.1 yellow plastic filter sheeting which has a sharp cut-off at 500 nm (Jensen and Barbetti 1979). It is found preferable to cover the outer surface of the fitting rather than the tube as this prevents rapid deterioration of the filter material due to heating at the ends of the fluorescent tubes.

Table 1.
Comparison of TL ages determined at 325°C and 375°C

Coarse grain quartz: 90-125 µm

Sample Ref.	Temp. Plateau (°C)	TL Age (ka) 325°C	375°C
A	300-500	106±21	86.8±7.5
B	300-500	49.5±5.6	46.8±3.0
C	275-500	33.2±6.8	34.4±4.0
D	275-500	83.8±7.1	83.5±7.1
E	275-500	99.4±8.6	95.3±6.3
F	300-500	47.0±3.8	45.9±3.8
G	300-450	19.7±3.9	25.5±3.5
H	325-450	26.5±2.8	29.8±2.9
I	325-500	21.2±2.4	24.7±2.8
J	325-500	23.7±4.6	29.4±4.6
K	300-500	34.2±3.8	33.6±2.5
L	300-500	47.7±4.5	47.8±6.1
M	300-500	41.0±7.2	43.2±3.7
N	300-500	65.6±3.9	63.7±4.1
O	300-500	16.8±1.7	15.2±2.0
P	325-500	9.8±1.0	13.6±1.6
Q	300-500	19.1±1.9	18.2±1.5
R	300-450	19.8±2.1	17.9±2.5
S	300-500	3.8±0.3	4.1±0.3
T	300-500	7.0±0.9	7.1±0.6
U	300-500	1.9±0.2	1.6±0.2
V	300-500	122±7	115±7

Note:
The data shown have been taken from four widely separated study areas. Samples A-F are from Page *et al.* (1991), the remaining samples are from unpublished work.

Effect of laboratory lighting upon TL samples

In total three separate tests have been conducted over a period of seven years. These tests involved a total of 34 sample aliquots as previously described. Each sample batch was irradiated to a level of about 36 Gy and divided into two subsets. One of these was placed at laboratory bench level under the laboratory lights for a period of 24 hours while the other was stored under dark conditions. Following this procedure the TL output of the two subsets was measured and the mean TL output compared at 25°C intervals between 200 and 500°C. At 375°C there was a mean TL loss of 4.1% for the three tests conducted and at 325°C there was a mean loss of 14.5% over the 24 hour period. It should be pointed out that at all times samples are stored under dark conditions so minimising exposure to the laboratory lights. The majority of exposure takes place during the preparation stage and most of this is under liquid chemicals and in a less well lit fume hood. The Wollongong procedure does not make use of a prolonged HF etch period (Readhead 1984).

Comparison of TL ages determined at 325°C and 375°C

This comparison involved the re-analysis of 22 fluvial samples which had previously been analysed at 375°C. The initial 16 samples were selected at random by a non-TL expert and the remainder by the author in order to fill out age gaps in the data. In each case comparison between the amplitude of the natural sample TL and that of a regenerated TL glow curve, selected to give a ratio of approximately unity, provided a plateau region generally extending between 300 and 500°C. The result of this comparison is shown at Table 1 and in graphic form at Figure 1.

Discussion

As indicated at Figure 1 there is an excellent overall agreement between the two sets of TL ages determined with a least mean squares regression coefficient of 0.99 and a slope of 0.90. If the three higher age values are ignored the slope becomes 0.96. As tempting as it may be, with the limited data available, it is not suggested that the relationship between the two data sets is other than linear beyond 100 ka.

The ages determined at 375°C for samples G, H, I, J and P exceeded those computed at the lower temperature TL peak. This was particularly noticeable in the case of samples G, J and P. Samples H, I, J and P displayed temperature plateaux which did not extend below 325°C although this is probably closer to 315°C allowing for a heating rate of 5°C s^{-1} and that the 110°C reference peak occurs at about 100°C. Examination of the glow curves for all of these samples suggests that this age difference might well be due to a mineralogy problem rather than one of

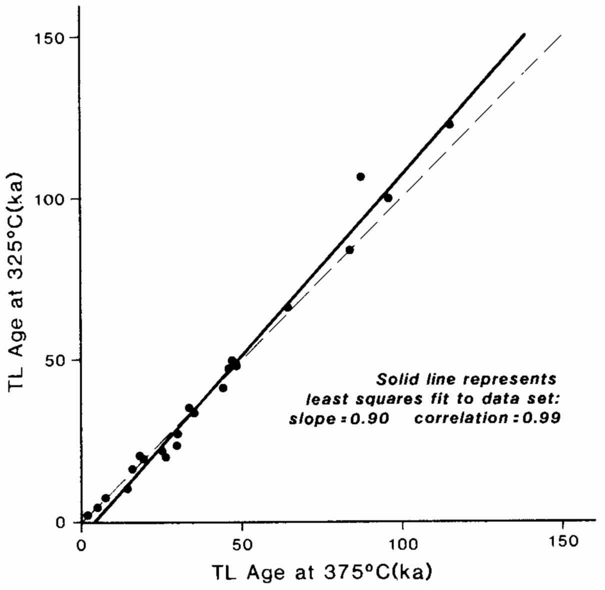

Figure 1.
Comparison of TL ages at 325°C and 375°C. The solid line represents the least squares fit to the data set, slope 0.90, correlation 0.99.

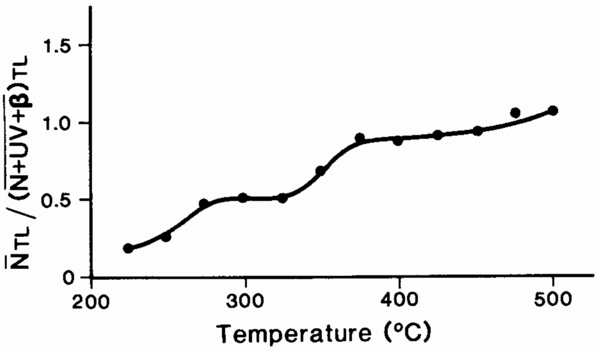

Figure 2.
Variation of natural TL/regenerated TL with temperature. Showing a two step temperature plateau relationship thought to be caused by partial re-exposure due to bioturbation. TL ages computed at 325°C and 400°C are 5.1± 0.8 ka and 9.1± 0.9 ka respectively. The associated ratio errors lie within the width of the plotted points. Site, Western Arnhem Land Plateau, N.T. (unpublished).

incomplete removal of the previously acquired TL although this possibility cannot be totally excluded. Each of the regenerated and second TL glow curves exhibited by these samples showed evidence of the presence of strong TL interference at around 200°C. This effect was not consistent between sample aliquots and not at all evident from the natural TL glow curves suggesting a relatively short lifetime. This interference has a much greater effect upon the lower 325°C regenerated TL glow curves as compared to the 375°C TL outputs. Thus the 325°C TL ages are thought to represent underestimates as the natural TL signal represents a lesser proportion of the enhanced TL peak. This effect could be due to the presence of inclusions within the quartz grains as reported by Fragoulis and Readhead (1991). The possibility of the problem being caused by interference from other TL sensitive minerals is further supported in that each of the samples in question originated from the same site.

Unlike the TL glow curves of Spooner *et al.* (1988) the majority of samples from this study exhibit dominant TL peaks in the 375°C region and this is found to be more often than not the normal situation. The exceptions to this were samples C and E which displayed dominant 325°C TL maxima. The criterion for the selection of a particular analysis temperature at the Wollongong laboratory is one of judging each sample upon its merits and the rate of change of the TL signal with temperature is a consideration in this choice. Where possible a point at which a slow change is taking place is preferred to one of rapid change. The existence of an extended natural/regenerated TL versus temperature plateau region is of prime importance.

Smith *et al.* (1985) recognised that, in certain circumstances, it is possible for a sediment to exhibit a two-step equivalent dose plateau. Partial exposure of the sediment during transport is thought to be sufficient to release those electrons trapped at lower energy levels but insufficient to release those stored at deeper levels. As is shown by Prescott (1985) a single plateau is not necessarily an indication of complete resetting of previously acquired TL over the entire temperature range. Figure 2, taken from work currently under way in this laboratory, shows a two-step plateau which is attributed to partial re-exposure of the sediment by ants (*Aphaenogaster* sp.) which are reported to be extremely active in the area (Bowman, pers. comm.). Further work is under way to verify this.

Conclusion

The objective of this exercise was to verify that, given sufficient care, it is possible to accurately determine the depositional age of water borne sediments by means of the 375°C quartz TL peak. The results of this study would seem to achieve this purpose and indicate that the level of sample exposure to the laboratory lighting is insufficient to have a detrimental effect on either the 325°C or the 375°C TL energy levels. Of paramount importance in the analysis phase of the sample is the existence of a lengthy temperature plateau region and that each sample should be judged upon its own merits rather than to a preconceived formulation.

References

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

Bell, W.T. (1978) Studies in thermoluminescence dating in Australasia. Unpublished PhD thesis, Australian National University.

Fragoulis, D.V. and Readhead, M.J. (1991) Feldspar inclusions and the anomalous fading and enhancement of thermoluminescence in quartz grains. *Nuclear Tracks and Radiation Measurements* **18(3)**, 291-296.

Gardner, G.J., Mortlock, A.J., Price, D.M., Readhead, M.L. and Wasson, R.J. (1987) Thermoluminescence and radiocarbon dating of Australian desert dunes, *Australian Journal of Earth Sciences* **34**, 343-357.

bin Hassan, K., Nakamura, T., Price, D.M., Woodroffe, C.D. and Fujii, S. (1993) Radiocarbon and thermoluminescence dating of the old alluvium from a coastal site in Perak, Malaysia. *Sedimentary Geology* **83**, 199-210.

Jensen, H. and Barbetti, M. (1979) More on filters for laboratory illumination. *Ancient TL* **7**, 10.

Nanson, G.C., Price, D.M., Short, S.A., Young, R.W. and Jones, B.G. (1991) Comparative uranium-thorium and thermoluminescence dating of weathered quaternary alluvium in the tropics of northern Australia. *Quaternary Research* **35**, 347-366.

Nanson, G.C., Chen, X.Y. and Price, D.M. (1992) Lateral migration, thermoluminescence chronology and colour variation of longitudinal dunes near Birdsville in the Simpson Desert, Central Australia. *Earth Surface processes and Landforms* **17**, 807-819.

Page, K.J., Nanson, G.C. and Price, D.M. (1991) Thermoluminescence chronology of late Quaternary deposition on the Riverine Plain of south-eastern Australia. *Australian Geographer* **22(1)**, 14-23.

Prescott, J.R. (1983) Thermoluminescence dating of sand dunes at Roonka. Third specialist seminar on TL and ESR dating. Denmark, 1982. *Eur. PACT* **9**, 505-512.

Readhead, M.L. (1984) Thermoluminescence dating of some Australian sedimentary deposits. Unpublished PhD thesis. Australian National University.

Smith, B.W., Prescott, J.R. and Polach, H. (1982) Thermoluminescence dating of marine sediments from Spencer Gulf. Archaeometry: An Australian perspective. Ed. Ambrose and Duerden. Australian National University, Canberra, 282-289.

Spooner, N.A., Prescott, J.R. and Hutton, J.T. (1988) The effect of illumination wavelength on the bleaching of the thermoluminescence (TL) of quartz. *Quaternary Science Reviews* **7**, 325-329.

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