# Light transmittance through dry, sieved sand: some test results

**Jeff Ollerhead**

Department of Geography, Mount Allison University, 144 Main St., Sackville, New Brunswick, Canada E4L 1A7

*(Received 19 February 2001; in final form 8 March 2001)*

***Abstract:*** *a series of measurements was made at different light wavelengths of transmittance through various thicknesses of dry sand grains from a variety of size classes. Transmittance was found to decrease approximately exponentially with increasing sand layer thickness and with decreasing grain size. Transmittance did not vary significantly with incident light wavelength. It is concluded that for any dry sand, a layer with a thickness of 7 mm, and possibly much less, is capable of reducing the transmittance of incident light to 0.05 % or less. This result should be considered when collecting a surface sample as a modern analogue for a sample to be optically dated.*

## Introduction

It is now generally accepted that optical dating techniques can be used to determine the length of time that has elapsed since a mineral was last exposed to daylight (Aitken, 1998; Huntley and Lian, 1999). However, as Wintle and Huntley (1982) noted almost two decades ago, a necessary criterion for a valid luminescence age is that a modern sample in the same context yield an age of zero. Thus, in an 'ideal world', a modern sample (usually a surface sample) from an environment under study yields an optical age of zero. However, this is not always the case. For example, Wintle *et al.* (1994) obtained an optical age of 40 ± 15 years for a surface sand sample. In my own work, I have obtained optical ages significantly greater than zero for modern samples. An age greater than zero for a modern sample can occur because: (i) the sample is not well bleached prior to collection, (ii) there is a deficiency in the dating technique used (*e.g.*, an inappropriate laboratory bleaching procedure, such as one which uses photons not present in nature, is used), or (iii) both (i) and (ii). The focus here is on one factor related to bleaching: overlying sediment that might block light penetration.

Modern samples should normally be collected as analogues for older samples being dated. If modern samples are found to be inadequately bleached, this raises questions about whether older samples of interest were adequately bleached prior to deposition. An understanding of the environment from which a sample is collected is clearly needed to address the question of whether or not one should expect mineral grains in a modern sample to be bleached sufficiently to yield an optical age of zero. In my own work, I have usually collected the top 0.5-1.0 cm of sediment from a site as a modern sample. This is done on the assumption that this layer of grains is well bleached. In an active environment (*e.g.*, on a beach) this is probably a fair assumption as the grains are usually in motion every few days or weeks. Nevertheless, it became apparent that a more concrete understanding of the magnitude of light attenuation through a given thickness of sediment is desirable.

A search of available literature revealed little data to aid in this understanding. Others have studied the bleaching process (*e.g.*, Huntley, 1985; Berger, 1990; Gemmell, 1994; Huntley and Clague, 1996) and most review papers on the subject (*e.g.*, Berger, 1995; Huntley and Lian, 1999) suggest various mechanisms for incomplete bleaching (*e.g.*, overlying water, rapid burial, coatings on grains, etc.). However, the only paper found directly related to this topic was that of Ditlefsen (1992) who investigated the bleaching of K-feldspars in turbid water suspensions. His approach was to bleach samples in different suspensions and then measure their luminescence and compare it to that of unbleached grains. He showed that in dense suspensions (> 0.05 g/l) little bleaching took place. This led him to consider the limitations of using optical dating techniques to obtain ages for water-laid sediments.

From Ditlefsen's (1992) results one can infer that light attenuation through dry sediments should be very rapid. The purpose of this study was to test this idea. The key variables were assumed to be: (i) sediment thickness, (ii) grain size, and (iii) light wavelength. Transmission of light through sand can happen in two ways: (i) transmission through grains, and (ii) transmission through spaces between grains. It was assumed that most of the light would be transmitted through spaces between grains although this was not tested. It was expected that light transmission would decrease exponentially with sand thickness. It was also expected that light transmission would decrease with decreasing grain size because, although the pore volume would be unchanged, there would be more reflections at grain surfaces and during each reflection a significant fraction of the intensity is not reflected. Given that the sand tested contained different minerals (*e.g.*, quartz, K-feldspar, etc.), a variation in light transmittance with wavelength was anticipated although the nature of such an effect was unknown. In order to test the hypotheses, a series of measurements were made at different light wavelengths of transmittance through various thicknesses of sand grains from a variety of size classes.

**Sample collection, preparation and measurement**

A large (~ 1 kg) sand sample was collected at Cape Jourimain, New Brunswick. In the laboratory it was rinsed with distilled water and then dried for 24 hours at 105°C. It was then sieved, in batches, to extract the following size fractions: -2.0, -1.0, -0.5, 0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 ϕ. In each case the size fraction value is that of the smallest grains in a fraction (*e.g*, the 1.0 ϕ fraction contains grains that fit through a sieve with 0.5 ϕ openings but not through a sieve with 1.0 ϕ openings). The mm equivalents for each ϕ size are provided in Table 1.

A custom holder was machined to hold a pair of standard microscope slides (25 mm x 75 mm x 1 mm thick) at the following spacings: 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 7.0, 9.0, and 11.0 mm. To establish a reference prior to each measurement, transmittance for a given spacing with no sample was measured from 320 to 820 nm at 2 nm increments using a Hewlett Packard 8452A diode-array spectrophotometer. Sand grains from a given size class were then poured into the space between the two microscope slides and transmittance measured from 320 to 820 nm at 2 nm increments. The instrument used is a single-beam, microprocessor controlled, UV/VIS spectrophotometer with collimating optics. The beam is 6 mm x 8 mm and its intensity is approximately 28 mW·cm$^{-2}$. Wavelength accuracy is ±2 nm and wavelength reproducibility is ±0.05 nm. The lower limit of measurable transmittance is 0.05 %. Some grain-size classes could not be measured at some spacings because the grains were larger than the space between slides. All results presented are for the mean of two independent trials.

| Grain-size class | | Sand thickness required to reduce T to ≤ 0.05 % |
|---|---|---|
| (ϕ) | (mm) | (mm) |
| -2.0 | 4.00 | 7 |
| -1.0 | 2.00 | 5 |
| -0.5 | 1.41 | 5 |
| 0 | 1.00 | 4 |
| 0.5 | 0.71 | 3 |
| 1.0 | 0.50 | 2 |
| 1.5 | 0.35 | 1.5 |
| 2.0 | 0.25 | 1 |
| 2.5 | 0.18 | < 1 |
| 3.0 | 0.13 | < 1 |
| 3.5 | 0.09 | < 1 |
| 4.0 | 0.06 | < 1 |

***Table 1.***
*Thickness of sand required (in mm) to reduce the transmittance of incident light to 0.05 % or less (the lower limit of the instrument used is 0.05 %) for the grain-size classes tested for incident light wavelengths from 320 to 820 nm. Transmittance was found to be independent of wavelength so this variable is not included in the table.*

**Measurement results**

Representative examples of the results obtained are presented in Figures 1 and 2. As expected, transmittance was found in all cases to decrease approximately exponentially with increasing sand layer thickness. For example, Figure 1(a) shows transmittance of about 7 % for a 1.5 mm thick layer of grains from the 1.4 mm size class; transmittance drops to about 1 % for a 3.0 mm thick layer of the same grains. Figure 1(b) shows that transmittance is only about 1 % for a 1.5 mm thick layer of grains from the 0.7 mm size class. It was also found that transmittance decreases approximately exponentially with decreasing grain size. For example, Figure 2 shows the rapid decrease in transmittance with decreasing grain size for a layer of sand 1 mm thick. As Figures 1 and 2 also indicate, no observable dependence on incident light wavelength was found.

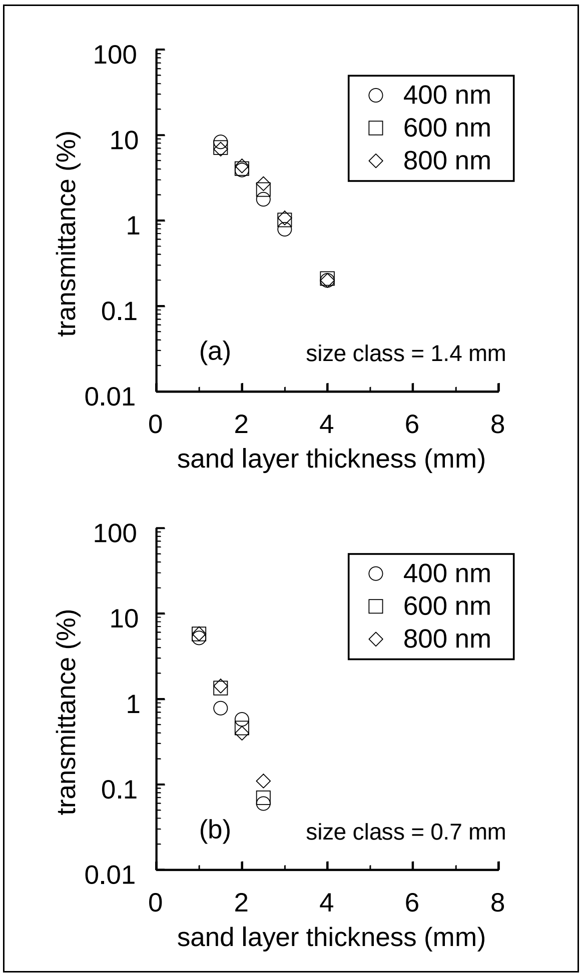


***Figure 1.***
*Relationship between light transmittance and sand layer thickness for light at 400, 600, and 800 nm for the (a) 1.4 mm, and (b) 0.7 mm grain-size classes.*

Table 1 shows the thickness of sand required (in mm) to reduce the transmittance of incident light to 0.05 % or less for the grain-size classes tested. These data show that a sand layer thickness of 7 mm is sufficient to reduce the transmittance of incident light to 0.05 % or less at all wavelengths tested for any grains smaller than 4 mm in diameter. They also show that a sand layer thickness of 1 mm is sufficient to reduce the transmittance of incident light to 0.05 % or less for all wavelengths tested for any grains smaller than 0.25 mm in diameter.

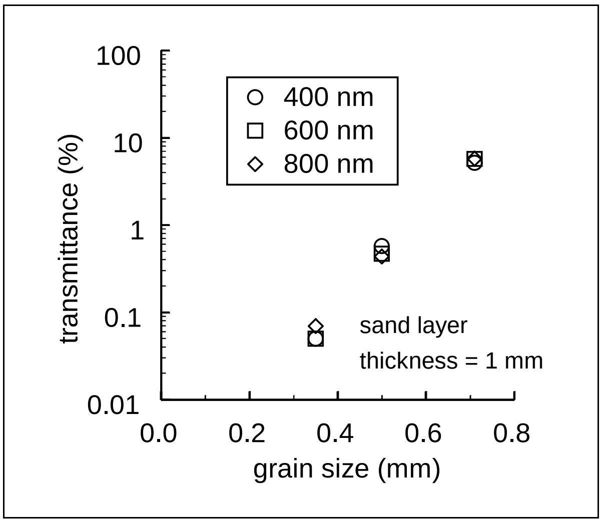


***Figure 2.***
*Relationship between light transmittance and grain size for light at 400, 600, and 800 nm for a layer of sand 1 mm thick.*

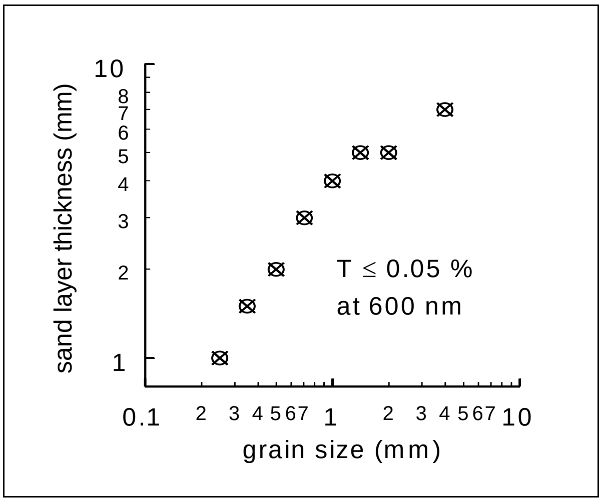


***Figure 3.***
*Sand layer thickness required to reduce the transmittance of 600 nm incident light to 0.05 % or less (the lower limit of the instrument used is 0.05 %) for the 8 largest grain-size classes tested.*

Figure 3 summarizes the results presented in Table 1 for 600 nm incident light. It shows the sand layer thickness required to reduce transmittance to 0.05 % or less for a given grain-size class. Although there is scatter in the data, primarily due to the fact that discrete sand layer thicknesses were used, the nature of the relationship is apparent.

## Discussion and conclusions

The results show that light transmittance decreases approximately exponentially with increasing sand layer thickness and with decreasing grain size. The greatest amount of scatter in the data was for the larger grain sizes. This may be due to much greater variability in the packing of the larger grains which tend to be more angular than their smaller diameter counterparts. In supplemental testing, tapping the microscope slides to consolidate grains in the larger size classes (≥ 2 mm) resulted in reductions of transmittance by a factor of two or three. For grains from the smaller size classes (≤ 1 mm), tapping the microscope slides had no measurable effect on transmittance. Note that 'natural sands' are likely to be well packed and include a variety of grain sizes and thus transmittance through them is likely to be much less than what is reported here for sands with a very limited grain-size range.

No relationship between light transmittance and incident light wavelength was observed. This does not mean that a relationship does not exist but it does suggest that light wavelength is not an important variable in predicting rate of light attenuation through dry sand where more than a monolayer is present. It may also be an indication that, as assumed, most of the light is being transmitted around the grains rather than through them.

The results indicate that for any sand, a layer with a thickness of 7 mm, and possibly much less, is capable of reducing the transmittance of incident light to 0.05 % or less. This should be taken into account when collecting a surface sample as a modern analogue for a sample to be optically dated. As suggested previously, collecting the top 10 mm of a sand in an active environment is probably reasonable since one would expect most of the grains to be in motion every few days or weeks and thus be well bleached. In a less active environment (*e.g.*, the bed of a sheltered lake), making this assumption is probably not wise. One should try to collect only the actual surface grains as a modern analogue in this case. One technique for doing this is by using adhesive tape as first described by Readhead (1984).

## Acknowledgements

Lynn Borse (field assistance), Karen Sekikawa and Marie Tower (laboratory assistance), Al MacDonald (machining assistance), and John Read are thanked for helping with this project. David Huntley, Jack Rink and John Prescott are thanked for their advice and for commenting on drafts of this paper. Financial support was provided by the Natural Sciences and Engineering Research Council of Canada.

## References

Aitken, M.J. (1998). *Introduction to optical dating*. Oxford University Press, Oxford.

Berger, G.W. (1990). Effectiveness of natural zeroing of the thermoluminescence in sediments. *Journal of Geophysical Research*, **95**, 12375-12397.

Berger, G.W. (1995). Progress in luminescence dating methods for quaternary sediments. *In*: Rutter, N.W. and Catto, N.R. (eds), *Dating methods for Quaternary deposits*, pp. 81-104. Geotext2, Geological Association of Canada, St. John's.

Ditlefsen, C. (1992). Bleaching of K-feldspars in turbid water suspensions: a comparison of photo- and thermoluminescence signals. *Quaternary Science Reviews*, **11**, 33-38.

Gemmell, A.M.D. (1994). Environmental controls on the TL age of modern (zero-age) proglacial outwash sediments. *Quaternary Geochronology (QSR)*, **13**, 485-489.

Huntley, D.J. (1985). On the zeroing of the thermoluminescence of sediments. *Physics and Chemistry of Minerals*, **12**, 122-127.

Huntley, D.J. and Clague, J.J. (1996). Optical dating of tsunami-laid sands. *Quaternary Research*, **46**, 127-140.

Huntley, D.J. and Lian, O.B. (1999). Using optical dating to determine when a sediment was last exposed to daylight. *In*: Lemmen, D.S. and Vance, R.E. (eds), *Holocene climate and environmental change in the Palliser Triangle: A geoscientific context for evaluating the impacts of climate change on the southern Canadian prairies*, pp. 211-222. Geological Survey of Canada Bulletin 534, Ottawa.

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

Wintle, A.G. and Huntley, D.J. (1982). Thermoluminescence dating of sediments - A review. *Quaternary Science Reviews*, **1**, 31-53.

Wintle, A.G., Lancaster, N. and Edwards, S.R. (1994). Infrared stimulated luminescence (IRSL) dating of late-Holocene aeolian sands in the Mojave Desert, California, USA. *The Holocene*, **4**, 74-78.

## Reviewer

J.R. Prescott

**Comments**

This is a useful piece of laboratory work in support of field measurements and is helpful in interpreting them. It is surprising how little direct laboratory work of this kind has been reported. Since it also good physics, it appeals to me. My generation would probably ask, "What did Rayleigh say about it?" The exponential absorption relation and its eventual breakdown would come as no surprise to him. For clean quartz, no wavelength dependence is expected for particles in this size range. In the wider luminescence dating world, almost everyone one who has tried it, finds that the surface layer 0.5-1.0 cm has a small but non-zero age, and/or that quartz bleached in layers in the laboratory reaches a lower level than surface quartz collected in the field. The present paper throws some light on this, if the play on words may be forgiven.

Such measurements were carried out quite early in the application of luminescence techniques to sediments. Ollerhead refers to Readhead's thesis (1984). This relatively inaccessible reference contains an account of considerable laboratory work, which was also reported, in part, at the Cambridge LED meeting: Readhead, Quater. Sci. Rev. 7, 257-264 (1988). Historians may also care to look up the Helsingor LED Conference Proceedings at: Council of Europe Journal PACT 9, 505-512 (1983). Modesty forbids naming the author.

It is worth adding that there is a difference between TL and OSL in that some samples are never completely zeroed for TL, no matter how long they are exposed to sunlight.