Geochronology in the Light

Luminescence Dating: A Critical Review of a New Technique

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I RECENTLY found myself in the unusual position of working in the field of geochronology, seeking to establish radiometric age estimates of river deposits for a doctoral thesis, whilst subsequently, by the grace of God, becoming convinced of a six day creation, young Earth and a global Flood. As such, this provided me with a rare opportunity for a specialist assessment of a developing dating technique in the light of biblical truth. In order for objective scientists to stay well-informed of new techniques, this résumé has been put together.

At the outset, it must be asserted that the word 'date' or 'age' is a misnomer. All good geochronologists are aware of the limitations of their techniques, consequently the numbers produced are, within the field, referred to as 'age estimates' and never as absolute. Unfortunately over-zealous geologists and the media take these numbers as absolute and (almost) without error, leading to the citation of age estimates as 'dates.' Geochronology, however, is a very inexact science.

Luminescence dating is a recent development in the broader field of geochronology which is applied to sediments of Late Quaternary origin (the Quaternary is the most recent part of the geological column, the Late Quaternary is the period of time preceding, during and following the last ice age, geologically speaking the last 130,000 years). It differs from radiocarbon and uranium series methods in being applied to sediment grains, usually quartz or potassium feldspars, rather than secondary precipitates or organic matter. The technique relies upon the resetting of the luminescence signal by light (when applied to sediments) or heat (when applied to pottery). In order for the reader to grasp the concepts involved in this technique, a simplified overview of the fundamental principles is outlined below.

Basic principles

When a mineral is formed by crystallisation from magma, its crystals will contain impurity atoms and other defects. Some defects are attractive to free electrons which are produced in abundance by nuclear decay of radioactive elements, notably uranium, thorium and potassium–40. Electrons thus become trapped within the defects in the crystal. As time passes, so more electrons are trapped. Defects/traps may be emptied of electrons by exposure to light (bleaching) or heating (at temperatures >300°C), at which point zeroing is said to have occurred, *i.e.* the luminescence signal, which is a product of the trapped electrons and described below, is set to zero. Luminescence techniques attempt to obtain a measure of the number of electrons that have accumulated over time in the lattice defects since the last exposure of the sediment to light (or pottery to heat)—*i.e.* the last zeroing event. Artificial exposure of the sediment grain to light (optically stimulated luminescence [OSL]) or heat (thermoluminescence [TL]) will release a portion of the trapped electrons. As electrons are released, some of them will combine at specialised defects / traps in the lattice known as luminescence centres (Aitken, 1985), such combinations release a photon of light per combination. The number of photons given off following exposure to light (OSL, see Aitken, 1992) or heat (TL, see Aitken, 1985) is detected in luminescence dating, with the principle being that the more light detected, the more electrons trapped, the larger the palæodose (amount of radiation received over time), thus the older the zeroing event (deposition of sediment or firing of pottery).

Luminescence age calculation

Luminescence age is calculated by the following formula:

$$\text{luminescence age} = \frac{\text{palæodose (Gy)}}{\text{dose rate (Gy/ka)}}$$

The palæodose, *i.e.* the amount of radiation received by the sediment over time, is measured by detecting light emissions following luminescence stimulation (described above). This is measured from the natural sample of sediment and subsequently on a sample of the same sediment which is dosed by a known amount of radiation, measured in grays (Gy). This is repeated, increasing the dose successively 4 to 5 times, producing a curve which shows the increase in luminescence signal with dose (Figure 1). The curve is then extrapolated back to the intersection with the x axis (zero luminescence signal) to define the palæodose of the sediment.

The dose rate, *i.e.* the rate at which the palæodose accumulated or the rate at which the sediment received radiation over time is then calculated, usually on the basis of grays per thousand years (ka). This is established by measuring the radioactivity of the modern sample, achieved by measuring the products of radioactive decay, *i.e.* β and γ emissions, together with the U, Th and K contents. The more radioactive elements in the sample, the greater will be these emissions, thus the higher will be the dose rate. Dividing the palæodose by this dose rate therefore gives an estimation of age.

Thus a high palæodose/large emission of light from a natural sample will be expected either where the sample is deemed 'old' or where it is more recent, but the dose rate is high. For the same palæodose, the higher the dose rate, the younger the sample.

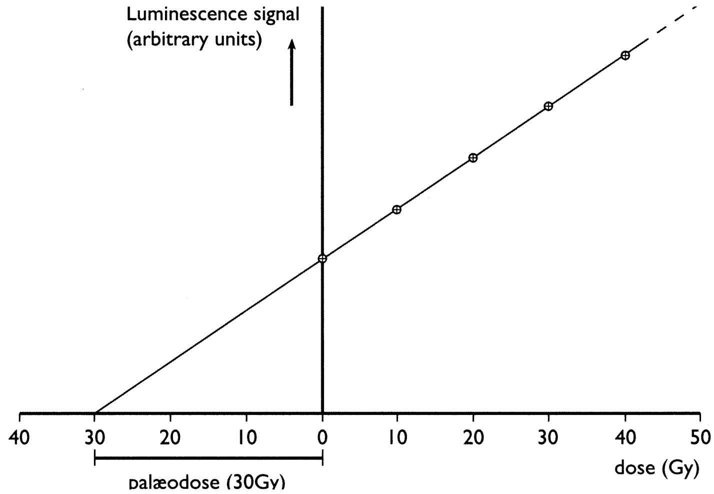

Figure 1: Construction of a growth curve using the luminescence signal of irradiated samples (10 to 40 Gy) and the natural sample (0 Gy). A best fit curve is constructed between these points and extrapolated to the x axis, in this case giving a palæodose of 30 Gy. The graph is entirely illustrative.

Limitations and assumptions

What we need to know when presented with luminescence ages in the scientific literature and via the media is what they actually represent. As the computation of any luminescence age is a two-stage process (palæodose and dose rate calculations), there is plenty of room for error, such that even within the geochronology fraternity, age estimates with a 10% error each way are common place and accepted. Any luminescence age is really a statement of statistical probability, purely resulting from the way it is calculated and the number of components which go into establishing it, which may be illustrated by listing the stages in determining dose rate:

1. Measurement of a dose rate based on U and Th content measured using thick source alpha counting.
2. Measurement of β dose rate using thick source beta counting (Sanderson, 1988).
3. Measurement of 40K (where grains of potassium are being measured) using geochemical determinations *e.g.* ICP-MS or AAS).
4. Measurement of γ ray contribution.
5. Estimation of cosmic ray contribution, based on depth of sample (assumed constant) (Prescott & Hutton, 1988).
6. Measurement of water content of the modern sample and an estimation of the most likely content in the past (water also attenuates radiation in the sediment body, the more water the greater the attenuation).
7. Measurement of sediment grain size (this attenuates radioactivity in the sediment grain—the larger the size, the greater the attenuation).
8. Estimation of alpha efficiency value (based on grain size and mineralogy) (Mejdahl, 1987).

Each of these stages of measurement introduces error into the procedure, which accumulate as they are put together as a dose rate and luminescence age. Consequently luminescence dating can only be a statement of probability, never of fact, even if the numbers are accepted and acceptation of the numbers even then may not be warranted.

Additionally, there are a number of limitations which question the whole basis of the technique and which may explain why, in a young Earth, ages >100,000 years are being obtained:

1. Complete zeroing of sediments at time of deposition is assumed, but often incorrectly. Experiments using sediments from a variety of sediment environments (æolian (Wintle, 1993), marine (Balescu & Lamothe, 1994), fluvial (Fuller *et al.*, 1994), glacial (Duller, 1994)) have demonstrated the existence of a residual luminescence signal—*i.e.* no matter how much the sample is exposed to natural light conditions, there always remains a residual number of electrons. The size of this residual is variable according to sample and the precise method of measurement used. The larger the residual signal, the greater the overestimation of luminescence age. Attempts have been made to correct for the residual level, but in reality it is impossible to determine.
2. A constant U, Th and K content is assumed over time. However uranium is soluble and may be leached away if water flows through sediments, either as infiltrating rainfall or percolating groundwater. If there has been substantial leaching of uranium, the dose rate measured in the laboratory will underestimate the real dose rate over time, resulting in an overestimation of age. This is a major limitation as the water content of any sediment body will have varied over time and water will have percolated through virtually every sediment body at some stage.
3. Sample preparation may create spurious luminescence—sediment samples usually require disaggregation, involving crushing and grinding with a pestle and

mortar, but such activity may result in additional luminescence signal when measured, leading to overestimation of luminescence age.

There may well be additional physical based reasons for the failure of luminescence dating. Those that are presented are those with which the author has become most familiar through his own research and is therefore best able to comment upon.

Conclusions

As objectively thinking scientists, we must be able to challenge so-called dates which are put around in scientific literature and media presentation. We can only have grounds to do this if we are familiar with the methods and their limitations, assumptions and flaws. This short paper has sought to communicate something of those which are associated with luminescence dating, a technique which is becoming increasingly used as part of the challenge to Bible truth.

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Following a B.Sc (Hons) degree in Geography (1989–92), the author undertook research applying luminescence techniques to river sediments, leading to a Ph.D. at the University of Wales, Aberystwyth (1992–95). He is currently lecturing in Physical Geography at the University of Northumbria, Newcastle, now researching contemporary and historic fluvial processes, although maintaining links with the geochronology fraternity.

Green Islands

Joachim Scheven

ANYONE strolling through an oak or beech forest in the autumn is sure to find them: among the innumerable brown leaves scattered on the ground lie some which are still green in one corner. Very green, in fact! On closer inspection, we discover there is a whitish spot or a winding brownish tapering trail—a 'blotch mine' or a 'linear mine.' The larva of a tiny mining moth is living inside the leaf. Leaf mining species also occur among beetles and flies.

Why do the infested leaves not turn completely brown like the rest? The larva excretes a hormone that keeps the surrounding area of the leaf fresh. The cells of these 'Green Islands' continue to assimilate food! And the larvæ live on the carbohydrates thus formed even after the leaf has dropped to the ground and has died. Only some time later do the larvæ leave the leaf and enter the ground to pupate.

This presents some riddles for adherents of evolution:

—Which were the first caterpillars to stumble on the idea of no longer gnawing the leaves from the outside but of crawling into their insides?

—How could the larvæ, that were thus transformed, know that 'our tree will shortly shed its leaves' so as to prepare for that event?

—What would have happened if the mining caterpillars had failed, at their very first attempt, to synthesise the right hormone, which alone guarantees that they can continue to live on the forest floor?

—What should we make of the fact that such leaf mines are found in the geologically very-oldest fossil leaves of