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THE DATING OF NEANDERTHAL SITES

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Abstract: This paper begins with a review of the range of techniques which are available for the absolute dating of sites of Neanderthal age. Descriptions are given of the types of material that are commonly dated, and the circumstances in which it is useful to measure their ages. Some of the difficulties that are faced by dating laboratories are then explained, with consideration of the different types of uncertainties that are inherent in date measurements. It is emphasised that no dating technique is invariably accurate, and that a comparative dating study, involving several methods, is the most reliable means of determining the age of an archaeological event.

Key Words: Uranium series dating, thermoluminescence dating, error analysis.

Absolute Dating Techniques

The techniques for dating archaeological materials can be divided into two classes: those which produce absolute dates and those which give relative ages. Absolute dating methods yield results directly in terms of calendar years. The principal techniques of absolute dating which are useful for Neanderthal sites include uranium series disequilibrium dating, thermoluminescence (or TL) and electron spin resonance (or ESR) dating. Contrasting with these, relative dating methods provide floating chronologies, which require a procedure of calibration before their findings can be presented as calendar dates. Measurement techniques that require calibration include radiocarbon dating and amino acid racemisation. While relative dating methods are valuable in a large number of cases, it is clear that calibrated results cannot be more precise or reliable than the absolute dates against which they are calibrated.

Uranium series dating has been most commonly used to date speleothems, and has found wide application in dating stalagmitic floors in cave sites. The TL technique is also applicable to dating stalagmites, but is also used to date the heating of flint and stone by fire, and the deposition of sedimentary material. The ESR method is closely related to TL, but has been applied mainly to dating teeth.

Uranium series dating of stalagmite

Uranium series dating makes use of the radioactive decay of U-234 into the isotope Th-230, which itself is unstable with a half-life of 75,000 years (Ivanovich & Harmon 1982). When stalagmites are newly formed, they incorporate small amounts of uranium, but much lower concentrations of thorium. The subsequent slow increase of Th-230, from decay of the uranium, provides a measure of the stalagmite's age. This technique can date speleothems up to 350,000 years old, at which age Th-230 is close to equilibrium with other isotopes of the uranium series.

In many archaeological cave sites, in situ stalagmitic floors provide easily identifiable marker horizons. These floors indicate an interval of time between the emplacement of the underlying sedimentary unit and the deposition of the overlying unit. It is often difficult to measure the ages of cave deposits directly, but the stalagmitic floors can be dated with relative ease, and often provide a reliable chronology of the emplacements.

TL dating of stalagmite

The TL dating method can be applied to various geological materials (Aitken 1985). It makes use of the property of many crystalline materials to record the amount of radiation dose to which they have been exposed. Figure 1 shows a thin slice cut from a portion of stalagmite, which is being heated at a rate of 2.5°C per second. It has reached a temperature of 275°C, where there is a maximum in the intensity of the luminescence which is being emitted from the slice. This is the phenomenon of thermoluminescence, or TL. The spatial pattern of the TL has been made visible for photography with the aid of an image intensifier tube (Walton & Debenham 1980, 1982). It shows bands of varying TL intensity which correspond to different growth layers in the stalagmite.

The phenomenon of TL can be used to date the stalagmite because the intensity of the emitted TL is related to the

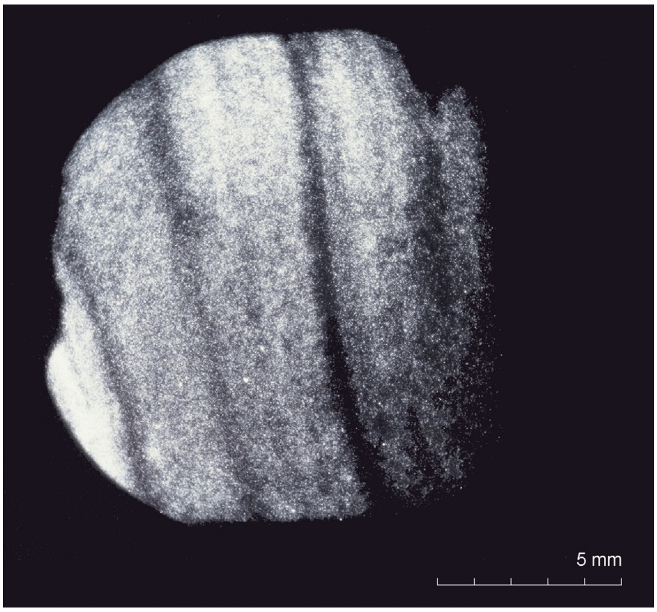

Figure 1. TL emissions from a thin slice cut from a stalagmite. The slice is undergoing heating at a rate of 2.5°C per second and has reached a temperature of 275°C. The spatial pattern of the TL was photographed using an image intensifier tube (Walton & Debenham 1980, 1982). The bands of varying TL intensity coincide with growth layers in the stalagmite.

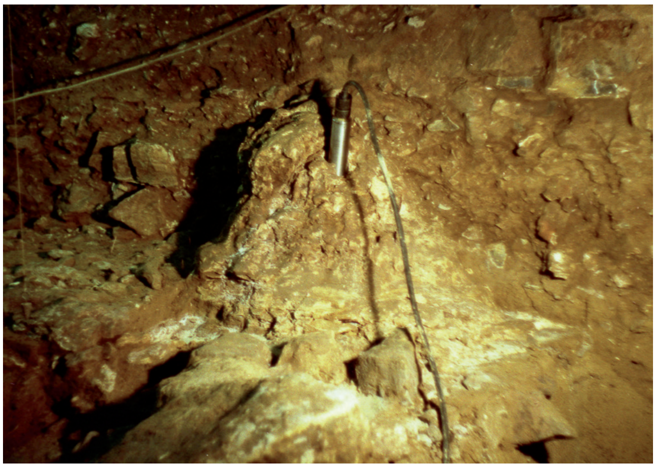

Figure 2. Measurement of gamma radiation intensity inside a large stalagmitic boss using a portable spectrometer. The stalagmite has been drilled with a coring machine, and a sample for TL dating has been obtained from the core. The detector of the spectrometer occupies the same position as the TL sample, and is recording gamma rays emanating from the stalagmite and underlying sediment.

total radiation dose that the calcite has received since it was formed. It is therefore possible to measure this quantity of radiation by means of TL observations. If both the total amount of radiation absorbed and the rate at which the dose was delivered are known, then the age of the stalagmite can be calculated.

Radiation is naturally present in all environments in the form of alpha, beta and gamma rays from radioactive elements, and also as cosmic radiation. Figure 2 shows a measurement of gamma radiation in La Grotte Scladina, Sclayn. A large stalagmitic boss has been drilled with a coring machine, and a sample has been taken from the core for TL examination. A gamma radiation detector has been placed in the hole, so that it occupies the same position as the TL sample. Gamma rays have a maximum range of approximately 30 cm, and the detector is recording the number and energies of gammas which are reaching it from other parts of the stalagmitic boss and from the underlying sediment. The detector is also counting the number of cosmic rays passing through the stalagmite.

Alpha and beta radiations are both short-range radiations. Their intensities can be determined in the laboratory from measurements of the stalagmite's radioactivity. When all the components of the radiation dose-rate have been measured, its total value can be combined with the TL measurement of the absorbed dose to yield the age of the stalagmite.

TL dating of heated flint and stone

The TL dating procedure for flint is similar to that for dating stalagmite (Valladas 1992). The main difference is that the flint needs to have been heated in antiquity in order that its age can be measured. In fact, the TL date refers to the heating of the flint, and a temperature of 400°C or more is necessary to make the date measurement possible. It is sometimes difficult to decide whether the heating was caused by human agency or by natural fire, but it is certain that, in order for the flint to reach a high temperature, it must have been lying on the surface of the ground. It follows that, at sites where flint débitage has been rapidly buried, the information provided by TL dating relates directly to the archaeological event.

The useful age range of the TL technique for dating flint extends from a few millennia to several hundred millennia. The method is well suited to dating Neanderthal sites, since they fall within the central part of this age range. It is equally applicable in both caves and open air sites. The technique has been especially useful in many parts of northern Europe where thick loessic deposits provide ideal conditions for dating heated flint.

TL dating of sediment

The general procedure for TL dating sediment is similar to that used for stalagmite and flint. However, in this case, the event that is dated is the exposure of the sediment grains to daylight (Debenham 1985). The necessary light exposure can only occur if the sediment is transported in a dispersed state over some distance. Thus, the TL method is well suited to dating loess depositions, but can also be applied to fluvial and colluvial sediments. In addition, it is found to be useful for dating buried palaeosols. In this case, the continual cycling of material to the surface by bioturbation, over a long period of soil formation, results in the entire volume of the soil receiving an exposure to light.

Date Information

The information that the archaeologist receives from the dating laboratory is summarised by two numbers. The first is the "age" of the dated event. This should be understood as the central value of the age range which is indicated by the date measurement. The age is of most value to the archaeologist when it is presented in absolute units, i.e. in calendar years. The second number gives the half-width of the measured age range, often referred to as the "error". Adding these two numbers gives the upper limit of the age range, and subtracting them gives the lower limit. The meaning conveyed by the two numbers is that there is a 68% probability that the actual date of the event lies between the upper and lower limits of the age range. It should be noted, however, that radiocarbon laboratories normally quote date limits which correspond to a probability of 95%.

Using this information, it is theoretically possible to estimate the likelihood that, for instance, one site predates another. Alternatively, the archaeologist may want to compare the date information for the human occupation with other measurements attached to environmental and climatic data. For these purposes, it is important that the age range indicated by the date measurement should be as realistic as possible. The question therefore arises: Do the error limits express all the uncertainties which affect the date measurement?

Sources of uncertainty

Three categories of uncertainties can be distinguished. The first category includes all uncertainties attached to measurements made in the laboratory or in the field. Scientists feel entirely confident about handling this type of uncertainty, and have well-established techniques for quantifying them. For this reason, measurement uncertainties are always included in the error limits which are attached to date information.

The second category includes uncertainties which are less easily quantified. In all dating procedures, there are complicating factors which adversely affect the measurement of the true age. In uranium series dating, attempts are often made to estimate the effect of the Th-230 which was already present in the speleothem at its formation, and to correct the measured dates accordingly. In TL dating, consideration must be given to how radiation levels may have varied in the past, and to the effect of such changes on the calculated date. All of these corrections carry an additional uncertainty which should be included in the error limits of the final date.

There is a third category of uncertainties which dating laboratories are unable to quantify, and which therefore are never expressed in the error limits of the age. These uncertainties result from failures of the basic assumptions on which the dating method rests.

Basic assumptions

It is worth remembering that dating laboratories do not measure time directly. Instead, they measure such things as isotopic ratios and intensities of luminescence. Time is an inference which is drawn from these measurements, based on assumptions about the initial state of the measured system, and the manner in which the system has evolved from its initial state. It follows that technical advances in our ability to measure isotopic ratios or signal intensities do not automatically lead to improvements in dating accuracy.

The basic assumptions differ among the dating methods. In uranium series dating, and also in radiocarbon dating, it is assumed that the sample has behaved as a perfect time capsule throughout its history; in other words, that it has been completely sealed from its environment. This supposition requires that there has been no movement of the relevant isotopes into or out of the sample.

In TL dating, various assumptions are taken depending on the material under examination. In the dating of heated flint, it is assumed that the sample was not reheated at a time significantly later than its use. In the case of stalagmite, there is the possibility of the material undergoing recrystallisation after its initial formation. If this has happened, the TL date may refer to the recrystallisation, rather than to the original formation of the sample. The dating of sediment is based on the assumption that the material was fully exposed to light at the time of its deposition. However, some mechanisms of deposition do not allow an adequate exposure, and the TL date will then refer to an earlier transportation of the material.

In all the above cases, it is not possible to detect failures of the basic assumptions directly, or to quantify the uncertainties that they transfer to the date measurement. However, this does not mean that it is impossible to reach a more realistic understanding of the uncertainties attached to date information. Fortunately, a way forward is suggested by the fact that, while all dating techniques are subject to unquantifiable uncertainties, they are not affected in the same way by the various circumstances that cause the errors. The methods can, in varying degrees, be regarded as independent of each other. To the extent that the errors are uncorrelated, comparisons between the results of different dating techniques will reveal the hidden uncertainties that affect them.

Comparative Dating Studies

It may be argued that, since all absolute dating techniques involve radioactivity in the natural environment, their results cannot be regarded as independent measurements. However, a distinction can be drawn between techniques which involve the observation of one particular isotopic ratio, such as uranium series and radiocarbon dating, and those which rely on the presence of a diverse ensemble of radioactive elements, such as TL and ESR. The dating of a stalagmitic floor can be taken as an example. Uranium series dating of the stalagmite is affected if the sample gains or loses uranium or thorium. In contrast to this, the TL date of the same stalagmite would be influenced by a net movement of all the radioactive nuclides into or out of the stalagmite and its surrounding sediments. In practice, it is unlikely that a given geochemical alteration would affect both dating methods in the same way. To a large extent, therefore, the two methods can be considered to be independent of each other. As a corollary, it is clear that, if uranium series and TL dating are in agreement on the age of a given stalagmite, greater reliability can be attached to the measurements.

One site which exemplifies the coordinated use of several dating techniques is Pontnewydd Cave in Wales (Green 1984; Aldhouse-Green 2005). More than eighty samples from this site have been dated; heated flint has been dated by TL, stalagmitic material was measured by both TL and uranium series techniques, several teeth were dated by ESR, and some bone was also dated by uranium series. The assessment of these data has also involved stratigraphic, faunal and climatic information. The result of this exercise has been twofold; firstly, a chronology has been determined for the human occupation and cave development which is more robust than one based on a single method of dating; and secondly, much knowledge has been gained about how the various dating techniques perform in particular circumstances.

Conclusions

It should be emphasised that the production of date measurements is an essentially impossible scientific task, because much of the information required to produce the date is inaccessible to measurement. As a result, all dating techniques are prone to unquantifiable uncertainties, and none can be considered to be invariably reliable. The best response to this situation is to apply the fullest range of dating methods to each archaeological context. By comparing all the results, hidden uncertainties in the different methods can be revealed. When date measurements from several sources are compared, not only does the archaeologist gain a more accurate view of the age of the site, but the dating specialists also learn more about the limitations of their measurements.

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