

HOW DOES THERMOLUMINESCENCE DATING WORK?

The thermoluminescence technique is the only physical means of determining the absolute age of pottery presently available. It is an **absolute** dating method, and does not depend on comparison with similar objects (as does obsidian hydration dating, for example).

Most mineral materials, including the constituents of pottery, have the property of thermoluminescence (TL), where part of the energy from radioactive decay in and around the mineral is stored (in the form of trapped electrons) and later released as light upon strong heating (as the electrons are detrapped and combine with lattice ions). By comparing this light output with that produced by known doses of radiation, the amount of radiation absorbed by the material may be found.

When pottery is fired, it loses all its previously acquired TL, and on cooling the TL begins again to build up. Thus, when one measures dose in pottery, it is the dose accumulated since it was fired, unless there was a subsequent reheating. If the radioactivity of the pottery itself, and its surroundings, is measured, the dose rate, or annual increment of dose, may be computed. The age of the pottery, in principle, may then be determined by the relation

$$\text{Age} = \text{Accumulated dose} / \text{Dose per year}$$

Although conceptually straightforward, TL has proven to be far from simple in practice. In all, close to two dozen physical quantities must be accurately measured to establish the relationship between doses of different kinds of radiation and light output, and to compute dose rate. A leaflet from Daybreak describing the TL technique in more detail and giving a bibliography will be provided to interested persons.

The phenomenon of thermoluminescence was first described by the English chemist Robert Boyle in 1663. It was employed in the 1950's as a method for radiation dose measurement, and soon was proposed for archaeological dating. By the mid-1960's, its validity as an absolute dating technique was established by workers at Oxford and Birmingham in England, Riso in Denmark, and at the University of Pennsylvania in the U.S.. The Research Laboratory for Archaeology at Oxford, in particular, has played a major role in TL research.

While not so accurate as radiocarbon dating, which cannot date pottery (except from soot deposits on cooking pots), TL has found considerable usefulness in the authen-

ticity of ceramic art objects where high precision is not necessary.

Since the university and museum laboratories involved with TL are research facilities, they generally will not accept art objects for authentication on a routine basis. The TL laboratory at Daybreak was established in 1977 to make TL available to the art community in general.

WHAT IS THE ACCURACY OF TL DATING?

Studies indicate that when all quantities entering the age equation are measured, the TL date of a single potsherd will typically fall within 15 per cent of the known date. When dates of a number of sherds associated together are averaged, the error is reduced typically to 7-10 per cent.

Unfortunately, it is not possible to achieve this precision for the majority of art objects. Among the reasons for this is the small amount of material that may be taken for testing. Drilling, the usual method of sampling, introduces some uncertainty. It is also rare that any information about the radiation from the burial soil can be obtained, as art objects are usually thoroughly cleaned. This radiation may in some cases contribute over half the total dose. Finally, one has to make the measurements regardless of whether the TL of the clay is well-behaved or not. Some clays are hardly thermoluminescent at all; some may not have a straight-line relationship between dose and TL; spurious luminescence due to chemical or pressure effects may mask the radiation-induced TL; occasionally, a condition called "anomalous fading", where part of the TL is unstable, may lessen the accuracy of the dose measurement.

Generally speaking, when a sample is drilled and there is no information available about the burial environment, one may expect an uncertainty up to 40 per cent of the TL age. This is adequate for the purposes of authentication where the question is whether the piece was fired in antiquity or recently; it will not differentiate, say, between a classic Greek terra cotta and a Roman copy. In some categories of objects, from China, for example, the actual age is quite precisely known for shortlived styles, and it is possible to work "backwards" to get information about the environment in many parts of the world, and some other parameters not usually measurable for art objects. Using this information often reduces the uncertainty to 15-25 per cent.

WHAT MATERIALS CAN BE DATED BY TL?

Nearly any mineral material which has been heated above 500C at a time one wishes to know is a candidate for TL dating. This includes all forms of pottery. Porcelains, being nearly vitrified, are a special case requiring a fairly large solid core sample, and routine TL dating of intact objects is not recommended because of the damage caused by sampling. Most porcelain dating is done for insurance purposes on broken objects. Much stoneware is not so hard as porcelain and may be sampled by drilling. The clay cores from lost wax metal castings may readily be tested. Heated stone material, such as hearths, pot boilers, and burnt flints, has been dated as well. Some regions known to present problems for TL include Indonesia and West Mexico; objects from these areas usually do not successfully yield TL dates.

HOW IS A SAMPLE TAKEN?

When the TL test is for routine authentication, a sample of about 100 mg, roughly a third the volume of a pencil-end eraser, is drilled out of an inconspicuous part of the object with a carbide dental burr. If the object is extremely small, the amount of sample may be reduced, but the error margin may increase. It is preferable, whenever possible, to obtain a fragment a half-inch in diameter and a quarter-inch thick, as the precision attainable is greater. This is advisable whenever the age, if genuine, is less than twice the age of the earliest forgeries.

If the object to be tested has been restored, it may be advisable to take more than one sample, as the component parts may differ in age or origin. Increasingly, forgeries are fabricated from ancient material, and the TL result may require corroboration by x-rays or other means to establish authenticity.

Sampling does not lessen the value of a piece; indeed, confirmation of antiquity by TL generally enhances an object's value and saleability considerably. The site of the samples may easily be restored if desired.

HOW IS AN OBJECT SUBMITTED FOR A TL TEST?

First, you should contact Daybreak to discuss the advisability of testing and to arrange sample-taking. We make regular trips to New York City for this purpose; travel elsewhere is by arrangement. You may also bring the

piece to Daybreak, located just east of New Haven, CT (about 1 3/4 hours from mid-town Manhattan). We have as well a network of conservators and restorers located throughout the country who can take samples for us (at an additional charge). If these alternatives are not practical, you may ship us the object, at your sole risk. We recommend registered mail as a means of shipment, as the cost of insurance is very reasonable. Please consult us about packing methods.

We recommend that you use our Sample Submission form, available on request, for providing information on the object, and it is necessary to include **two photographs unless the object comes to Daybreak**. One photo is retained in our files for reference; the other is annotated with the result, signed, and returned with the test result. Polaroid snapshots are adequate; it is necessary only that the object be readily identifiable from its picture. If the sample is taken by anyone other than Daybreak or its representative, it is recommended that the sampling be witnessed (as provided for on the Sample Submission form), asserting that the sample is indeed from the object depicted in the photographs. **The sample-taker must sign both photos**. Otherwise, the test report must state that the object submitted is "a fragment (or powder) sample said to be from a _____ of the _____ culture".

It is extremely important to note whether the object is known or is suspected to have been exposed to x-rays or neutrons, as this could alter the results. Exposure to airport security x-rays does not present any problem. Also, if the piece has been heated for some purpose during restoration, the TL result may be affected. In either case, consultation is required to determine whether the object can be accepted for test.

Please be assured that all information about objects submitted is held in the strictest confidence.

HOW LONG DOES IT TAKE?

Usually test results are available verbally within two to four weeks after the sample arrives at Daybreak, with the written report to follow. Rush service (as soon as the next day) may be available at a premium, if our schedule permits. A large number of samples submitted as a group may take longer.

WHAT IS THE COST?

We charge US\$ 310 per object submitted for routine authenticity dating, covering multiple samples from an object if required (a reasonable additional charge may be levied when three or more samples are to be analyzed). In the rare event that we are unable to obtain a reliable TL date after a good faith effort, this fee is reduced, usually to US\$ 150. You will pay return shipping of any object sent to us. Inquire about the charges for porcelains. We now make an additional charge for examination and sampling, due to the increased amount of time we must spend on this. Generally this is a flat fee of \$35 (plus travel expense) or an hourly rate, whichever is less. Sampling by others is charged by them directly to the client.

Quantity rates are available for objects submitted in groups of five or more at the same time: US\$ 285 per TL date (5-9 objects), and US\$ 265 (10 or more). Prices are subject to change without notice.

For further information, please contact Dr. Victor Bortolot, our technical director.

GENERAL REFERENCES

Aitken, M.J., *Thermoluminescence and the Archaeologist*, *Antiquity*, **LI**, 11-19 (1977)

Aitken, M.J., *Thermoluminescence Dating*, Academic Press (London) 359 pages (1985)

Ehlers, E.G., *Thermoluminescent Dating of Ceramic Materials*, *Archaeology*, **28**, 98-101 (1977)

Fleming, S.J., *Thermoluminescence Techniques in Archaeology*, Clarendon Press (Oxford) 229 pages (1979)

ABOUT DAYBREAK...

Daybreak Nuclear and Medical Systems, Inc., was founded in 1977 to produce laboratory systems for TL dating in archaeology and geology, and to provide dating services to the art community. We are the world's leading manufacturer in this field, with more than 100 systems installed throughout the world. In 1994 a second company, the Bortolot Daybreak Corporation, was formed to perform Daybreak's dating services. At the beginning of 2001, our client list for TL dating numbered over 900, including many museums throughout the world. We remain the only commercial TL dating laboratory in the Americas.

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