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EQUIPMENT NECESSARY AND DESIRABLE FOR TL AND OSL DATING

In setting up a laboratory for TL dating, a number of instruments and pieces of laboratory apparatus are absolutely necessary. Some are necessary for certain measurements but need not belong to the TL lab, and some are helpful or labor-saving but not truly necessary for determining TL ages. The following list of the major apparatus needed gives a short explanation of why required, and whether it is necessary. In some cases, where equipment is available elsewhere, such as radiation sources, it may be possible to begin dating with only the TL reader, software, computer, and atmosphere control (vacuum pump and purge gas supply). However, this can limit the amount of work possible and makes one dependent on others' schedules.

The choice of base system will depend largely on whether you will be doing any substantial amount of TL measurement, where an evacuable system is, depending on sample materials, either optional or necessary. While the most versatile of our systems, the 1100, can accomplish both TL and OSL measurements very well, the new 2200 high capacity OSL system is the better choice where the primary technique is OSL, and especially where TL capability already exists in the lab. The 1150 high capacity TL system is designed for additive dose geological measurement where the irradiations are external; now that single aliquot OSL techniques that require multiple irradiations are popular, this is not the best choice. It should also be mentioned that the single aliquot techniques are quite time consuming since there are so many lengthy irradiations. A platter load of 20 disks may take from a day to two weeks to finish, so that high capacity is really not an issue.

The recommendations for TL and OSL are given separately below.

1. **TL reader system**. The 1100 is a general-purpose automated reader that accommodates 20 samples, and can take all the accessory systems, including irradiators and OSL exciters. It also can be used in the single sample mode (as in the 1000 system). While beta irradiations can be done on the 1100 (with the irradiation port and sample elevator, and a 740 beta irradiator plus Sr-90 source), it is recommended that the 801 multiple sample alpha/beta irradiator be used instead since samples should preferably be irradiated and held for 12-24 hours at 100-150C to remove any fading component. This is particularly important for archaeological dating, but in some cases is necessary for authenticity dating as well, when there is

considerable anomalous fading. An alternative option for on-instrument irradiation, especially attractive for authenticity dating and single aliquot techniques, is the model 770 beta irradiator/transfer arm, which moves the irradiator to the 1100 only when required, thus avoiding the troublesome elevated dark count from bremstrahlen radiation from a nearby source. The preheat capability of the ramp cycle can be used to remove part of the fading, but generally not all. When a great number of samples will be measured (as in geological dating), a higher capacity reader system is very desirable. The Daybreak model 1150 has a 57-sample capacity, but does not permit irradiations on the instrument. The IRIS4 quad detector permits recording glowcurves in four wavelength passbands simultaneously, and is useful for characterizing sample emission. An efficient quartz light guide system with large input aperture makes it considerably more efficient than wavelength dispersive systems.

2. **TLAPPLIC/FirstLight software**. This software package is necessary to run the 1100 TL system, and includes not only data-taking functions, but also complete display, subtraction, filtering, shifting, and data analysis. Data analysis includes not only growth curve analysis for archaeological dating, but all current methods of geological dating as well with a very comprehensive fitting suite, plus a complete age computation with error analysis. The TLAPPLIC license covers up to three TL systems in a laboratory, and there are free upgrades for two years. A Windows version, FirstLight, is to released in January 2001, and is a general purpose application for TL, OSL, and, shortly, ESR. It is a major step up from the DOS version, basically a database-centered application, and virtually free of restrictions on size or contents. The fitting suite includes linear, saturating exponential, exponential plus linear, polynomial, and user defined functions. All currently accepted methods are implemented. Please refer to the description of FirstLight for details. Of particular importance is the new script-based data taking, which permits very easy implementation of complex measurement protocols, without having to enter data about each measurement cycle.

3. **Computer system**. While a simple 386SX system (if you can still find one!) is perfectly adequate to run the DOS version of TLAPPLIC, a minimum of a Pentium II at 200 MHz is preferred since it most likely will serve other purposes in the lab as well, and is required for FirstLight. A dot matrix or laser/inkjet printer is needed for output.

4. **Oven atmosphere control.** The glow oven must be evacuated, and then purged with a flow of oxygen- and water vapor-free gas to reduce spurious light signals from the sample. A two-stage vacuum pump of 50-100 liter/minute free air capacity is necessary. An Alcatel 205DSM is recommended as a very sturdy, quiet vacuum pump that should last forever if you change oil frequently. A source of high purity inert gas, nitrogen or argon, is required as a purge and cooling gas. Its purity should be at least 99.999%. Pre-purified grade of nitrogen is sufficient for most purposes. A two-stage regulator (for precise control) is much preferred over the somewhat less expensive single stage variety, and a flowmeter is needed to set and monitor the purge gas flow rate (approximately 2-4 liters/minute). Omega Engineering makes an inexpensive flowmeter that is suitable. **DO NOT** get a flow regulator, as the pressure in the purge gas line gets very high when the purge and cooling gas control valves are turned off, resulting in a "puff" that could disturb the samples when the valves open.

5. **Irradiation system.** It is necessary to have both beta (or gamma) and alpha comparison doses to determine the growth curves of the samples being dated; the reason being that the alpha sensitivity varies a good deal between samples, from 0.02 to 0.40 times the beta (or gamma) sensitivity. It is necessary to get both beta and alpha growth curves for all samples. The 100 mCi Sr-90 and 250 μCi Am-241 sealed sources are appropriate for archaeological dating. If suitable irradiation facilities are available locally, it would be possible to irradiate samples outside the lab for later measurement. It is, however, very much preferable to have your own sources dedicated to TL The 801 multiple sample irradiator is preferred for the reasons mentioned above, but the two-position sample elevator with irradiation port, together with the 740 and 750 irradiators plus sources do present a significant cost savings (about $3000). This savings is reduced if you purchase the 770 beta transfer mechanism, which reduces greatly the increased dark count that results from

the close proximity of the beta source to the PMT when the irradiator is in place on the TL reader system. In situations where the signal level is low, and it is convenient (or necessary) to do beta irradiations during the measurements, the 770 is a necessity.

6. **Alpha counting system.** The major source of radiation dose contributing to the TL of a sample is the uranium and thorium in the pottery itself, and in the surrounding soil. The easiest and most cost-effective means of determining U and Th content is by alpha counting, whereby the alpha activity is measured directly, and the beta and gamma contributions are computed. Since, worldwide, U and Th concentrations may vary by an order of magnitude, alpha counting should be done for every sample. The 583 counter has pairs detection and counting, in addition to the usual totals count, and the U/Th ratio may be determined for increased dating precision in demanding dating programs. The 583 is a printing data logger that also does data reduction, computing the count rate and its uncertainty, plus the U/Th ratio. It has battery-protected memory to save data in case of power failure, although running the counter from an uninterruptible power supply is recommended for power conditioning if the AC line is prone to fluctuations. For high precision, samples on ZnS scintillator screens deposited on mylar and used in sealed counting cells are counted unsealed and then sealed to determine effects of radon loss. For routine authenticity dating, ZnS powder is dusted on cellophane tape in plastic rings for inexpensive scintillator cells. It is recommended that 2-3 sealed cells per counter, plus a supply of scintillator screens be purchased. Counting time will vary from 6 hours to 4-6 days depending on the counting precision desired. For many clays, alpha activity is about 6 counts per kilosecond for a 43 mm scintillator. Eventually, more than a single counter will be needed. The current production is a new standalone model that replaces the now-retired modular packaging. The module packaging will be available while existing stocks of case parts remain, for those wanting to fill existing slots in their 503 enclosures.

7. **Potassium measurement.** Beta and gamma dose from K-40 may contribute 10-50 per cent of the total dose rate, so that potassium measurement is necessary for precise dating (although an approximate range is generally sufficient for authenticity dating). While an atomic absorption spectrometer or flame photometer and appropriate sample preparation apparatus would be desirable, it probably would be more cost-effective to have these measurements done outside the lab. This measurement is simple and fairly inexpensive.

8. **Alternative doserate measurements.** While traditionally, dose rates have been computed from alpha count rates and potassium content, there are other means available. For example, gamma spectrometers are sometimes used to make measurements of the U, Th, and K content of samples and soils. Portable gamma counters (four-channel or multichannel analyzers) and now commonly used for making direct environmental dose rate measurements in the field. Beta counters of various types have been successfuly used also. Unfortunately, all these methods are in the luxury category on account of cost, so most workers in the field start out with just an alpha counter.

9. **Other equipment.** A small amount of additional equipment is needed, mostly for sample preparation. Samples are either drilled (from art objects) powder or crushed sherds. A small highspeed drill or flexible shaft motor with carbide burrs is needed for sample drilling and cleaning. Some inexpensive hobby drills are quite suitable. For crushing sherds, a vise with a stainless steel sheet V-shaped trough to crush and catch the powdered pottery is a simple solution. Samples are prepared by sedimentation in acetone and then deposited on aluminum or stainless steel disks. For this, some glassware is needed--test tubes and shell vials, and sample disks (we can provide aluminum sheet and a punch for cheaply making disposible disks, although some workers prefer stainless steel), and finally an oven for drying the sample disks. A simple lab drying oven is suitable. An automatic pipettor (0.5 ml) with a supply of tips is really necessary here. An inexpensive one like the lower-priced Centaur West models is fine. Lighting in the lab must be very low, and contain no UV component. Red or amber photographic safelights are suitable, as are fluorescent lamps covered with red or amber filters. Low pressure sodium lamps are increasingly used in many laboratories. For OSL measurements, lighting requirements are extremely stringent, as both UV/blue/green AND IR

ambient light are a problem. Special sample preparation techniques are necessary for problem materials, where spurious light emission from the sample interferes with measurements of the radiation-induced TL, and fine grain dating is inappropriate. Here, coarse grain dating is indicated and some means of mineral separation is useful after crushing and sieving (to remove the clumps of iron- bearing fine grains that cause the problem). The usual apparatus is the Frantz magnetic separator that is very often found in geology departments, and so may not need to be purchased.

SPECIAL CONSIDERATIONS FOR SEDIMENT DATING

TL dating of sun-bleached sediments requires a zeroing step in the course of the measurements. For sediment dating by optical bleaching methods, the one indispensible piece of equipment needed in addition to that necessary for pottery dating is a solar simulator for bleaching samples. This may be as simple as a Hg tanning lamp mounted in a box with fixed lamp to sample distance and perhaps a broadband interference filter set for investigating bleaching response as a function of wavelength. Or, if your budget permits, we offer the Sol 2 solar simulator from Dr K. Hönle GmbH in Germany, as an excellent choice. This should be ordered with the H2 filter and a spare lamp. Because the number of sample disks used in sediment dating is greatly increased over pottery dating, it is well worth considering the Daybreak model 1150 TL reader system which has a 57-sample capacity (by stacking three sample platters) for only a small increase in price. This instrument does have the limitation that irradiators may not be fitted to it. For the most part, this should not be a limitation in practice, except for certain specialized methods (pre-dose dating and single aliquot OSL dating).

OSL dating, which measures only the bleachable electron population, does the optical bleaching during the course of complete shinedowns. This avoids the problem of determining the fraction of unbleachable TL signal, since the unbleachable population is never detected, and makes life considerable simpler, especially for young and partially bleached sediments. Because of this, OSL dating has now almost completely supplanted TL, and there is little use for TL in sediment dating except in some techniques like single aliquot regenerative, where sensitivity changes may be monitored by recording low temperature TL during the course of ramping up to a preheat temperature. The low temperature TL is not subject to interference by spurious TL signals, so the 2200 OSL-only system (fitted with the nichrome sample stage) will serve to do this. While it is certainly worthwhile retaining TL measurement capability in the laboratory for those few cases where it is necessary, the lower price and greater simplicity (and ease of service) of an OSL-only system is very much worth considering. It should be noted that with the optional purge gas inlet and control, the 2200 may be used for many TL measurements, even though it cannot be evacuated.

OPTICALLY STIMULATED LUMINESCENCE

Since TL and OSL reader systems share almost all their constituent elements, the most economical means of setting up a combination TL/OSL dating lab is to add the excitation light source as an accessory to a TL reader. To that end, Daybreak offers a number of solutions. The 1100IR/G all solid-state combination IR and green (or blue) OSL exciter is the best choice, superceding all earlier models for general purpose dating. Both IR and blue (or green)excitation power is completely programmable from zero to full intensity (50

mW/cm^2 for IR, and 60 mW/cm^2 for blue). Both IR and blue LED arrays have internal glass blocking filters to reduce detector background. There is, of course, zero maintenance (no lamp replacement). The other possible OSL options are described in the specification supplement. For those interested in OSL alone, the 2200, a new high capacity OSL reader, optimized for OSL, is the best choice. This unit has a number of useful features, including 60-sample removable platter, two temperature controlled stages, one for detection which may be either one based on a thermoelectric module for stable sample temperature in the 0-200C range (that is, cooling as well as heating) or on a nichrome heating plate for ambient to 500C (so TL is possible); the other (optionally heated) is the irradiation stage for elevated temperature irradiations, making preheats unnecessary. The 2200 has additional control of OSL measurement timebase, and supports linear ramping of OSL excitation power. It supports the IRIS4 quad detector, especially useful for IROSL, and the new single grain array green laser scanner that measures more than 80 grains on a single sample disk. The grains are irradiated simultaneously, saving considerable time.

ABOUT DAYBREAK..

Daybreak Nuclear and Medical Systems, Inc., is a small, privately held corporation founded in 1977, which specializes in luminescence (TL and OSL) dating instruments and services. (Daybreak's founder and present Technical Director, Victor J. Bortolot, Ph.D., has been involved with luminescence research and instrumentation since 1971.) We are the world's leading manufacturer of laboratory systems for TL and OSL (optically stimulated luminescence) dating in geology and archaeology with more than 100 systems installed worldwide. Daybreak makes available a wide range of automated and conventional TL and OSL reader systems, nuclear counters, and sample irradiators, and has developed outstanding applications software for luminescence dating.