D.RICHTER

Ancient TL

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"Study the past if you would divine the future." Confucius

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THE REPRODUCIBILITY OF TL DATA FROM FINE GRAIN DISCS

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In the course of studying the TL characteristics of pottery it has occasionally been necessary to sample the same potsherd more than once, and to make up and measure different sets of discs at different times from different pieces of the same sherd. It has been found that although the TL data obtained from these different sets of discs from one sherd may have excellent internal reproducibility with linear growth curve characteristics both on first and second glow, and a good plateau region, nevertheless the values obtained for the equivalent dose, ED, intercept, I, and a value are not compatible. To illustrate this, data from 4 archaeological samples from different sites, and one modern gamma irradiated sherd are presented in table 1. It must be emphasized that,

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considered on its own merits, each of these evaluations for each sherd would be considered entirely acceptable, and yet it can be seen that there are significant variations in all three of the parameters obtained from TL data. In addition it has been found that some sherds, which on one deposition appear to give good linearity in the first and second glow growth curves, may show unacceptable non-linear behaviour on a subsequent deposition, although still with good disc to disc reproducibility.

All of these samples appeared homogeneous, and there was no observable difference in the radioactivity measurements (alpha counting and β TLD) made on the different samples from the same sherd. Thus it must be concluded that the differences in the values of ED, I and a obtained are, at least in part, due to some unknown differences in experimental procedure, rather than to intrinsic differences in the TL behaviour of different portions of the sherd. Fortunately the effect of these variations on the age is often within the experimental error, partly because the spread in the archaeological dose (ED + I) is nearly always less than the variation in the individual values of the ED and I, are partly because the variation in the a value usually tends to compensate for the variations in the ED. Nevertheless this data serves to illustrate the often repeated warning that all of the TL measurements necessary for a fine grain date should be obtained from discs from a single deposition only. It is very unsafe to use, for instance, an ED from one deposition, and an I from another.

Table 1

TL data obtained different depositions of the same potsherd

Sample	ED(rads)	σ	I(rads)	σ	a	σ	Age(years)	σ
1 i)	1610	80	0	50	0.140	10	5965	510
ii)	1136	56	258	100	0.100	5	5720	770
2 i)	990	60	0	60	0.170	5	785	75
ii)	660	20	0	50	0.100	5	625	60
3 i)	20565	825	0	500	0.10	1	48000	3700
ii)	18110	725	3000	1000	0.12	1	46000	4000
4 i)	3020	150	280	100	0.125	5	6870	650
ii)	3140	180	0	50	0.130	5	6450	700
γ irradiated sherd (modern Peruvian)	643	13	30	50	A			
	650	60	145	20	B			
	657	40	54	15				

Notes:
- a) the gamma irradiated sherd was given a total dose of 690 ± 10 rads
- b) i and ii represent the same worker at different times; A and B represent different workers
- c) the errors in the ages are experimental errors only
- d) errors are in the least significant figures

BETA SOURCE CALIBRATION: SOME PROBLEMS ASSOCIATED WITH THE UTILIZATION OF THE GAMMA IRRADIATION OF QUARTZ AND OTHER PHOSPHORS

PART I

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INTRODUCTION - PART I

The problem of beta source calibration has been discussed in some detail recently (Wintle and Aitken, 1977; Wintle and Murray, 1977; Murray and Wintle, 1979) and the methods suggested for calibration have usually been based on the use of a TL phosphor such as calcium fluoride for intercomparing the beta source with a well-calibrated gamma source. Aitken (1979) proposed the interlaboratory calibration of beta sources using 100 µm grains of natural fluorite and then calculation of the equivalent dose-rate to quartz. He did suggest, however, that quartz itself would be a better phosphor to use if sufficient quantities possessing satisfactory TL characteristics were available. Pernicka and Wagner (1979) described the use of commercially available Merck quartz for beta source calibration and proposed that irradiated samples of this quartz could be distributed for interlaboratory calibration. Although the use of quartz for calibration purposes excludes the uncertainty involved in the calculation of the dose-rate to quartz from the measured dose-rate to the TL phosphor, care must still be applied to every detail of the procedure in order that the most accurate result possible may be attained.

This paper has been prompted partly by the lack of adherence to this latter principle by Pernicka and Wagner (1979) - resulting in a minor uncertainty in their source calibration - and partly by the desire to recount some other complicating factors associated with the transparency of the quartz grains themselves which can also have important effects for TL dating. In Part I, given here, the effects of the gamma irradiation of matter in general and in particular the problems which arise when an interface divides two different media being irradiated by gamma rays are described. In Part II, which will be published in the next issue of this newsletter (No. 11, June 1980), the irradiation of quartz grains for beta source calibration purposes is discussed and some unwelcome phenomena associated with the transparency of the quartz grains are described.

THE EFFECTS OF GAMMA IRRADIATION OF MATTER

In the energy range and for the materials of interest to us, the primary interaction of the gamma rays (photons) with absorber atoms is via three quite distinctive processes: -

(i) The photoelectric effect: a photon gives up all of its energy to a bound electron (usually from the K or L shell) which is then ejected from the atom with a kinetic energy equal to the incident photon energy minus the binding energy of the electron in the atom. This effect is particularly important at low photon energies, i.e. less than 100 KeV, and for high atomic number absorbers. The photoelectric absorption coefficient varies rapidly with atomic number Z, approximately as Z^4.

(ii) The Compton effect: a photon is scattered from its original direction of motion by a collision with an atomic electron. This results in a Compton scattered photon and a Compton recoil electron. The Compton electrons will have a range of energies distributed around a mean value. Compton scattering is important for photon energies around 1 MeV and for low and medium value atomic number materials. The compton scattering coefficient is almost independent of Z.

(iii) Pair production: a photon travelling in the field of a nucleus, and to some degree the field of an electron, can be completely annihilated giving rise to an electron-position pair. Pair production predominates at high photon energies and for high atomic number materials. A minimum threshold photon energy of 1.02 MeV is required for pair production in the field of a nucleus, and a threshold of 2.04 MeV is required in the field of an atomic electron.

These three effects are described in detail by Evans (1958, 1968) and Davisson (1968).

Thus the interaction of gamma rays with matter usually involves the production of energetic secondary electrons and it is the interaction of these secondary electrons which accounts predominantly for the ionization and excitation of the absorber atoms. For example, the interaction of a 1 MeV gamma ray travelling in quartz-like material will produce a secondary electron whose most probable energy will be 440 KeV. This electron can then go on to ionize over 10,000 further atoms before being brought to rest. The electrons liberated in these ionizations can themselves go on to produce further showers of lower energy electrons and this process continues until all of the energy imparted by the initial photon collision is dissipated within the material.

Within the bulk of a gamma-irradiated material there will exist an equilibrium fluence of electrons where the number of electrons produced within a small volume is balanced by the number absorbed. At the surface of a material exposed to a gamma ray beam, however, this equilibrium will not exist because there will have been no electrons produced before the surface. As we move into the material, the increase in the production of electrons initially outweighs the increase in absorption, so that the electron fluence builds up until eventually the production and absorption rates become equal and the equilibrium value is attained. This secondary electron equilibrium is achieved at a distance from the surface of the material equal to the average range of the initial photon collision electrons. Thus there will be a thin surface layer of the material in which the equilibrium value of the electron fluence is being built up and the relative importance of this layer will depend on the actual dimensions of the material being irradiated.

The following three cases will now be considered:

(i) the dimensions of the irradiated material are large compared to the secondary electron range,

(ii) the dimensions are small compared to this range, and

(iii) the dimensions are comparable to the range.

Figure 1 shows the gamma irradiation in air of a TL phosphor whose dimensions are large compared to the average secondary electron range, so that the surface layer in which secondary equilibrium is being built up will be very small compared to the total phosphor volume. Thus the build-up layer can be neglected and it can be assumed that secondary equilibrium exists

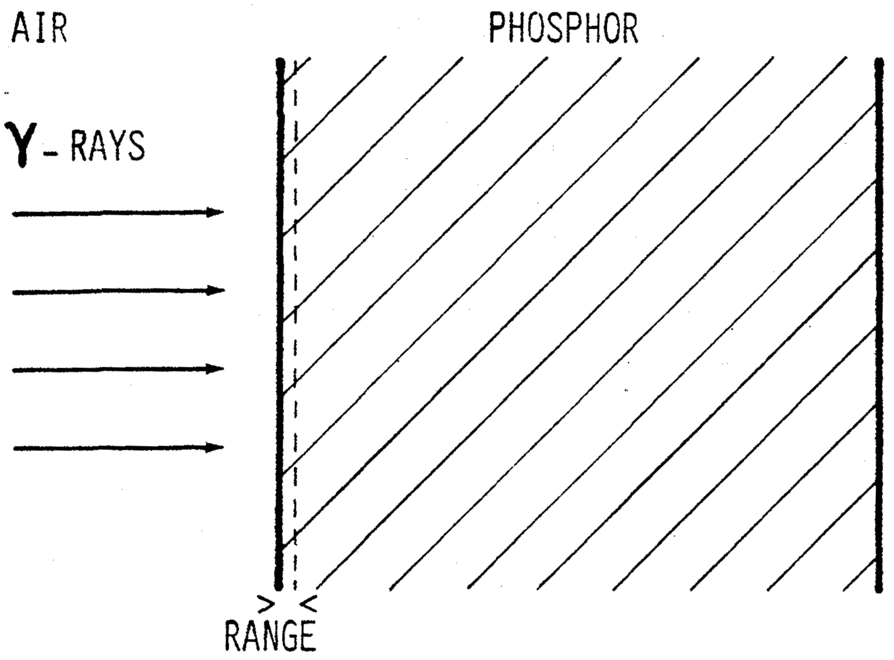

FIGURE 1: The Gamma Irradiation in Air of a TL Phosphor whose Dimensions are Large compared to the Average Secondary Electron Range (Range). Secondary electron equilibrium exists within the bulk of the phosphor except for the thin surface layer in which it is being built up.

throughout the phosphor volume. However two additional, although relatively small, effects are neglected in this assumption - (i) the attenuation of the primary gamma beam (less than 1% attenuation per mm quartz), and (ii) the build-up of secondary, scattered photons. These effects work in opposite directions though, and for the situations considered here they will tend to be self-cancelling. The dose deposited in the phosphor by the gamma beam is given by,

$$D = 0.869 \times \frac{(\mu_{en}/\rho)_{\text{phosphor}}}{(\mu_{en}/\rho)_{\text{air}}} \times X \qquad (1)$$

where D is the dose to the phosphor in rads (1 Gray = 100 rads),

X is the gamma exposure in Röntgen,

0.869 is the number of rads deposited in air by an exposure of one Röntgen,

absorption

and $(\mu_{en}/\rho)_{\text{phosphor,air}}$ are the photon mass-energy attenuation coefficients for the phosphor and air respectively, in cm^2/gm at the energy of the gamma rays.

When, on the other hand, the dimensions of the phosphor are small compared to the secondary electron range and some other medium is used to build up secondary electron equilibrium, the probability that any photon collisions will occur within the phosphor itself will be small. But even if there were any collisions, the electrons thus produced would most probably escape from the phosphor volume and deposit a negligible part of their energy therein.

Hence the dose to the phosphor will be delivered by the secondary electrons entering the phosphor volume from the build-up medium. If the thickness of this build-up medium is sufficient to give secondary electron equilibrium then the dose to the phosphor is given by,

$$D = 0.869 \times \frac{(\mu_{en}/\rho)_{medium}}{(\mu_{en}/\rho)_{air}} \times \frac{{}_{m}S_{phosphor}}{{}_{m}S_{medium}} \times X \qquad (2)$$

where ${}_{m}S_{phosphor,medium}$ are the mass electron stopping powers for the phosphor and medium respectively, in MeV. cm^2/gm, at the mean secondary electron energy.

In the intermediary situation, the phosphor dimensions comparable to the secondary electron range, the dose to the phosphor will come partly from electrons generated in the build-up medium and partly from electrons produced within the phosphor itself. In this case, Charlton and Cormack (1962) have shown that, assuming the electrons are generated isotropically, the dose at any point x within the phosphor, D(x), will be given by,

$$D(x) = 0.869 \times \left[\frac{(\mu_{en}/\rho)_{medium}}{(\mu_{en}/\rho)_{air}} \times \frac{{}_{m}S_{phosphor}}{{}_{m}S_{medium}} \times G(x) + \frac{(\mu_{en}/\rho)_{phosphor}}{(\mu_{en}/\rho)_{air}} \times \{1 - G(x)\} \right] \times X \qquad (3)$$

where G(x) is the geometrical function for a plane interface defined by Charlton and Cormack (1962).

It can be seen that equation (3) is a combination of equations (1) and (2) together with the geometrical function G(x). It must be remembered, however, that the assumption of isotropic electron generation will not always be valid particularly for low atomic number materials and high photon energies. This is because in low atomic number materials the scattering of the high energy electrons generated by the high energy photons is not very pronounced. Hence the electrons remain biased in their original direction of motion, i.e. in the direction of the photons, and the spatial characteristics of the electron field should be taken into account when determining the dose to the phosphor, although this will not always be possible. Another particularly complex effect, the differential scattering of electrons across the interface between two media, must also be taken into account when the atomic numbers of the two media are significantly different and this is discribed below.

Electron scattering at an interface.

Dutreix and Bernard (1966) have shown that for high energy X-rays and gamma rays passing through an interface separating media of different atomic compositions, electron scattering can have a significant effect on the dose to the material in the vicinity of the interface. Figure 2 is taken from Dutreix and Bernard's (1966) work and it shows the dose distribution at the interfaces between copper and water irradiated by Co-60 gamma rays. The equilibrium electron fluence generated by the photons within the copper region is composed of electrons moving in the forward direction, i.e. the same general direction as the photon beam, and electrons which have been scattered so that they are moving in the backward direction. Within the

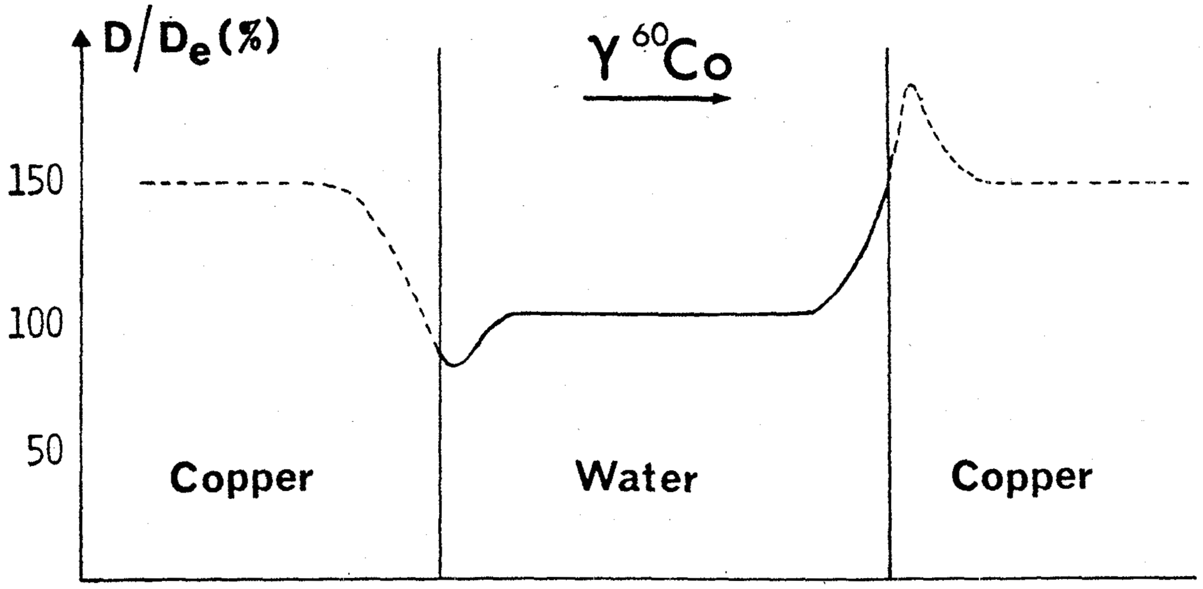

FIGURE 2: The Dose Distribution in Water in the Vicinity of an Interface with Copper. The ordinates correspond to the ratio of the absorbed dose D to the dose D_e in water under electronic equilibrium conditions. The dotted curve corresponds to the dose in an infinitely small mass of water located in the copper and the arrow shows the direction of the Co-60 gamma rays. There is an underdosage in the vicinity of the copper-water interface and an overdosage in the vicinity of the water-copper interface.

water region the electrons are assumed to be moving predominantly in the forward direction as scattering is very much less pronounced than in copper and hence there is negligible back-scattered electron fluence.

As the copper-water interface is approached (Figure 2), the backward component of the electron fluence begins to decrease as the amount of backscattering material decreases, so that at the interface only the forward component of the electrons from the copper exists. In the water behind the interface, the electrons from the copper progressively vanish, but at the same time the electron fluence in water is generated and builds up to the equilibrium value. The attenuation of the copper electrons is more rapid than the build-up of the water electrons and hence the dose distribution curve passes through a minimum.

As the water-copper interface is approached the number of back-scattered electrons from the copper begins to increase so that the dose at the interface is considerably higher than the equilibrium dose in water. In the copper behind the interface the dose distribution passes through a maximum as the forward component of the electrons from the copper builds up, while the water component is simultaneously attenuated. The transition zones of underdosage or overdosage are approximately 2-3 mm thick which in certain circumstances can have important dosimetric consequences (Dutreix and Bernard, 1966).

Carlsson (1973) showed that electron scattering must be taken into consideration for much lower photon energies (100 and 200 KeV) when a high atomic number material forms an interface with a low atomic number material. She showed that at a plane interface between lead and mylar the measured dose in the mylar was about a factor of two less than the dose calculated neglecting electron scattering, i.e. a calculation based on a form of equation (3). This is because at the interface the electrons created in the lead and crossing the interface for the first time are not nearly so effectively back-scattered as from the high atomic number material, which results in a reduced electron fluence at the interface. The transition zones on either side of the interface are, however, only a fraction of a millimetre thick because of the short range of the low energy secondary electrons and hence this effect will be of minor importance in most situations.

It is worth noting here the results of Wintle and Aitken (1977), who showed that electron back-scatter is also important for beta source irradiations. They irradiated a 350 μm thick slice of the TL phosphor CaF_2:Dy with a Sr-90 beta source on a nichrome plate and on perspex. By measuring the TL from the slice they found that the average dose to the 350 μm slice irradiated on the nichrome plate was 17% higher than when irradiated on perspex. The increase is entirely due to back-scattered electrons from the nichrome.

Thus we have seen how the motion of the secondary electrons plays a vital role in the energy deposition by gamma rays in two media separated by an interface. In Part II of this paper it will be shown how this effect must be taken into account when quartz grains are irradiated by a gamma source for the purpose of beta source calibration. In addition, Part II describes the problems which can arise due to differences in grain transparency between different quartz samples.

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THERMOLUMINESCENT DATING OF ANCIENT TOCONCE POTTERIES

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SUMMARY: The dating of five samples from different depth levels of the same archaeological "site" Toconce was made by TL measurements. These results agreed with the estimated values obtained by the archaeological context and the radiocarbon method.

INTRODUCTION: The study of the natural thermoluminescence (NTL) and the artificial thermoluminescence (ATL) produced by irradiation with the beta source was made on five pottery samples from the archaeological "site" Toconce at Antofagasta in the north of Chile. The pieces of pottery were chemically washed and sieved in order to get the quartz grains with a diameter of 100 microns. The radiation dose received by each sample, after its original firing, was determined by the "plateau" and the "pre-dose" methods. The annual dose was calculated from the concentration of radioactive trace elements of the sample and the burial soil. An analysis of the TL glow showed that the light emission is proportional to the dose received by the sample. The calculated ages of the five samples differ by about 10% from the values given by the radiocarbon and context methods.

METHODS AND MATERIALS: The quartz grains, were poured onto a stainless steel sample holder, and placed on a heater plate. The heating rate of 20°C/sec was controlled electronically and measured with a chromel-alumel thermocouple welded to the heating plate. The luminescent emission was detected with a photomultiplier (Phillips 56-AVP) connected to a high tension source (Keithley 246). The signal from the photomultiplier was amplificated with an electrometer (Keithley 610 c), and recorded through channel Y of a Hewlett-Packard 7004-B recorder. The signal from the thermocouple was recorded through channel X of the same recorder giving the glow curve. The quartz grains were irradiated with a 85 rad/min dose rate from a fixed position Sr-90, 10 mCi source.

SAMPLE PREPARATION: The pottery samples were crushed and washed with "Aqua regia" and 1% HF solution. The quartz inclusions were sieved to obtain grains with 100-200 microns diameter in order to use the quartz inclusion technique (1).

THE EQUIVALENT DOSE (ED): The dose received by the sample after its original firing, the equivalent dose (ED),was calculated by the "plateau" and the "pre-dose" methods. In the plateau method the curves of NTL and ATL, for 850 rad β dose, were recorded.

These measurements for a particular pottery were repeated in order to obtain a mean value of the plateau. In the pre-dose method, the samples received a test dose and a laboratory dose of 850 rads. The obtained ED value is also a mean value of a serial of measurements. Figure 1, 2 and 3 show the curves obtained for two of the studied samples.

A preliminary examination of the luminescent emission, as a function of the received radiation dose was made for each dated sample. After a heating of 450^o during 3 hours, the samples were irradiated from 0.5-12 min. with the Sr-90 source. The linearity existing in this zone made possible the calculation of the equivalent dose.

THE ANNUAL DOSE (D): The concentrations of radioactive trace elements in one of the pottery samples and the burial soil were determined by the Neutron Activation Analysis Department of "Comisión Chilena de Energia Nuclear", La Reina at Santiago-Chile. These concentration values are in Table I.

Table I

	U-238 (ppm)	Th-232 (ppm)	K (%)
Pottery (IFUC-3)	3.8 ± 0.3	16.4 ± 0.4	1.5 ± 0.3
Soil	4.0 ± 0.3	13.3 ± 0.8	2.1 ± 0.4

The contribution of each of these elements to D was calculated by Aitken's method (2). Since the quartz grain diameter is about 100 microns the alpha contribution to D was neglected. The calculated D was 0.43 rad/yr. and was used for dating each sample, in spite of the fact that these were not found in the same depth level (50-100 cm).

RESULTS: The calculated dates for the Toconce potteries are in Table II.

Table II

Sample #	ED(rads)	Method	D(rad/yr)	TL age(yrs.)	Estimated age(yrs.)
IFUC-1	410	Predose and Plateau	0.43	950	850 ± 50 context
IFUC-2	430	Plateau	0.43	1000	1050 ± 150 context
IFUC-3	490	Plateau	0.43	1140	1075 ± 75 context
IFUC-4	460	Predose	0.43	1070	950 ± 50 context
IFUC-5	330	Plateau	0.43	770	700 ± 10 radiocarbon

CONCLUSIONS: The dating of ancient pottery by thermoluminescence measurement was made for the first time in this country. The calculated TL ages differ by about 10% from the values determined by the other methods. These results can be improved with an accurate determination of D by means of "in situ" dosimetry with $CaSO_4$: Dy dosimeters.

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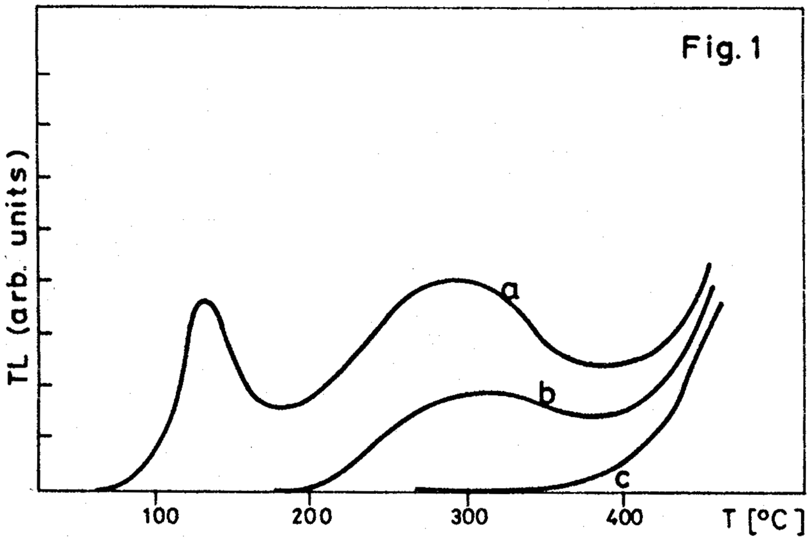

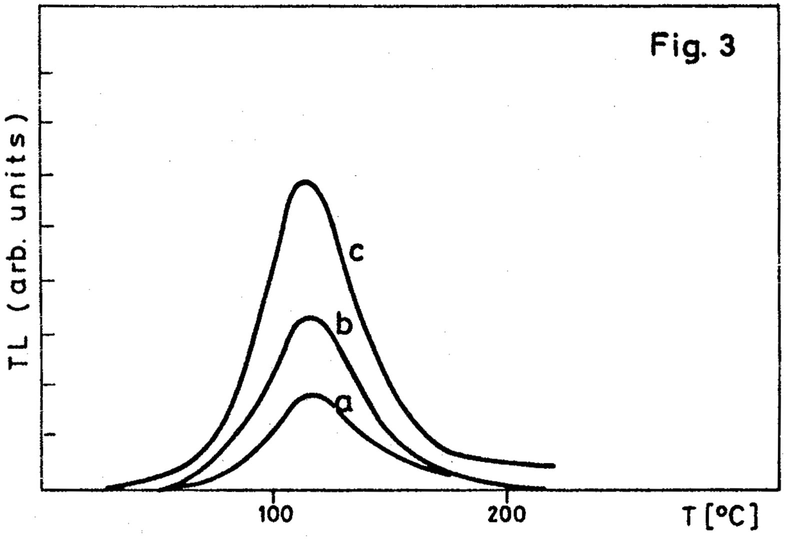

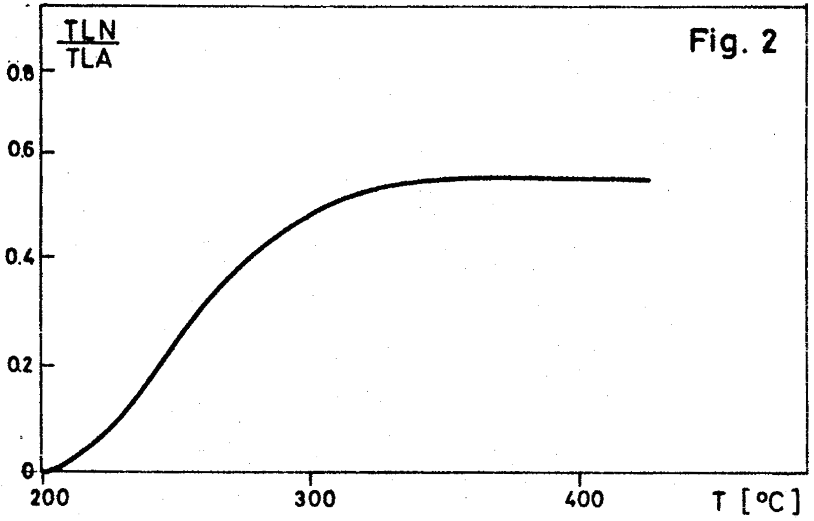

Fig. 1: IFUC-3 TL curves.

a) ATL for 850 rad β dose
b) NTL
c) Thermique radiation

Fig. 2: IFUC-3 plateau test

Fig. 3: IFUC-1 pre-dose effect

a) S_0 response
b) S_N response
c) $S_{N+\beta}$ response

The experimental conditions for all glow-curves were: Heating rate 20°C/min; sample weight 8 mg, and N_2 flow 4 l/min.

A BETA IRRADIATOR FOR USE IN TL DATING

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An irradiator unit is briefly described which houses a 40 mCi Sr90/Y90 beta source (RCC Amersham; type S1P, 1cm^2 active area, 19mm overall diameter). It has been designed with the following aims in mind;

a) to remove the hazard of accidental exposure of the operator to the source.

b) to obtain radiation levels external to the irradiator of the order of mrad h^{-1} or less in routine operation.

c) to irradiate samples located on the heater plate of the TL oven.

Construction

A cross-section of the irradiator unit (without its transport mechanism) located on the TL oven is shown in figure 1. The oven body and lead housing of the irradiator have cylindrical symmetry about the same vertical axis. The lead housing, manufactured in two parts, has a spherical cavity within which the source-carrying mechanism is located.

The stainless steel axle runs in precision bearings which are supported by two pillars mounted on the steel baseplate. Two rods are fixed to the centre of the axle at right angles to its axis and in the same plane. The source, surrounded by a lead shield, is mounted on one rod and on the other, a lead counterweight/shield. Both lead shields are shaped so that the whole assembly can be rotated within the spherical cavity. An extension of the axle passes through the lead housing and is attached to a control handle. The operator, by turning the handle through 180°, takes the source from its SAFE position to IRRADIATION position facing vertically downwards (there is a stop to locate the source in its correct position). The lead housing and baseplate have been cut so as to provide a circular aperture in the underside of the unit. When in the SAFE position (as shown) the lead counterweight blocks the aperture providing shielding from bremsstrahlung and scattered low energy beta radiation (M.J. Aitken, TLS 60, PACT 3). The lip shown along the outer edge of the horizontal division of the housing also prevents the escape of scattered low energy beta radiation. The source is located at a fixed distance - 15.3mm - above the heater plate (nichrome) by means of three reference locators, one of which is shown in the figure. The locators are manufactured from titanium but stainless steel would be equally suitable.

Use in Laboratory

The oven body, as shown in figure 1, is surrounded by a 25mm thick lead collar from the bench level upwards (6.5cm). The bench is 1m above floor level and wire mesh is fastened to the bench structure to prevent any access to the underside (where the maximum dose-level during irradiation is in excess of 50 mrad h^{-1}).

The irradiator unit is transported to and located on the oven by means of a gantry running on rails (figure 2). The unit is stored in a fire proof steel storage box, adjacent to the oven. The irradiator housing is lowered on and raised from the oven by means of a hydraulic ram.

Once located on the oven, a safety bar (figure 2) is pulled towards the operator, locking the unit onto the oven and allowing the control handle to be rotated. The housing cannot be raised until the handle is restored to the SAFE position as shown and the safety bar returned to its original position. After irradiation the unit is simply raised and wheeled back into the storage box.

Radiation Levels

Measurements with uncalibrated beta and gamma contamination meters have indicated maximum dose-rates on the surface of the housing to be in the region of several mrad h^{-1} and over a substantial area surrounding the unit, below 1 mrad h^{-1}. The maximum dose-rate measured at the wire mesh (below bench level) during an irradiation was 2 mrad h^{-1}.

Subsequent measurements with LiF dosimeters (NRPB, Harwell) placed at various locations on the bench and irradiator during routine use confirmed that the radiation levels are below 2 mrad h^{-1}.

Calibration

The source has been calibrated using a similar procedure to Murray and Wintle (PACT 3, 1979) with calcium fluoride grains on stainless steel discs (calibrated gamma irradiations by NRPB, Harwell). The source delivers a dose-rate of 162 ± 1.5 rad min^{-1} (std. error of six measurements) to 90-105 µm grains of quartz on 0.48mm thick discs of stainless steel resting on the heater plate. The calibrated dose-rate is some 7% less for grains located directly on the heater plate. For pre-dose dating work, an aluminium absorber (3mm thick), interposed between source and sample, gives a 100 fold reduction of the full dose-rate.

A 'probe' disc (with CaF_2 grains spread within a circle of 3mm diameter) has been used to map the dose-rate at different positions on the heater plate. The results show a 10% fall-off in dose-rate at a distance of 5mm from the centre of the plate which is similar to Zimmerman's findings (see Aitken, TLS 60, PACT 3). The mapping procedure, besides providing a useful check on the alignment of the source, gives an important reminder to the operator that 'calibrated' dose-rates apply only over a defined area. For samples spread over a greater area corrections may be necessary.

The Oxford laboratory is also currently testing various designs of irradiator housing, requiring less lead than we have used here.

The author appreciated discussions with Dr. M. Weston (University Radiation Protection Officer) and Mr. A. Sutherland of NRPB, Leeds.

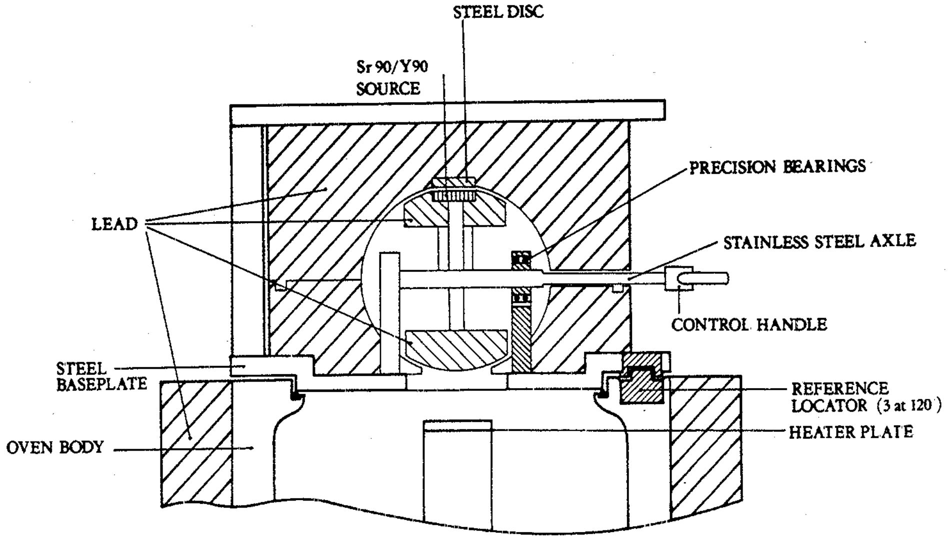

FIGURE 1 Cross-section of irradiator housing located on TL oven (Oxford design). The locators and pillars are spaced at intervals of 120° as indicated in Figure 2.

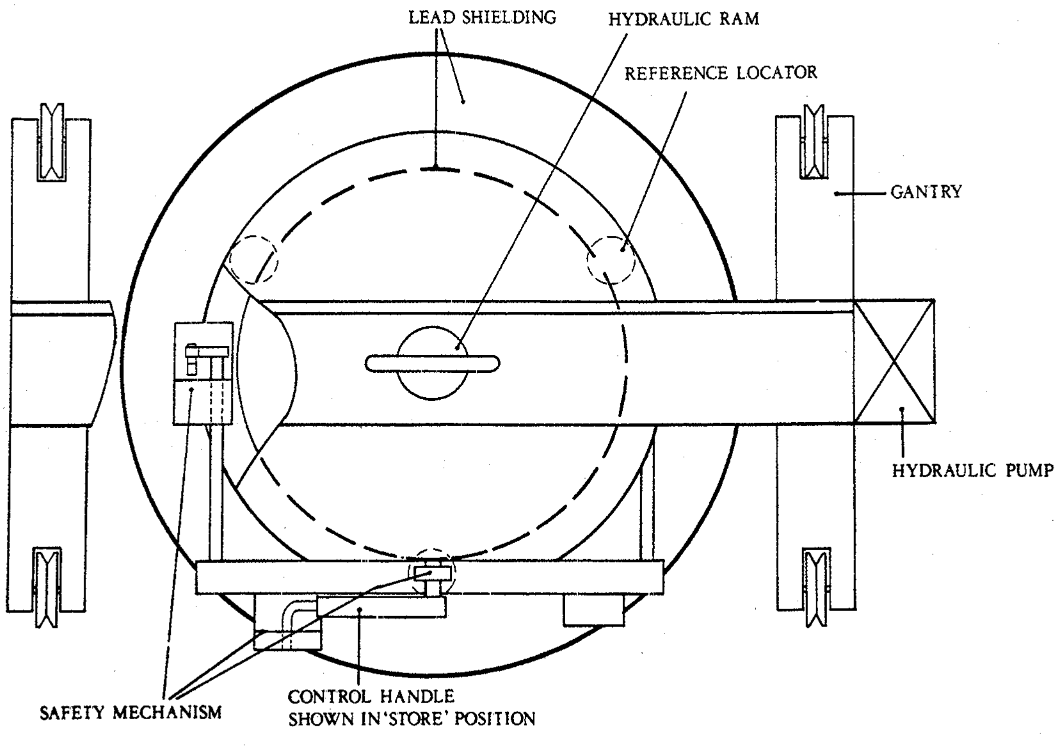

FIGURE 2 A plane view of the irradiator unit, located on the TL oven, with its transportation gantry. The cut-away shows a detail of the safety mechanism. The rails and steel storage cabinet are omitted.

15cm

READERS' CLUES AND QUERIES

FELLOWSHIP INFORMATION

The Thermoluminescence Laboratory of the University of Missouri provides one research assistantship earmarked for a graduate student of Archaeometry. The holder must be enrolled in a degree program in Anthropology, Physics or logically related disciplines. The total salary depends upon just how much research the student has time to do, but is nominally $4,000 for a half time. Address enquiries to Professor Ralph M. Rowlett, Department of Anthropology, University of Missouri-Columbia, Columbia, MO. 65211. The assistantship has already been filled for the academic year 1980-1981.

LABORATORY SAFETY MANUALS

Listed below are several references which provide useful information on various aspects of laboratory safety. Additional references would be gratefully received and should be sent to the editor.

"Handbook of Laboratory Safety", edited by Norman Steere, C.R.C. Press, Cleveland, Ohio, 1967. Fire, chemical, toxic, radiation, electrical and mechanical hazards; protective equipment; laboratory design; first aid.

"Health Physics: Principles of Radiation Protection", D. J. Rees, M.I.T. Press, Cambridge, Mass., 1967. Radiation dosimetry, biological effects, protection standards, protection against internal and external radiation, laboratory design.

"Handbook of Radioactive Nuclides", edited by Yen Wang, C.R.C. Press, Cleveland, Ohio, 1969. Nuclear data, instrumentation, dosimetry, biochemistry, medical and industrial applications, radiation protection and regulations, reference data.

"Fundamentals of Radiation Protection", Hugh F. Henry, John Wiley & Sons, Inc., 1969. Radiation principles and effects, permissible limits, radiation detection, intensity reduction, practical protective measures, emergency procedures.

"Radiation Protection Instrumentation and Its Application", International Commission on Radiation Units and Measurements (ICRU) Report No. 20, Washington, D. C., 1972.

"Dangerous Properties of Industrial Materials", N. Irving Sax, Reinhold Book Corp., New York, 1963. Toxicology, radiation hazards, storage and handling, shipping regulations.

"Handbook of Reactive Chemical Hazards", L. Bretherick, C.R.C. Press, 1975. An indexed guide to published data on chemical hazards.

"Fire Protection Guide on Hazardous Materials", National Fire Protection Association, Boston, Mass., 1975. Hazardous reactions; flashpoints, flammabilities, and other data.

TRANSLATION

I have had translated from Geokhronologiya SSSR Vol 3, 1974 the sections on the thermolominescent method; these are headed "general principles" and "the age determination of loess deposits". The latter by V.N. Shelkoplyas contains 92 TL dates and a few (too few) details of the method. It is too long for Ancient TL but copies may be obtained by writing to me if you enclose $2. D.J. Huntley, Physics Dept., S.F.U. Burnaby, B.C. V5A 1S6, Canada.

RESEARCH POSITION AVAILABLE

Position: Museum Research Scientist

Responsibilities: Technical examination and authentication of fine art objects and archaeology material in a museum Objects Conservation Department.

Faculties: Thermoluminescence dating, x-ray fluorescence, x-ray radiography, infra-red spectrophotometry, optical microscopy.

Experience: Advanced degree in physical sciences, thermoluminescence and/or x-ray fluorescence experience highly desirable.

For more information: Dr. Gary Carriveau
Senior Research Physicist
Metropolitan Museum of Art
Fifth Avenue at 82nd Street
New York, New York 10028

SOME RECENT BIBLIOGRAPHY

"Calculation of the Average Energy Absorbed in Photon Interactions," J. R. Cunningham and H. E. Johns, Medical Physics 7(1), Jan./Feb., 1980, p. 51-54.

"TLD Reader with Photon Counting and DC Techniques for Wide Range Radiation Dose Measurement," A. Sankaran, S. Kannan, and P. Gangadharan, Medical Physics 7(1), Jan./Feb., 1980, p. 73-75.

"Palaeointensity and Thermoluminescence Measurements on Cretan Kilns from 1300 to 2000 B.C.," Y. Liritzis and R. Thomas, Nature vol. 283, no. 5742, Jan. 3, 1980, p. 54.

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There is still some space available in the next issue of Ancient TL. Deadline for acceptance of contributions is May 31, 1980.