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"An expert is someone who knows some of the worst mistakes that can be made in his subject, and how to avoid them." Werner Heisenberg

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LETTER FROM THE EDITOR - Research Contributions to be Refereed

ANCIENT TL was initiated in 1977 by David Zimmerman to "facilitate the communication of helpful and practical information between researchers actively involved in thermoluminescence dating." Now in its third year and eleventh issue, the newsletter has become an important publication for technical papers on TL dating. Consequently, it has now become desirable and vital to referee research note contributions. Accordingly, refereeing will commence with notes submitted for issue twelve. The refereeing of contributions is intended to be somewhat informal. Referees will be urged to waive anonymity and to communicate directly with authors regarding revisions. It is hoped that this informality will be attractive to referees and authors alike as an opportunity for valuable dialogue between TL researchers. The expeditious distribution of the notes and other information contained in ANCIENT TL is still highly desirable and, thus, the newsletter format will be continued.

Stephen Sutton

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

PART II

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INTRODUCTION - PART II

In Part I of this paper, given in the last issue of this newsletter (No. 10, March 1980), the interaction of gamma radiation with matter was described and the particular problems which arise when an interface separates two media under gamma irradiation were discussed. It was shown that the motion of the secondary electrons created by the initial photon interactions must be taken into account when the dose distribution in the vicinity of an interface is to be assessed. Three particular cases were 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 this range.

Equations were given to describe the dose, D, deposited in a phosphor by a gamma beam for each of the three cases given above. These equations will be used in this second Part and hence they are repeated here for convenience. The symbols have all been defined in Part I.

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

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

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

THE USE OF QUARTZ FOR BETA SOURCE CALIBRATION

As mentioned in Part I of this paper, Pernicka and Wagner (1979) have proposed the interlaboratory calibration of beta sources using quartz as the TL phosphor. They suggest that some quartz samples should be irradiated by them with a gamma dose from an accurately calibrated Co-60 source and then be distributed to various TL laboratories for the beta source calibrations. Because of the fundamental importance of such a source calibration it is necessary to discuss here a small error in Pernicka and Wagner's irradiation procedures.

The quartz grains, in the size range 70-150 µm after etching in HF, were prepared for gamma irradiation by packing approximately 100 mg of the grains into small polyethylene bags so that the sample thickness was less than 1 mm, or alternatively 2 mg was placed in small polyethylene containers. The irradiations took place behind 0.5 cm of perspex in order to "achieve secondary electron equilibrium conditions". They then calculated the dose to the quartz according to

$$D = 0.869 \times \frac{(\mu_{en}/\rho)_{\text{quartz}}}{(\mu_{en}/\rho)_{\text{air}}} \times X \tag{4}$$

It can be seen immediately that equation (4) is directly equivalent to equation (1). However, equation (1) was valid only for the case where the dimensions of the phosphor were large compared to the range of the electrons set in motion by the photon collisions. For Co-60 gamma rays ($\bar{E}$ = 1.25 MeV) the average range of these electrons is approximately 2 mm in quartz. The thickness of the quartz samples is less than 1 mm and as the samples are packages of much smaller quartz grains, then the actual thickness of solid quartz will be considerably less than 1 mm. Hence the dimensions of the phosphor are not large compared to the secondary electron range and equation (4) is not valid for this situation.

On the other hand, the dimensions of the phosphor are not small compared to the secondary electron range so that equation (2) is not valid either. The true situation lies somewhere between the two cases with the dose absorbed by the quartz delivered partly by the electrons generated within the perspex absorbers and partly from electrons generated within the quartz grains themselves. Thus some form of equation (3) would need to be used to calculate the dose to the quartz grains but the evaluation of the geometrical function G would be an exceedingly complex, if not impossible, problem. This is firstly because there is not a plane interface between two solid materials as on one side there are polyethylene bags packed with grains, and the density of packing of the grains will have an influence on the absorbed dose. Secondly, the spatial characteristics of the electron field generated in the perspex would have to be taken into account because perspex is a low atomic number material exposed to high energy photons and hence the electrons will be biased in the forward direction as described above. It is not thought that the electron scattering phenomenon of Dutreix and Bernard (1966) will have much influence here due to the small volume of back-scattering material.

The problems associated with evaluating the dose to Pernicka and Wagner's quartz grains would not exist if quartz absorbers were used instead of perspex. The secondary equilibrium electron fluence generated within the absorbers would then be that of quartz and the dose to the grains would be given by equation (1). If we put values in equation (1) we find that the dose D_1 is given by

$$D_1 = 0.867 \times X \tag{5}$$

Substituting values in equation (2) is rather more complex because it requires the ratio of the mass stopping powers of quartz and perspex. These figures are slightly energy dependent, so the problem of deciding at which energy to take the ratio arises. Dutreix et al. (1962) found that for Co-60 gamma rays the secondary electron fluence penetrating an ionisation chamber from wall materials of different atomic numbers behaved as though the mean energy of the electrons was in the order of 0.01 MeV. Taking the ratio of the stopping powers at this energy and using equation (2), gives

$$D_2 = 0.757 \times X \tag{6}$$

The difference between equations (5) and (6) is seen to be quite considerable and as mentioned above, the true figure for Pernicka and Wagner's irradiation should lie somewhere between these limits. This was investigated experimentally here by irradiating simultaneously in a Co-60 gamma beam some quartz grains behind 0.5 cm thick quartz absorbers and some grains behind the same thickness of perspex absorbers. Both samples of grains were packed in polyethylene bags to a thickness of approximately 1 mm. It was found that the dose to the quartz grains irradiated behind the perspex was (5.0 ± 0.3)% lower than the dose to the grains behind quartz implying that for this irradiation procedure equation (3) gives

$$D_3 = 0.826 \times X \tag{7}$$

It is not possible, however, to say that this value in equation (7) should apply to Pernicka and Wagner's irradiations since the density of packing of the grains could have been somewhat different.

It is strongly recommended, therefore, that if quartz grains are to be used for calibration purposes, the gamma irradiations should take place behind quartz absorbers in order to circumvent the problems and uncertainties in the dose assessment as described above.

THE EFFECT OF GRAIN TRANSPARENCY ON BETA SOURCE CALIBRATION

A limiting factor in using one type of quartz grains, or any other phosphor, for a "once-and-for-all" beta source calibration is the dependency of the measured dose-rate of the beta source on the transparency of the particular quartz grains as was first described by Bell (1979). Further studies have now been completed however the results, described below, are still somewhat preliminary. A detailed account of this transparency phenomenon will be published soon.

The dependency on grain transparency is thought to arise from the comparison of the non-homogeneous dose distribution to the grains from the beta source, with the homogeneous dose distribution from the gamma source. The non-homogeneous beta dose distribution is a result of two effects. The first is the dose build-up with depth described by Wintle and Aitken (1977) which is due to the increased obliquity of the electron paths caused by multiple scattering as the electrons penetrate the sample. Thus the path length per unit thickness, and hence the energy loss, increases with depth until it reaches a maximum (at about 40 mg/cm^2 for a Sr-90 source and aluminium absorbers) after which attenuation effects predominate and the dose decreases. For 100 µm quartz grains the dose will increase through the grains so that the lower regions will receive a higher dose than the upper regions.

The second effect, which probably has a greater influence on the dose distribution, is the back-scattering of electrons from the high atomic number material on which the grains are resting during beta irradiation. Murray and Wintle (1979) showed that 100 µm grains of CaF_2 receive a 40% higher dose when irradiated on nichrome instead of perspex and for lead the increase is over 60%. These back-scattered electrons will have energies very much less than the initial source energy and will not penetrate very far into the quartz grains, thus depositing most of their energy in the lower regions of the grains.

In contrast, the gamma irradiation of quartz grains will result in a homogeneous distribution of the dose throughtout the grain volume. Hence the TL measured after a beta irradiation will come more from the lower regions of the grains than the TL measured after a gamma irradiation. Therefore the beta induced TL will be more attenuated than the gamma TL if the grains are not very transparent; whereas there will be little difference in the attenuation if the grains are very transparent.

We have measured a large number of different quartz samples using a Co-60 gamma source and a Sr-90 beta source (20 mg of grains resting in platinum cups of area 52 mm^2 for this latter irradiation) and the results for the apparent dose-rate values of the beta source were found to vary over a wide range - approximately 20%. Optical inspection of the quartz grains from the two extremes showed that the sample whose grains had a very transparent, "shiny" (Bell and Zimmerman, 1978) appearance gave a high dose-rate figure for the beta source, indicating that little difference in the attenuation of the beta and gamma induced TL had occured. By comparison the grains from the other sample which had a less transparent, "frosty" appearance gave a 20% lower dose-rate figure for the beta source, implying a greater attenuation of the beta TL than the gamma TL.

As a result of this phenomenon a beta source calibration is now performed for each individual archaeological sample dated by this laboratory. In this context it is interesting to report that the two extreme samples mentioned above both give very good results for the ages when the individual source calibration figures are used, but if a mean calibration figure is used then the dates obtained fall outside the known age limits for the archaeological samples. The same effect is also true, to a lesser extent, for many other samples studied.

Furthermore, preliminary investigations tend to show that there is perhaps a correlation between firing temperature of the sample and the degree of transparency after etching in HF acid. Quartz grains from a geological sand were divided into two fractions - one fraction heated to 1000° C for four hours and the other remaining unheated. The two fractions were then etched in HF for one hour and it was quite noticeable that the unheated grains had a slightly more "frosty" appearance than the heated grains. We hope to publish full details of the experimental methods we use and a full account of the effects of grain transparency in the near future.

It is recommended here that individual TL dating laboratories should pay attention to this transparency effect and that whenever possible beta source calibration experiments should be performed for each archaeological sample studied. This is particularly important when the quartz grains under consideration have either a very "frosty" or very "shiny" appearance.

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110°C QUARTZ PEAK: A NEW NORMALIZATION FACTOR

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It is well known that in our attempt to measure the total archaeological dose a pottery sample has received since the last firing, we follow the "additive procedure" which simulates the natural TL acquisition. The construction of the first built up curve is usually made by using the following normalization procedures:

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1) By adding beta doses to quartz samples, heated to 500°C with subsequent normalization with a monitor beta dose. This drainage of a sample often causes a significant change of TL sensitivity due either to a transparency change associated with mineralogical alterations brought about by heating of the sample (Tite, 1966) or to more subtle effects arising from the radiation dose received before drainage, the "predose", (Fleming, 1975) or may be attributed purely to rearrangements of the impurity ions (centres or traps) during cooling.

2) By heating to 500°C and weighing the samples.

A new normalization procedure that has been adopted here is based on the sensitive 110°C quartz peak or the 120°C feldspar peak, with many advantages in mind. Prior to any irradiation or read out, the sample is administered a dose of the order of 1-4 rads and subsequently heated to approximately 120°C, followed by heating to 500°C. The procedure is otherwise the "additive" as described above in (1). By this way, the high temperature peaks of quartz are normalized with the 110°C peak reading. Therefore, the first built up curve is made by avoiding complications of crystal sensitivity changes.

This technique has been successfully applied to a dating programme on ancient Hellenic artifacts (Liritzis, 1979). Some results are shown in table 1. Comparisons of TL/110°C with other normalization procedures (i.e. TL/rad and TL/mg) gave satisfactory results.

M. J. Aitken has shown this normalization to be valid using the low temperature peak of calcite (Ancient TL #9, p. 13).

It is thus our pleasure here to verify and recommend this technique for quartz.

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TABLE 1

Sample	Peak (°C)	Normalization Technique	Intercepts (Rads)		Total Dose (Rads)
			Q	I	
SKB(1)98	350	TL/mg	3390	-30	3360
	350	TL/110°C	3070	-110	2960
SK14	335	TL/mg	2450	-45	2410
	335	TL/rad	2570	-70	2500
	375	TL/mg	2650	-275	2380
	375	TL/110°C	2940	-340	2600
	425	TL/mg	3150	-500	2650
	425	TL/rad	3090	-430	2660
SKB(1)28	365	TL/mg	2270	75	2350
	365	TL/rad	2460	100	2560
	325	TL/mg	1810	225	2040
	325	TL/110°C	2270	240	2510

ISOLATION OF SILT-SIZED QUARTZ FROM SEDIMENTS

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In our on-going study of the TL properties of sediments we have found it useful to isolate quartz from other phases. For fine grain sizes (5-10μ, say) the usual density and magnetic methods are tedious and ineffective and will not permit the separation of quartz from plagioclase because their densities and magnetic susceptibilities overlap. Chemical methods seem very promising but most of these do not remove quartz efficiently or require using temperatures above 50°C.

For some months we have obtained very good results with hydrofluosilicic acid (H_2SiF_6). Given the proper pre-treatment, this acid will selectively dissolve the major non-quartz components, leaving the quartz untouched. The susceptibility of minerals to attack by H_2SiF_6 has been attributed to the extent of aluminum in tetrahedral substitution (Syers et al 1968). Hence, most aluminosilicates are attacked while quartz is unscathed. Because H_2SiF_6 removes Fe oxides and hydrous Fe oxides very inefficiently, we initially treat our samples with 0.1N HCl. Some magnetic minerals will still remain but in much smaller amounts than feldspars and quartz for most sediments.

We have removed these magnetic minerals by using a Frantz magnetic separator in a "wet mode" (Greene and Cornitius 1970, Parsonage 1979). We use the modification of Greene and Cornitius without a feeder and with the vibrator turned off to minimize turbulence. Furthermore, rather than using acetone as the suspending medium we use a 0.01N sodium oxalate solution (deionized water) to prevent the flocculation which sometimes occurs in acetone. The price we pay is a much longer (∿ 4 hours) feed-through time. The sample is added periodically with a spatula. We have found that since the magnetic minerals contribute only about one-tenth the TL of a comparable amount of quartz, and since the magnetic separation is relatively tedious, one may dispense with this step and apply the H_2SiF_6 acid immediately after the HCl step.

The use of H_2SiF_6 to isolate quartz was suggested as early as 1933 (Knopf 1933) and has been described more recently by Syers et al (1968), Sridhar et al (1975) and Jackson et al (1976). For convenience to the reader we outline here our adapted procedures.

The acid is pretreated by adding 4-88μ (since our samples are 4-11μ) commercial silica (sized from 240 mesh commercial silica powder), and storing at 4°C for at least three days with occasional stirring. Prior to use of the acid the commercial silica is centrifuged out. Sufficient acid is added to the sample to give a liquid:solid weight ratio of 40:1. This is kept at ∿ 18°C and stirred at least twice a day. The digestion time depends on the amount of non-quartz present which we estimate from optical examination in oils of the 10-40μ size fraction, assuming that the 4-11μ fraction has a similar composition. Following Jackson et al (1976) we store the mixture for 3 days for each 50 mg of plagioclase and then double this for good measure. The purity of the final residue (removed by centrifugation) is checked by XRD powder patterns. For a sediment that has not been heavily weathered this procedure yields a residue of at least 90-95% quartz. Since the remaining contaminants are not feldspars but mainly opaques, they probably contribute negligible TL. For heavily weathered samples, pre-treatment with 6N HCl (rather than 0.1N HCl) might be preferred.

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PUTTING ANCIENT ROME TO USE

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The active TL-dating laboratory will commonly have a steady flow of work in classes ranging from simple authenticity measurements, through relatively straight-forward dating of archaeological potsherds etc., to forward-looking research measurements on new materials. There will also, hopefully, be research on improving the technique itself and coming to better terms with the basic physics which is involved. A description of a typical development of such activity in a university laboratory over a period of years has been given recently by Mortlock (1979).

Of great importance in this day-to-day activity is the periodic checking that there has been no drift in the physical standards which form essential reference points in the dating measurements. While this can be achieved by checking obvious things such as the calibrated radioactive sources used for in-laboratory irradiations, in the final analysis it is the ability to reproduce the age figure for a specific archaeological object which is important.

In order to monitor this, it is necessary to acquire a ceramic object of good age which has satisfactory thermoluminescence characteristics and which can be sampled separately a number of times. If it is of accurately known age, and this age is known by a method which does not involve physical measurement, than that is an added advantage because it further tests the ultimate validity of the procedures of the thermoluminescence dating laboratory. Such objects are surprisingly difficult to find.

An appropriate object was kindly made available to the laboratory by Dr. Ann Moffatt of the Department of Classics at the A.N.U. It was a fragment of fired clay wall brick found on the ground at Ostia near Rome. The evidence suggested it had recently fallen from a nearby wall. On its surface was an imprint or stamp which, when translated from the Latin, reads:

> From the brickworks of Aburnius Caldicianus, in the consulship of Paetinus and Apronianus.

As it is known that Paetius and Apronianus were consuls in A. D. 123, we can take the brick to be the same age, namely 1857 yrs. B. P. as consuls were normally appointed for one year.

A difficulty with the determination of the TL-age is the assignment of the environmental dose rate, D_γ, due to gamma rays. We could assume that the brick was located in the face of the wall and was relatively thin in relation to its height and length. Also it was surrounded on its inner side by bricks of the same composition as itself. Then, if the nearby ground is free of radioactivity, D_γ can be calculated from Bell's (1979) Table 2 but must be reduced by a factor of two to obtain the true dose rate due in this case. In fact, there will be some gamma ray contribution from the nearby ground towards the wall-mounted brick. A simple shielding experiment with a Rad 21 dosimeter, Mortlock (1979), mounted on the outside wall of the Physics Department Building showed that the contribution due to the ground would be of the order of 10% of the total dose recorded by the Rad 21 unit under these conditions. This means that the effective D_γ is approximately 55% of that calculated using Bell's Table 2. This result will not be fully accurate because the radioactivity of the nearby ground can be anticipated to be different from that of the wall both in Canberra and Ostia. Also at Ostia the wall was made of concrete and the brick, as has already been assumed, was simply a facing. However, the error is expected to be relatively small and constant at a particular site.

Utilizing this correction the following data were obtained by two different skilled laboratory workers studying the brick from Ostia and employing the fine grain dating method:

Worker	Time	Archaeological Dose (rads)	A.D.R. (rads/yr)	Age (y B.P.)	Discrepancy (%)
J. D.	Nov., 1978	997	0.571	1746	-6.0
G. G.	Nov., 1979	1175	0.636	1848	-0.5

Separate measurements were made of the amounts of the contributing long-lived radioactive isotopes present on both occasions and there were small shifts in these, perhaps due to inhomogeneity in the brick, perhaps due to scatter in the analytical techniques employed. This explains the change in the calculated annual dose rate (A. D. R.).

The observed variation here in the archaeological dose is consistent with the scatter noted in a separate series of measurements of the archaeological dose associated with a potsherd from Thailand (Code KKG2 DA (2)) supplied by Dr. Pam Gutman of the Department of Asian Civilisations at the A.N.U. The observations in that case were spread over a year and are presented in the figure. The ratio of sample standard deviation to the mean in the case of the Thai potsherd was 13.3% whereas that for the brick from Ostia was 11.6%. It is assumed here that, other things being equal, the fractional error rather than the absolute error is what remains constant in measurements of archaeological doses of different magnitudes.

Clearly further measurements on the fired clay brick from Ostia are required, and it is intended to carry these forward in due course. Both a series of measurements close together in time and a series spread out in time are required to distinguish the sources of the observed variation. However, it is apparent even at this early stage that repeated measurements of this nature on well-behaved objects of known age are a useful means of monitoring laboratory procedures.

The help of Mrs. Jadwiga Duniec and Mrs. Glenys Gardner in carrying out the laboratory measurements is gratefully acknowledged. The fired clay brick from Ostia is listed in the description of the Classics Museum at the A.N.U., *Antiquities*, compiled by J. R. Green and Beryl Rawson and published by the Faculty of Arts, A.N.U., Canberra (1979), 119, item 7705.

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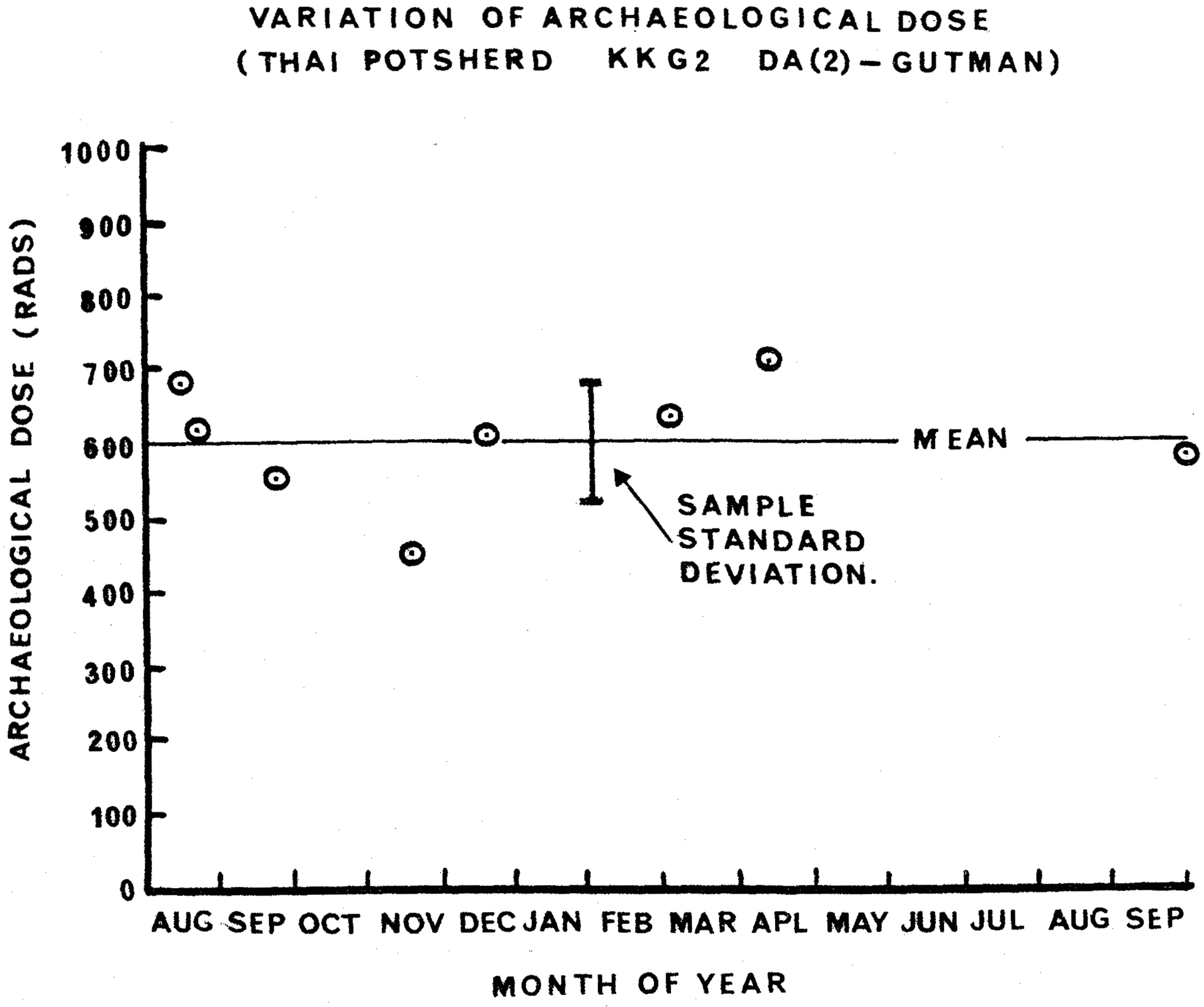

READERS' CLUES AND QUERIES

One Remedy for High Dark Counts in PMTs

Dark counts for our PMTs, normally between 50 and 100 cps, occasionally increase dramatically in the summertime. We have found that this is apparently caused by high humidity in the housings. The humidity can be high because the housings are not completely airtight and St. Louis summers are very humid. A simple remedy is to place a small amount of dessicant inside the housings to absorb the water vapor. The dark counts typically return to normal within a few minutes after introduction. In our case, the effective lifetime of the dessicant is on the order of a year at which time replacement is required.

S. R. Sutton, Washington University

CONFERENCE SUMMARIES AND INFORMATION

The 1980 Symposium for Archaeometry (March 26-29,1980, Paris)

The 1980 Symposium for Archaeometry was held at Ecole Normale Supérieure in Paris from March 26 to 29. Topics included general analyses, ceramic analyses and provenance, data processing, obsidian, metals, glass, prospection, ^{14}C dating, dating earlier than 40,000 B. P., thermoluminescence, archaeomagnetism, dendrochronology. In the thermoluminescence session, seven papers were presented on spatial inhomogeneities of TL sensitivity in calcite, dating of heated rocks from palaeolithic fireplaces, an automated dating procedure including results for samples from sites of known age, use of the temperature of TL emission for dating and the use of gamma meter measurements to determine total doserates. Publication of the papers in numbers 4 and 5 of the "Revue d'Archéométrie" is planned. Inquiries for copies should be directed to:

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Centre de Recherches Geophysiques Garchy
58150 Pouilly sur Loire, France

Next year's symposium will be held May 18-21 at Brookhaven National Laboratory, Long Island, New York, U. S. A. For additional information, contact G. Harbottle at Brookhaven. Those planning to attend this symposium will also be interested to know that, on the following day (May 22), a seminar has been planned at the Smithsonian Institute to discuss the future direction of archaeometry. No further details are available at this time.

S. R. Sutton, Washington University

6th International Conference on Solid State Dosimetry (1-4 April,1980, Toulouse)

The conference included sessions on mechanisms, radiation response, dosimetry properties, new products, instrumentation, TSEE, LL, applications to personal, environmental, neutron and medical dosimetry and archaeology.

Some 60 papers were presented orally and 40 listed for poster presentation. A high proportion of the papers were concerned with TLD (particularly using LiF) for radiation monitoring. There were others of direct interest to those involved in TL dating. A theoretical paper from Birmingham (MacKeever et al) showed that with a simple one trap/centre model with recombination during irradiation, a dose-rate effect is predicted. In a world wide environmental dosimetry survey using different TL phosphors, de Planque et al (New York) found tha CaF_2:Mn gave the lowest s.d.. Prokic (Belgrade) presented details on a highly sensitive phosphor MgB_4O_7:Dy/(Tm) - there followed some lively discussion. Two papers (Portal et al and Aitken et al) were concerned with dosimetry at elevated temperature. The high temperature capability of the TL reader developed by Brou and Valladas (NIM, 1975, 127) used by the authors of the former paper might be of interest in A F research.

Some promisingly titled papers were not presented; a paper from Montpellier on a feasibility study of a laser pulse heating system for TL microsamples and all the papers from the BARC (India) group who had not been able to attend the conference.

In the archaeology session, papers were presented on an automated TL apparatus, dose-rate dependence, pre-dose dating of burnt flint from paleolithic sites, dating of burnt sandstone from prehistoric fire places and dating of dental enamel. On the latter, but concerned with more recent problems, an earlier paper on x-ray exposures to dental patients is well worth reading in the proceedings for Ancient TL readers and their dentists alike.

The proceedings are expected to be published in Nuclear Instruments and Methods this year.

I. K. Bailiff, University of Durham

Specialist Conference on Archaeometry (August 27-28, 1980, Christchurch, N.Z.)

Following is a partial list of papers to be presented at the conference:

The Hydration of Natural Glasses- T. Tombrello, Caltech

New Approaches to C^{14} Dating- E. Hall, Oxford

The Thermoluminescence Dating of Sediments from beneath Lake George, New South Wales- A. Mortlock and D. Price, ANU

Sourcing Obsidian in Lapita Sites- R. Green, Prehistory, Auckland

Dating N.Z. Obsidians by Resonant Nuclear Reactions- F. Leach, Otago, and H. Naylor, Auckland

Obsidian Sourcing Using Non-Dispersive X-Ray Fluorescence- G. McCallum, Institute of Nuclear Sciences

Thermoluminescence Dating of Indian Archaeological Sites- A. Singhvi, Physical Research Lab., India

Physical Analogues of Regional Exchange Systems- J. Ericson and A. Babitz, Peabody Museum

Fluorine Concentration Profiles in Bone by Nucelar Microprobe- G. Coote and R. Spanks, INS, D.S.I.R.

Accelerator - Mass Spectrometer Experiments at Auckland- H. Naylor, Auckland

Titles of other papers not available at time of writing:

Conference organized by Dr. Foss Leach, Department of Anthropology, University of Otago, Dunedin, New Zealand, as part of New Zealand National Physics Conference

The Second Seminar for TL Specialists (September 1-6, 1980)

This seminar will be held in Oxford, England. The deadline for abstracts was May 15, 1980, however, short late entries are being considered if received by July 15, 1980. For more information, contact Martin Aitken, Research Laboratory for Archaeology, 6 Keble Rd., Oxford OX1 3QJ England.