A note on spurious luminescence from silicone oil

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Introduction

Previous studies have shown that the slow component of quartz OSL exhibits considerable thermal stability and dose response, which suggests that this component could be used to date beyond the age range covered by conventional luminescence techniques (Singarayer et al., 2000; Singarayer and Bailey, 2003; Jain et al., 2003; Rhodes et al., 2006). The first step in all slow component studies is to distinguish the slowly decaying dosimetric signal from a background level, obtained (for instance) from a blank disc that is put through the same measurement sequence as the sample. In view of the thermal stability and bleaching characteristics of the slow component, background evaluation using quartz grains which have been heated or bleached is not thought to be appropriate. Measurements of the background have previously been reported – for instance Li (2007) observed that background count rate varied with optical stimulation power, while Singarayer (2002, her Fig. 2.4) found that, at a constant stimulation power, the background from both blank and "dead" discs increases with measurement temperature.

In the course of our investigations into the potential of the slow component for dating, we observed anomalously high background count rates from blank silicone-sprayed stainless steel substrates (cups or discs). This high background appears to originate with a spurious signal from the silicone oil. The signal can be observed upon stimulation of the silicone using blue diodes at an elevated temperature, such as during the high temperature clean-out (at 280°C) that is usually inserted between each cycle of the SAR protocol to minimize recuperation (Murray and Wintle, 2003). Investigations of the slow component involve more stringent heat treatments and possibly stimulation at elevated temperatures; as such these measurements are particularly sensitive to interference from such spurious luminescence.

Analytical facilities

The measurements reported here were performed using an automated Risø TL/OSL DA-20 reader equipped with blue LED's emitting at 470nm (FWHM 20nm). Luminescence was detected through a 7.5 mm thick Hoya U-340 detection filter placed in front of a bialkali EMI 9235QA photomultiplier tube. Details on the measurement apparatus can be found in Thomsen et al. (2008). The background signals were obtained from stainless steel substrates (cups or discs). The silicone oil used throughout this work is "Rüsch Silkospray", which is manufactured by Willy Rüsch GMBH, D-71394 Kernen-Rommelshausen, Germany.

Experiments and results

The existence of a spurious OSL signal is demonstrated in Fig. 1. A blank silicone-sprayed stainless steel cup was first heated to 500°C, and subsequently stimulated for 100 s using blue diodes at 50°C. This was followed by a further measurement at the same temperature but without switching on the blue diodes. This measurement cycle, with and without stimulation, was then repeated at progressively higher stimulation temperatures up to 275°C. Finally, the experiment was repeated for stimulation temperatures of 50°C, 125°C and 275°C. The aliquot was not exposed to ionising radiation in the course of the experiment. Fig. 1a shows some of the observed signals; the spurious (non-radiation-induced) signals do not decay significantly during the 100 s of stimulation. The average count rate is plotted as a function of stimulation temperature in Fig. 1b. The OSL signal (squares) progressively increases with stimulation temperature from 125°C onwards. The signals recorded without optical stimulation (circles) are indistinguishable from the PM dark count at room temperature (dashed line). At least in this experiment, the spurious signals appear to be reproducible (open symbols in Fig. 1b).

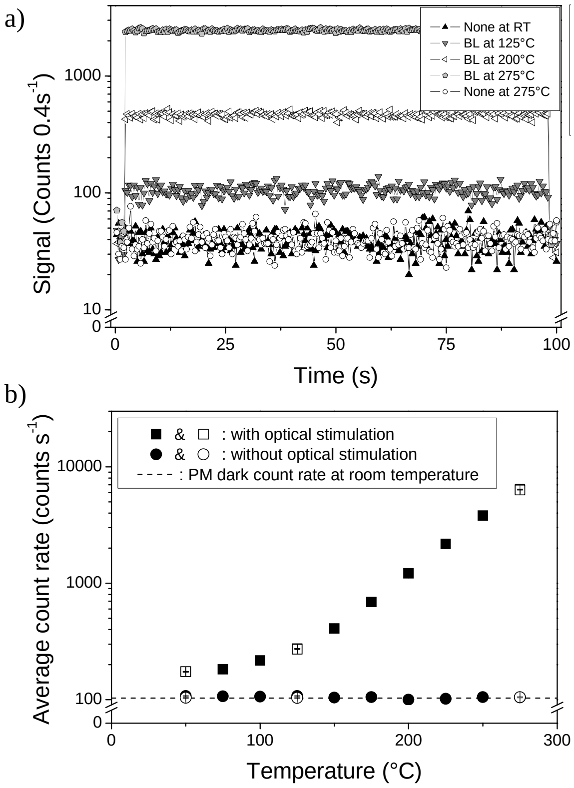

Figure 1: *(a) Signals observed from an annealed blank silicone-coated stainless steel cup during stimulation with blue diodes at various temperatures. RT refers to room temperature (~20°C) (b) Average count rate plotted as a function of stimulation temperature. The squares and circles represent the count rates observed with and without optical stimulation, respectively; the open symbols indicate repeated measurements. The dashed line marks the PM dark count rate at room temperature. Note that the aliquot was not beta irradiated during the course of this experiment.*

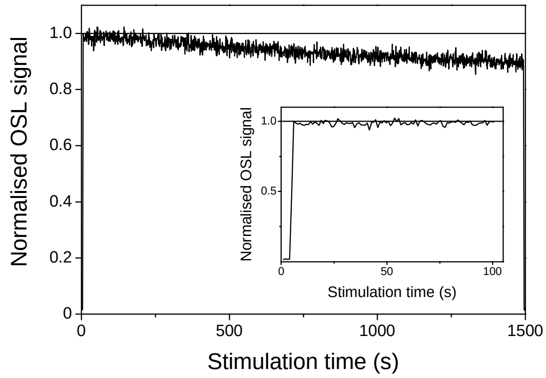

Figure 2: *Signal observed from an annealed blank silicone-sprayed stainless steel cup during stimulation with blue diodes for 1500 s at 250°C; the signal has been normalised to that observed in the first second of stimulation. The inset shows the signal observed during the first 100 s of stimulation.*

Spurious OSL was also monitored over longer stimulation times. Fig. 2 shows the OSL signal (normalised to the light-level observed in the first second of stimulation) from a blank silicone-sprayed disc that was stimulated for 1500 s at 250°C; the disc had previously been heated up to temperatures of as much as 600°C. Although the signal appears to remain relatively constant over the first 100 s (inset Fig. 2), on the longer timescale it can be seen to decay slowly over the entire 1500 s of stimulation to ~90% of the initial value.

We investigated whether the spurious signals originate with the silicone oil, and whether they exhibit a preheat and/or dose dependence. This experiment used 4 stainless steel cups; 2 had been used previously ("old cups") and 2 had never been used before ("new cups"). The two old cups were carefully cleaned with propanol, and all four cups were examined under a microscope to ensure that there were no quartz grains adhering to them. One old and one new cup were sprayed with silicone oil, while the other two were not. All cups were then put through a measurement sequence consisting of a ~16 Gy beta dose, preheat of 10 s at 300°C, stimulation with blue diodes for 100 s at 125°C, ~16 Gy beta dose, preheat of 10 s at 300°C and stimulation with blue diodes for 100 s at 250°C. The experiment was then repeated for preheat temperatures of 500°C and 600°C. After this, the experiment was further repeated for the preheat at 300°C twice, once without dosing and once with dosing. Finally, the aliquots were once more put through the measurement cycles employing the 300 and 600°C preheats, but this time the signal was recorded without switching on the blue diodes. The observed average count rates are summarised in Table 1.

The signals measured from the new cup without silicone oil stand out in that they are independent of the thermal pre-treatment and measurement temperature, and have an intensity that is comparable to that of the signals measured without optical stimulation (Table 1, last two columns). For the three other cups, the OSL signals measured at 250°C are significantly higher than both the background level and the corresponding light levels at 125°C. For the silicone-sprayed cups, stimulating at 125°C generally increases the light-level above that measured for the cups without silicone oil; however, there is no detectable dependence of the signal on pre-treatment (in contrast to results of measurements performed at

Cycle	Treatment	Count rates (cts/s) observed for: Old cup with silicone spray		Old cup without silicone spray		New cup with silicone spray		New cup without silicone spray	
		at 125°C	at 250°C	at 125°C	at 250°C	at 125°C	at 250°C	at 125°C	at 250°C
1	Dose + 10 s at 300°C + optical stimulation	308 ± 2	341 ± 2	310 ± 2	707 ± 3	205 ± 1	354 ± 2	275 ± 2	212 ± 1
2	Dose + 10 s at 500°C + optical stimulation	289 ± 2	1785 ± 4	268 ± 2	1189 ± 4	271 ± 2	2855 ± 5	193 ± 1	145 ± 1
3	Dose + 10 s at 600°C + optical stimulation	218 ± 2	4120 ± 7	170 ± 1	1095 ± 3	239 ± 2	5306 ± 7	143 ± 1	146 ± 1
4	No dose+ 10 s at 300°C + optical stimulation	237 ± 2	3906 ± 6	155 ± 1	1066 ± 3	271 ± 2	5015 ± 7	129 ± 1	131 ± 1
5	Dose + 10 s at 300°C + optical stimulation	240 ± 2	3681 ± 6	157 ± 1	1025 ± 3	268 ± 2	4554 ± 7	133 ± 1	128 ± 1
6	Dose + 10 s at 300°C + no optical stimulation	86 ± 1	85 ± 1	86 ± 1	84 ± 1	85 ± 1	84 ± 1	89 ± 1	81 ± 1
7	Dose + 10 s at 600°C + no optical stimulation	84 ± 1	83 ± 1	81 ± 1	83 ± 1	81 ± 1	84 ± 1	79 ± 1	85 ± 1

Table 1: *Average count rates (± 1 standard deviation) observed from various blank stainless steel cups after various preheat treatments and at two different measurement temperatures (125°C and 250°C). Except where indicated otherwise (no dose; no optical stimulation), the aliquots received a beta dose of ~16 Gy prior to each measurement and were stimulated using blue diodes.*

250°C). Finally, it is also interesting to note that spurious signals can be observed from a cup that was cleaned after previous use with silicone-oil.

From the observation of spurious OSL signals at 125°C following high temperature treatments, it is reasonable to ask whether a spurious signal is also emitted during measurement in conventional (i.e. fast component) SAR routines. To examine this in greater detail, a stainless steel cup was sprayed with silicone oil and put through a measurement sequence that contained the main heat treatments of a conventional SAR protocol. The sequence consisted of preheating for 10 s at 260°C, measuring the signal at 125°C both with and without stimulation using the blue diodes, applying a cutheat to 220°C, and measuring the signal at 280°C, again both with and without blue diode stimulation. This sequence was repeated 8 times in total. The average count rates are plotted as a function of measurement cycle in Fig. 3. It can be seen that the signals with and without blue light stimulation at 125°C are not identical (solid and open circles, respectively). The optically stimulated luminescence signals do not change throughout the period of measurement (38 s) and the average count rates remain relatively constant over the 8 measurement cycles. The overall average count rate (± 1 standard error) is 169 ± 4 cts.s^{-1}. This value falls within the range of observations for a new cup without silicone oil (Table 1). Thus, it seems unlikely that the signal stimulated at 125°C originates with spurious OSL from silicone oil. On the other hand, spurious OSL signals can be clearly observed at a stimulation temperature of 280°C; this signal progressively increases with measurement cycle, after an initial decrease (solid squares in Fig. 3). It is concluded that conventional SAR measurements of the quartz fast component at 125°C do not usually suffer interference from spurious OSL from silicone oil. It should be noted that, even if there had been a spurious OSL signal at 125°C, the SAR protocol would be self-correcting so long as this signal was a constant underlying the fast component signal; it would, however, reduce our ability to detect light levels of a comparable intensity.

Discussion and conclusion

Thermally stimulated spurious luminescence signals from silicone oil have been observed in combination with aluminium but not with stainless steel (Murray, 1981). We are unaware of any previous observations of spurious OSL in this context.

The main purpose of the present note is to point out the existence of spurious signals in the specific context of studies related to the quartz slow OSL component. No comprehensive investigations of the behaviour of silicone oil as a function of measurement conditions were carried out. However, we can add that the spurious OSL signal associated with silicone oil can behave in an unpredictable manner, increasing first as it receives cumulative heating, and then dropping down in intensity (Fig. 3). Furthermore, although the signal shows no significant

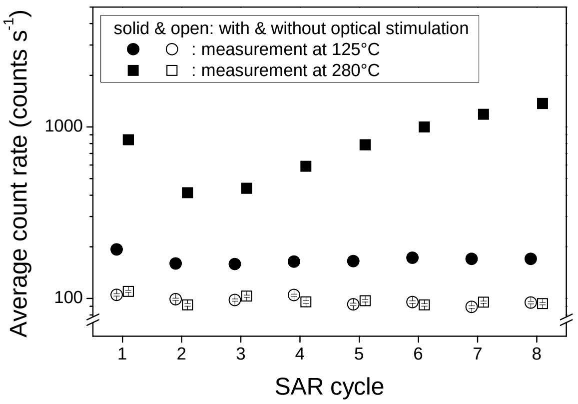

Figure 3: *Effect of the repeated thermal treatments typical of a SAR protocol on the signals (expressed as average count rates) observed from a blank and silicone-coated stainless steel cup. Stimulation was performed using blue diodes at 125°C and 280°C (circles and squares, respectively); the open symbols indicate the signals observed without optical stimulation. The aliquot was not beta irradiated during the course of this experiment.*

decrease over short stimulation times (40-100 s; see Figs. 1 and 2), it can be seen to decay slowly but steadily over longer stimulation times (of the order of 1-2 ks; Fig. 2). Finally, it is worth pointing out that the intensity of the spurious signal may be dependent on the amount of silicone oil sprayed upon a disc (see Table 1).

Measuring the slow component usually implies detecting low signal levels. From our observations above it is concluded that silicone oil can significantly interfere with such measurements, and that the spurious "slow component" is not easily corrected for. The original reason for using silicone oil was to ensure a mono-layer of grains during beta irradiation. This was because the beta dose rate is strongly dependent on both the build-up material in front of the grains (air for a mono-layer, otherwise other grains), and backscatter from the substrate (stainless-steel in the case of a mono-layer, otherwise other grains). Thus it would be unwise to avoid the use of silicone oil. However, we recommend that one should always test for the presence of spurious signals by measuring blank and silicone-oil coated substrates. Based on our Table 1, the same recommendation holds for cleaned substrates that have a history of use with silicone-oil. Indeed, there are probably better silicone degreasing agents available than the propanol we have used.

Acknowledgements

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Reviewer

J.H. Choi

Editors' comment: An alternative solvent for removal of silicone oil is ethyl methyl ketone, also known as butanone.

Thesis Abstracts

Author: Claire Boulter
Thesis Title: Reconstructing the palaeoenvironmental history of East Central Texas since the last glacial maximum
Grade: PhD
Date: October 2007
Supervisors: Mark Bateman, Charles Frederick
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Prevailing opinion holds that thick, unconsolidated, largely homogeneous sand deposits located in East Central Texas were formed by *in situ* weathering of the underlying friable sandstone bedrock combined with pedoturbation. This being the case, archaeological and palaeoenvironmental work in the region would have little or no value. An extensive series of one hundred and twenty-nine samples from twenty sites in summit, hillslope and palaeogully settings were collected to assess the veracity of such claims. A protocol for assessing the presence and extent of post-depositional disturbance was developed using a range of indicators derived from optically-stimulated luminescence (OSL) results, as well as down-profile changes in magnetic susceptibility and particle size. Application of this protocol to the sites studied showed that, whilst many sites had experienced a significant degree of reworking, mixing was generally not of sufficient magnitude to preclude the extraction of a viable chronology or meaningful palaeoenvironmental information. The resulting data show unequivocal evidence for numerous pulses of aeolian and colluvial activity spanning the last 100 ka. Enhanced sedimentation occurred during the Mid- to Late Holocene generally, and specifically at around 8-5, 4-2 and 1-0 ka.

To assess whether such pulses were driven by climate, pollen analysis of a peat core retrieved from a rare upland bog was undertaken. This provided an 18.7 ka record of vegetation and, by proxy, climate change in the region. Broadly speaking, climate was characterised by cool, moist conditions at the Last Glacial Maximum, followed by increases in both temperature and precipitation during the deglacial period, then progressive warming and drying, interrupted by small-scale returns to cooler and/or moister conditions, throughout the Holocene. Comparison of this record with those from neighbouring regions highlights the existence of an east-west precipitation gradient, which fluctuated in position and steepness during the Holocene. This caused pronounced shifts from mesic to xeric conditions in the study region, which have not been observed elsewhere. Integration of records of climate and geomorphic activity reveals that linkages between the two are not clear-cut, but appeared to show that phases of instability are controlled primarily by sediment availability and small-scale (possibly single event) changes in climate (e.g. storms, droughts). Complex interactions exist between different geomorphic settings and modes of deposition.

Author: Alicia Huntriss
Thesis Title: A Bayesian analysis of luminescence dating
Grade: PhD
Date: October 2007
Supervisors: Michael Goldstein, Ian Bailiff and Andrew Millard
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Luminescence dating is a widespread dating method used in the fields of archaeology and Quaternary science. As an experimental method it is subject to various uncertainties in the determination of parameters that are used to evaluate age. The need to express these uncertainties fully, combined with the prior archaeological knowledge commonly available, motivates the development of a Bayesian approach to the assessment of age based on luminescence data. The luminescence dating procedure is dissected into its component parts, and each is considered individually before being combined to find the posterior age distribution. We use Bayesian multi-sample calibration to find the palaeodose in the first stage of the model, consider the problem of identifying a plateau in the data, and then use this, along with the annual dose, to estimate age. The true sample age is then modelled, incorporating any prior information available, both for an individual sample and for a collection of samples with related ages.

Author: Mathieu Duval

Thesis Title: Evaluation du potentiel de la méthode de datation par Résonance de Spin Electronique (ESR) appliquée aux gisements du Pléistocène inférieur: étude des gisements d'Orce (bassin de Guadix-Baza, Espagne) et contribution à la connaissance des premiers peuplements de l'Europe
(Evaluation of the potential and limits of electron spin resonance dating applied to the Lower Pleistocene sites of Orce (Guadix-Baza basin, Spain), and a contribution to the understanding of the first human settlements of Europe)

Grade: PhD

Date: November 2008

Supervisor: Christophe Falguères

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This work presents an evaluation of the potential and limits of the Electron Spin Resonance (ESR) dating method for ancient periods (Lower Pleistocene) in archaeological and/or geological contexts. ESR was used to analyse samples from the Orce sites (Fuente Nueva III, Barranco León and Venta Micena), located in the eastern part of the Guadix-Baza intramontane basin (Andalusia, Spain). These are considered key sites for the understanding of the first settlements of Europe.

Two types of material were analyzed: dental enamel and quartz extracted from sediments. The methodological study focused on: (1) an inventory of the error sources and uncertainties associated with the calculation of the equivalent dose (D_e); (2) the non-destructive ESR analysis of enamel fragments, with an extraction of the main components of the ESR signal of hydroxyapatite in order to check their influence on the D_e value; (3) the 3-D mapping of uranium series isotopes in dental tissues by laser ablation ICPMS (LA-ICPMS) to establish the spatial distribution of the radioelements, and to evaluate the impact of the tissue preservation on the diffusion processes.

The combined ESR-US method applied on tooth enamel shows that the dose rates of the dental tissues are the most crucial parameters for the age calculation of samples from old sites (>700 ka). Because of high $^{230}Th/^{234}U$ ratios, implying U-leaching, most of the samples could not be dated. When age calculations were possible, the results were generally in agreement with independent age estimates, implying that ESR can be successfully applied on Lower Pleistocene samples. An alternative to ESR-US, the US_e model, was developed to calculate a theoretical maximum ESR-US age and to account for uranium leaching from the dental tissues.

ESR dating of optically bleached quartz extracted from sediments was tested on the fluvio-lacustrine deposits of the 20 m thick sedimentary sequence of Barranco León. ESR ages calculated on more than twenty samples show some good reproducibility and are overall coherent, even though several problems were encountered (necessity of an *in situ* dosimetry, disequilibrium in the ^{238}U decay chain). The chronological results confirm that the sedimentary sequence covers the whole Lower Pleistocene period.

ESR ages calculated for the two types of material were overall in agreement with the chronostratigraphical framework already established by other independent methods such as biochronology and palaeomagnetism, and confirm the chronological positioning of the Orce sites within the Lower Pleistocene. The results obtained in this work show that the ESR dating method can be applied to the Lower Pleistocene period.

Author: Asger Habekost Nielsen

Thesis Title: On the evolution of beach ridge plains: Luminescence dating, geomorphology and soil development at the Jerup beach ridge plain, Denmark

Grade: PhD

Date: October 2008

Supervisors: Bo Elberling and Morten Pejrup

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Beach ridges are important coastal features, marking ancient coastlines and acting as sediment archives. This thesis focuses on the Jerup beach ridge plain in Northern Jutland, Denmark. The Jerup beach ridge plain contains 161 ridges plus two foredune ridges that are included as modern pseudo-analogues. A beach ridge chronology is constructed by collecting and analysing 90 samples from the beach ridge plain and the surrounding region. The samples are dated using Risø reader equipment, a SAR protocol and dose rate calculations based on gamma

spectrometry of the samples. The luminescence signal consistency is checked by dose recovery tests and SAR-specific consistency tests. Luminescence ages are validated against independent age control (mainly radiocarbon ages). With OSL dates at hand, the rates of soil development in the ridges can be assessed. The soil development is analysed by collecting 134 samples from 14 soil pits. The soil samples have been analysed for organic C content, pH (H_2O) and extractable Fe, Al and Mn concentrations.

The overall luminescence-based chronology of the Jerup beach ridge plain is ~10 to ~4000 years before AD 2005, if the modern dune ridges are included. The dose recovery test had a mean test ratio of 1.007±0.004, and the luminescence ages are in good agreement with independent age controls. The mean luminescence error margin is ±6.28%. According to the luminescence chronology, the beach ridges formed every 24 years on average and the mean coastal progradation rate is 1.6 $m.a^{-1}$. Judging from the GPR survey and ridge transect observations, the ridges are initially formed as marine berms or debris lines, but the ridges are reinforced by aeolian deposition shortly after the incipient ridge formation. The aeolian deposits magnify the original 1–1.5 m high marine ridge to a 2–4 m high ridge. Later aeolian deposition has occurred in at least three different periods that correlate with known periods of cold and windy climatic spells. Spodosols have been discovered found in a ~1,500-year old ridge, indicating an intermediate podzolization rate. Finally, soil development interference with luminescence dates is assessed by evaluating radionuclide distributions in three podzolised soil profiles. Radionuclide activity concentrations from 100 samples collected in five podzolised areas in Jutland (including the Jerup beach ridge plain) are correlated against soil physical and chemical parameters using the Kendall's Tau-b method. These experiments revealed no correlation of soil chemical parameters and radionuclide distributions.

Based on the results from the Ph.D. project, the luminescence chronology improves the chronological resolution of the Jerup beach ridge plain by more than an order of magnitude. Luminescence dating in young sediments is also tested at a large scale, allowing a detailed error analysis on a large sample set. The effects of podzolisation on luminescence dating is also tested systematically, and reveal that, under the local conditions, the podzol-related redistribution of iron, aluminium and organic compounds do not affect the dose rates (and, in turn, the luminescence ages).

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Conference Announcements

7th International Conference on Luminescent Detectors and Transformers of Ionizing Radiation, LUMDETR-2009

Kraków, Poland

12-17th July 2009

The Institute of Nuclear Physics of the Polish Academy of Sciences is pleased to invite you to the *7th International Conference on Luminescent Detectors and Transformers of Ionizing Radiation LUMDETR 2009* which will be held in Kraków, Poland on July 12th-17th 2009. This scientific conference continues the tradition of the conference series initiated in Latvia (Riga, 1991).

The Summer School of Luminescence will take place during the LUMDETR-2009. The School, open for all participants, will take the form of "refreshment lectures" on basic aspects of luminescence, presented at the beginning of each conference day by an expert in the field.

The conference proceedings will be published in the journal *Radiation Measurements*.

Full details of deadlines for the conference can be found on the web page given below, but in brief:

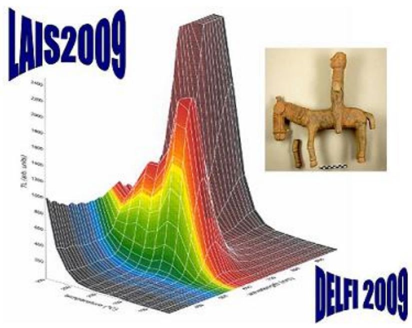
Deadline for abstract submission : 23rd Jan 2009
Deadline for early registration : 12th May 2009
Deadline for paper submission : 17th Aug 2009

All information about the conference may be found at the web page: www.lumdetr2009.pl

Conference Announcements

1st Luminescence in Archaeology International Symposia (LAIS)

Delphi, Greece



9-12th September 2009

Nearly 50 years after the publication of the first thermoluminescence ages, the field of luminescence dating has reached a level of maturity, in both research and applications in archaeology and geology.

LAIS is a new international initiative that mainly focuses on the use of luminescence dating for materials and questions of archaeological significance; in addition it supports archaeological and archaeometrical communities of the World to further develop and expose luminescence issues.

LAIS meetings aim at bringing together experts in the fields of luminescence, archaeology and archaeological materials from all around the world. In an exchange of knowledge, the techniques and tools available in luminescence dating and luminescence applications will be introduced to the archaeologists and archaeological problems will be presented for the scientific community.

The 1st LAIS Symposium will take place in Greece and symbolically be hosted at the European Cultural Centre of Delphi (www.eccd.gr), Greece in September 9-12, 2009.

The papers and posters presented at these conferences will be published in a special edition of a peer-reviewed international journal related with luminescence.

Topics

The topics range from fundamental studies of the physical basics and mechanisms of luminescence dating, through advances in equipment technology and analytical procedures, to sound applications and studies on archaeological material from various cultures of the World. Comparisons with other dating methods are encouraged. A few invited lectures will provide an overview on the main topics. Both oral and poster contributions will be considered for presentation.

Scheduled Sessions

Dating of heated and solar bleached archaeological material (artefacts, sediments, rocks and buildings) and Rock Art, dating in Prehistoric, Classical Antiquity and Medieval Eras, New World Archaeology, Case studies for the World Palaeolithic, Geoarchaeology, New methodological developments, Dosimetry applications, Combined chronological studies (Luminescence, Radiocarbon, Uranium Series, etc), Precision and Accuracy in luminescence, Authenticity Testing, Instrumentation and facilities, Statistics in luminescence, Use of luminescence in archaeological material studies, Innovations and Special Applications.

Registration Fees

Speciality	**Early**	**Late**
All specialists	€ 250	€ 290
Accompanying persons	€ 120	€ 150
Students	€ 120	€ 150

Deadlines

Early registration deadline:	April 30, 2009
Abstract submissions deadline:	April 30, 2009
Paper submissions deadline:	Sept 12, 2009

Further information

Further information about the conference can be found at the following web sites:

http://kalamata.uop.gr/~LAIS2009

http://www.zita-congress.gr/49/article/greek/49/4/index.htm

Prof Ioannis Liritzis (liritzis@rhodes.aegean.gr)

Conference Announcements

Japanese Meeting on Luminescence and Electron Spin Resonance Dating and Dosimetry 2009

Act City Hamamatsu
(http://www.actcity.jp/index.php) and
Hamamatsu Photonics
(http://jp.hamamatsu.com/en/index.html)
Hamamatsu, Japan

2-4th March 2009

The next Japanese Meeting on Luminescence and Electron Spin Resonance Dating and Dosimetry will be held at Hamamatsu, from 2nd to 4th March 2009. We seek oral and poster presentations for both fundamentals and applications using luminescence and ESR. You will be invited to a tour of the photomultiplier tube factory and the laboratory of Hamamatsu Photonics on 4th March. Hamamatsu is located ~200 km west of Tokyo, and 1.5-2 hour from central Tokyo by express train (~3 hours from Tokyo International Airport). It is about the same distance from Osaka. The city is also famous for Yamaha and Kawai, and you can also visit their piano factories, if you are interested.

Please contact Atsushi Tani, the local organiser, for further information.

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