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Editorial – 30 years of Ancient TL

Thirty years ago, in the autumn of 1977, the first issue of Ancient TL was published by David Zimmerman at Washington University in St Louis, USA. The introduction to that first issue was prescient in its objectives for the journal, “Ancient TL is a quarterly newsletter intended primarily to facilitate communications of helpful and practical information between researchers actively involved in thermoluminescence dating. The major subjects of contribution are expected to be experimental techniques and new equipment, TL data of various phosphors and minerals, and data and information on dosimetry and radioactivity determinations. Other topics may include lists of recent publications, announcements of meetings, lists of theses available, and readers’ queries.” Sadly David Zimmerman did not live long enough to see the extent to which the journal achieved all of these objectives.

The journal has regularly provided information on forthcoming conferences, including the PACT meetings of the 1980’s, the Solid State Dosimetry meetings, the International Seminars and Conferences on Luminescence and Electron Spin Resonance Dating, the UK Luminescence meetings, and more recently the New World Luminescence Dating Workshops and the Asia Pacific Luminescence Dating conferences. A bibliography of recent publications has been a consistent feature of the journal, enabling readers to keep abreast of publications in the field. This job has grown in size as the field has matured over the years!

In the 30 years that the journal has now operated, it has published a wide range of articles on thermoluminescence, optically stimulated luminescence, dosimetry and equipment. In addition, many papers on the closely related topic of Electron Spin Resonance (ESR) have also been published. What has characterised the journal has been the mixture of subjects addressed. As foreseen by Zimmerman, the topics cover both the scientific results obtained, but also, and equally importantly, the practical information required to successfully operate a luminescence or electron spin resonance laboratory. Thus, back issues of Ancient TL hold a wealth of information on methods of sample collection, on laboratory illumination, on the impact of security x-ray scanners on samples, on the isolation of quartz or other minerals, and many other topics.

Much of this information is as relevant today as it was when it was published. In recent years a major project has been undertaken to make back issues of Ancient TL available electronically. This was begun three years ago in 2004, and I am pleased to report that this process is now complete, with all back issues now freely available via the Ancient TL website (www.aber.ac.uk/ancient-tl). I am grateful to Helena Rodnight and Daniel Richter for their enormous help in completing this task.

In order to help readers to find information in previous issues, the website contains two means of searching previous issues. The first is an index of authors of all papers. This lists every paper published by each author, and has hyperlinks that will display a PDF of the papers suitable for viewing on screen or printing out. Using standard web browsers one can use the Ctrl-F function to search for text in the titles of the papers (e.g. calibration, fading, laboratory lighting etc). The second method for searching for articles is through an EndNote database provided by Daniel Richter. For those with access to EndNote this database can be downloaded and interrogated.

Theses online

A new initiative, starting in December 2007 to coincide with the publication of this issue of the journal, is for the web site of Ancient TL to also make available electronic copies of research theses in order to increase the accessibility of these to the community. In certain countries it is commonplace for theses to consist of a number of published articles. In these cases, there is probably little additional information in the thesis, except perhaps an overview of the papers, and additionally there may be copyright issues which would make placing them on the web difficult. However, in many other countries theses are not directly based on published papers. Whether for masters degrees or doctorates, theses have often been difficult to get hold of, and consequently read by only a limited number of people. This is the case for both recent and older theses.

Ancient TL is now acting as a host, enabling the authors of these theses to make their work available as a PDF. Authors wishing to submit their theses are requested to send a single PDF, containing the complete thesis, to the Editor. The intention is to periodically list the complete suite of theses that are available via this web site in the pages of this journal.

The future

The fields of luminescence and electron spin resonance have undergone dramatic growth in the last 30 years. An impression of this growth can be gained by glancing through the bibliographies published in Ancient TL over this time. In the first decade of the journal the bibliography rarely exceeded 20 papers, while now it is not uncommon for Ann Wintle to list over 150 papers. So what is the role of Ancient TL in the future, as the field continues to develop?

Continued growth in luminescence and ESR is likely to see the number of laboratories rapidly increasing around the world. As this occurs, the objectives of Ancient TL outlined 30 years ago, namely to facilitate communications of helpful and practical information between researchers actively involved in the field, become ever more important. The journal continues to provide an avenue through which scientific results, and practical advice can be disseminated through both paper and electronic formats. By providing a venue for listing recently completed research theses and publications it helps to "glue" the community together, assisting in the rapid dissemination of information that has helped the field to grow so rapidly and successfully. The founders of Ancient TL felt that communication between scientists was vital. This remains as important today as it did then. I hope that electronic access will enable the latest generation of scientists in this field to benefit from the accrued knowledge in the subject.

Geoff Duller
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1st December 2007

Phosphorescence spectra from alkali feldspars as they are cooled

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Abstract

We report here phosphorescence spectra over the range 1.55 to 5.5 eV from three alkali feldspars after irradiation as they are cooled from room temperature to 130 K. The dominant emission was at 1.7 eV. With decreasing temperature, the intensity of this band initially decreased, but then increased below 250 K, consistent with the observation of Visocekas and Zink. We confirm their inference that they were measuring the 1.7 eV emission band characteristic of Fe^{3+}. Other emission bands were observed at 2.2, 2.7 and 4.3 eV; their intensities decreased with decreasing temperature.

We were also able to measure the emission spectra of one sample after a 30 minute heating at 120°C; the 1.7 eV band was much reduced and the emission now dominated by the 2.2 eV band, characteristic of Mn^{2+}. The 1.7 eV band now did not show thermal quenching.

Introduction

Phosphorescence emission spanning from IR to UV is detected from irradiated feldspars. Emission occurs when electrons escape from the traps and recombine at the luminescence centres (Aitken 1985). Visocekas et al. (1994), Visocekas and Zink (1995), and Visocekas (2002) reported on phosphorescence emission from feldspars from room temperature to liquid-N_2 temperature. They irradiated feldspars (mostly K-feldspars) with a beta source at room temperature, and phosphorescence emission intensity was measured as a function of time **t**, initially at room temperature. Then measurements were continued with the samples cooled to liquid nitrogen temperature. They found that as the samples were cooled the emission intensity first decreased and then increased, the increase being attributed to thermal quenching. We also note that at low temperature, thermal excitation from shallow traps would not occur, and recombination emission could result only from tunnelling. They also found the emission intensity to be proportional to $\mathbf{t^{-1}}$ and interpreted this as the consequence of tunnelling with a distribution of tunnelling distances (see Huntley, 2006, for recent theory). Visocekas and co-workers also reported that the emission occurred only in the near-IR, with photons of energies less than 2.1 eV (~ 590 nm). They reasoned that this emission was probably the known band at ~ 1.7 eV (~ 730 nm) due to impurity Fe^{3+} substituting for Al^{3+} in the tetrahedra which constitute the frame of the feldspar lattice. However, Visocekas et al. did not show emission spectra during tunnelling in support of this. The object of the present work was to establish this and the temperature dependences of the various emission bands.

In our research we measured several samples belonging to both plagioclase and alkali feldspar groups. Here we give results only for the alkali feldspars; those for the plagioclase feldspars are quite different and have been reported elsewhere (Huntley et al. 2007). Previously, Baril (2002) and Baril and Huntley (2003b) reported phosphorescence spectra of some feldspars at room temperature and above from 1.24 to 5.5 eV (1000 to 225 nm).

Samples

The potassium feldspars studied here are:

K8	-	Microcline, Ward's[1]	45E2941
K12	-	Orthoclase, Ward's[1]	49E5919
K14	-	Microcline, Ward's[1]	49E5918

Aliquots of the samples were prepared by gluing small chips (2 – 3 mm) on aluminum planchets using Crystalbond[2] dissolved in acetone. The planchets were placed in an oven at 50°C for 1 hour to harden the Crystalbond.

[1] Ward's Natural Science, 397 Vansickle Road, St. Catherines, Ontario, L2S 3T5, Canada
[2] Crystalbond 509: Aremco Products Inc., P.O. Box 517, 707-B Executive Blvd. NY 10989, USA

Emission spectra

Aliquots were given a ~ 800 Gy dose of ^{60}Co gamma radiation and phosphorescence emission spectra were then measured using the spectrometer described by Baril and Huntley (2003b). The CCD-detector was cooled to ~ -60°C using a Peltier cooler and a dry ice/alcohol bath in order to reduce the noise level. Spectra were measured from 1.55 to 5.5 eV (800 nm to 225 nm).

The irradiated aliquots were placed in a cryostat to reduce the sample temperature (minimum 130 K). Light from a sample was guided to the CCD-spectrometer by an optical-fibre bundle. Spectra recorded as the samples were cooled are shown in Fig. 1a to Fig. 1c.

At room temperature sample K8 showed spectral bands at 4.4 eV (280 nm), 2.6 eV (470 nm), 2.2 eV (570 nm) and 1.7 eV (730 nm) (Fig. 1a). At 250 K the intensities of all the bands were reduced, however with further cooling the intensity of the 1.7 eV band increased, while the other bands remained almost unchanged (Fig. 1a). Samples K12 and K14 showed similar behaviour (Figs. 1b and 1c) except they lacked the 2.2 eV and the 4.4 eV bands. The broad feature from 3 – 5.5 eV seen in Figs. 1b and 1c is an artefact, probably due to light scattered within the spectrometer.

To remove the unstable electrons from the shallow traps of irradiated feldspars, we preheated the samples for 30 minutes at 120°C. One hour after the preheat, the samples were measured again. Only the brightest of the three, K8 gave a measurable intensity. The intensity of the 1.7 eV band was much reduced compared to that of the 2.2 eV band by this short preheat. The spectrum is shown in Fig. 2. As this preheat (30 min at 120°C) may not have been sufficient for complete removal of shallow-trap electrons, the samples were heated further at 160°C for 1 hour for their complete removal. The emission intensity was then too weak to measure the spectrum. Fig. 2 also shows the spectra from K8 as it was cooled to 130 K. It is seen that the intensities of both the 1.7 and 2.2 eV bands decreased. There is no indication of the thermal quenching of the 1.7 eV band seen in the non-preheated sample.

Discussion

Phosphorescence spectra from irradiated feldspars at room temperature have been previously reported by Baril and Huntley (2003a) (see also Baril, 2002). In their measurements the same spectrometer was used, but with a different grating, which allowed them to measure spectra from 1.24 to 5.5 eV (1000 – 225 nm). The earlier measurements show that there is also

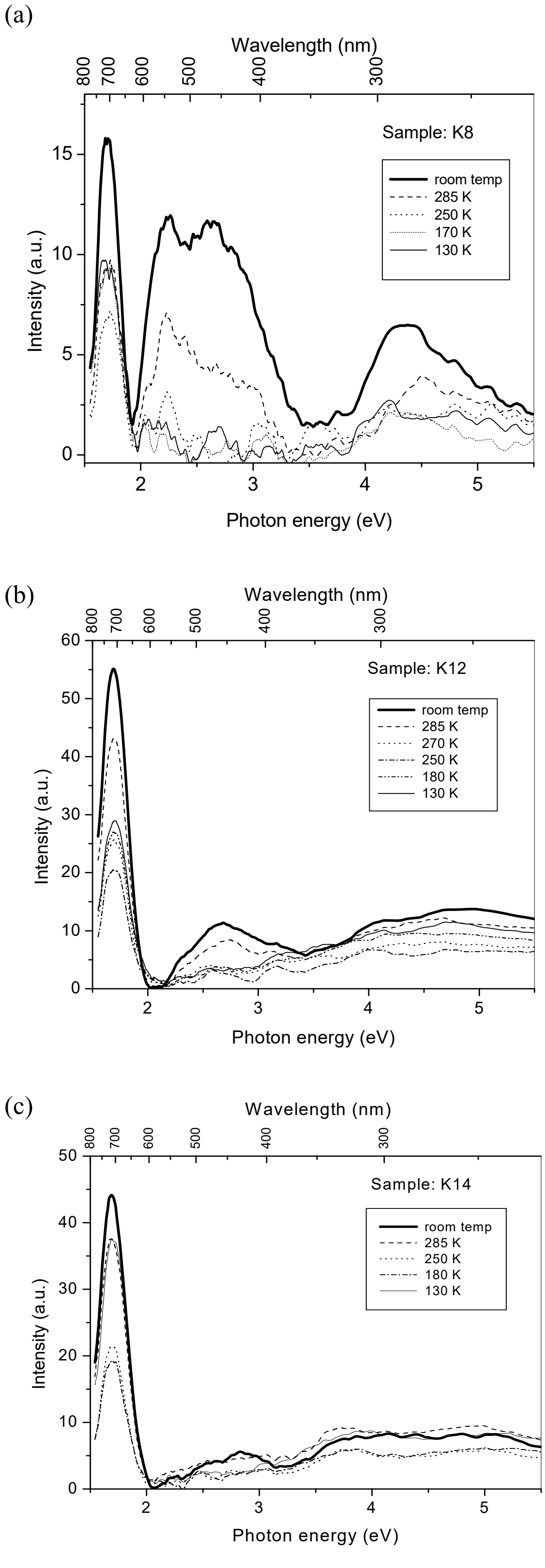

Figure 1: *Phosphorescence spectra of irradiated feldspars K8, K12 and K14 at room temperature and cooler.*

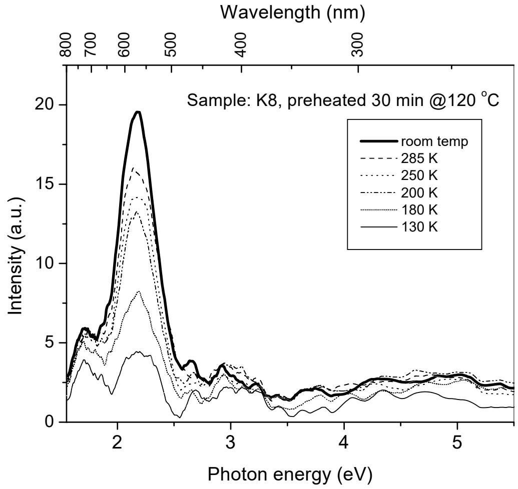

Figure 2: *Phosphorescence spectra of feldspar K8 at room temperature and cooler. The sample was first irradiated and heated 30 minutes at 120°C.*

an emission band at 1.37 eV (900 nm), which is outside the measurement range of the present work. The present measurements showed a band at 4.4 eV, which was seen by Baril and Huntley in other feldspars but not in K8. We presume this is because we used different aliquots, and that K8 is not homogeneous. When the sample K8 was preheated at 120°C for 30 minutes there was a drastic reduction of the bands at 1.7, 2.6 and 4.4 eV. This leads us to think that thermal excitation of, or tunnelling of, shallow-trap electrons leads to the 1.7 eV, 2.6 eV and 4.4 eV emission bands.

The objective of the present work was to test the inference of Visocekas that the phosphorescence emission below 2.1 eV (above 590 nm) was essentially all in the 1.7 eV (red-IR) band due to Fe^{3+}. Our spectra support this, though it is possible that the tail of the 2.2 eV band may make a contribution for some samples as it would for our K8.

As did Visocekas, we found thermal quenching for the 1.7 eV band. White et al. (1986) found an activation energy for thermal quenching of 0.056 eV, and Poolton et al. (1995) found a value of 0.34 eV. However, it was absent for the heated sample (Fig. 2). Thermal quenching depends on the local environment of the center and we thus deduce that the environments are different in the different cases. For us either the heating has changed the environment or the phosphorescence from the heated sample is from a subset of the Fe^{3+} ions that contributed to the phosphorescence of the unheated sample.

Acknowledgements
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Reviewer
A.G. Wintle

Reviewer's Comments
The results of this study indicate the complexity of luminescence emission from K-feldspars. It is of particular interest that the main emission observed for all three samples is at 1.7 eV and is thus not observed

when using conventional bi-alkali photomultiplier tubes. Two of the samples were microclines, K-feldspars that have been shown by others to exhibit anomalous fading. The observation for the microclines in this study that there is emission when the sample is cooled well below the irradiation temperature indicates that considerable release of electrons occurs subsequent to irradiation at room temperature. Although emission at this wavelength, attributed to Fe^{3+}, is drastically reduced by heating for 30 minutes at 120°C, a preheat that is longer than that usually used in dating protocols, phosphorescence at 2.2 eV, attributed to Mn^{2+}, was still observed indicating release of electrons that may manifest itself as anomalous fading.

Thesis Abstracts

Author: Kathryn Fitzsimmons
Thesis Title: The late Quaternary history of aridity in the Strzelecki and Tirari Desert dunefields, South Australia
Grade: PhD
Date: October 2007
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Linear dunes occupy more than one third of the Australian continent, but the timing of their formation and their reliability as proxies for arid conditions is poorly understood. This thesis investigates the late Quaternary history of aridity of the Strzelecki and Tirari Desert dunefields, a region in the driest part of Australia. This was achieved using a threefold approach. Firstly, the morphologic variability of linear dunefields was investigated, in order to understand dunefield formation over regional scales, and to assess the degree to which local geomorphologic context influences dune response to arid conditions. Secondly, the sedimentological and stratigraphic characteristics of linear dunes were used to interpret the degree to which dune activity can be used as a proxy for aridity. The reliability of dune records, based on evidence for reworking and the extent to which stratigraphy is preserved, was also assessed using this evidence. Finally, the timing of dune activity, interpreted using an OSL chronology, was used to provide a proxy history of late Quaternary aridity within the driest part of the arid zone.

The morphological variability of linear dunes in the Strzelecki and Tirari Deserts of Australia was assessed using a dune classification scheme, based on quantifiable variables of substrate, spacing and junction frequency. The use of high spatial resolution ASTER satellite imagery enabled detailed analysis, including spectral characterisation of substrate, at both local and regional scales. The classification of the linear dunes revealed close relationships between substrate type and dune spacing, reflecting local sediment availability. Both downwind evolution and sediment nourishment from local sources play a role in linear dune formation, although the latter dominates. Maps illustrating the spatial distribution of planimetric variables provide a useful tool for investigating linear dune characteristics, although additional variables such as height, width and dunefield age add to the complexity of dune formation and must also be considered.

The extent to which dunes act as proxies for aridity, and their reliability as palaeoenvironmental archives, was examined by characterising dune sediments, stratigraphy, and evidence for reworking. In the Strzelecki and Tirari Deserts, linear dune activity took place in response to intensified aridity. Clay pellets, which form by the efflorescence of salts on seasonally exposed clay flats with high evaporation rates, were found at several sites, and indicate incipient aridity and periodic inundation of adjacent swales. Their presence and inherent fragility suggests that linear dune sediments are mostly derived from local sources. The similarity of dune and underlying substrate characteristics supports the local windrift model for dune formation.

The reworking of underlying palaeosols within dunes, indicated by abrasion and partial preservation of grain cutans, is ubiquitous across the dunefields. Although not all dunes preserve every identified episode of activity due to local reworking, the widespread sampling strategy adopted in this study reduces bias towards more recently reworked periods. In this study, 82 samples from 26 sites across the Strzelecki and Tirari Deserts were collected to provide an optically stimulated luminescence chronology for the dunefields. Standard tests for the luminescence behaviour of aeolian quartz, including dose recovery and the measurement of recycling ratios and thermal transfer, showed that the linear dune sediments are well suited to the OSL SAR protocol. The dunes each preserve up to four stratigraphic horizons, bounded by palaeosols, which represent evidence for multiple periods of reactivation interspersed by episodes of increased environmental stability. The OSL chronology was shown using standard statistical tests to contain five distinct age populations, interpreted to correspond to aeolian events, at 73.3-65.8 ka, 34.7-28.7 ka, 22.1-17.8 ka, 14.1-12.1 ka and 11.7-10.0 ka. A cluster of ages from approximately 3.5 ka to the present suggests that dune activity also took place during the late Holocene, but does not form a statistically significant population by the same tests. Stratigraphic evidence suggests that dunes may have been partially active over long periods of time, resulting in slow net accumulation punctuated by short-lived, substantial sand-shifting events. Dune activity coincided with cold, arid conditions during early marine oxygen-isotope stage (MIS) 4, mid-MIS 3 and the Last

Glacial Maximum (LGM), and warm, dry climates during the Pleistocene-Holocene transition and late Holocene. The timing of widespread dune reactivation coincided with dune activity in other dunefields within Australia, although aeolian activity prior to MIS 5, recorded elsewhere, does not appear to be preserved in the Strzelecki and Tirari Deserts. Aeolian events during early MIS 4 and the LGM correlate with increased dust flux to the Tasman Sea and Antarctic ice cap, glaciation in southeastern Australia, cooler regional sea-surface temperatures, and increased ice volumes in the southern hemisphere and Antarctica.

Author: Li Bo
Thesis Title: Development and application of optical dating using quartz and potassium-feldspar from Quaternary sediments
Grade: PhD
Date: June 2007
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New methods were presented for the dating of Quaternary sediments using luminescence signals from quartz and potassium-feldspar (K-feldspar) grains. These are based on fundamental studies carried out on separated quartz and feldspar grains.

Estimation of the equivalent dose using the fast component and the medium component of optically stimulated luminescence (OSL) from quartz grains was investigated using both linear-modulated OSL (LM-OSL) and continuous-wave OSL (CW-OSL) techniques. By mathematical fitting of the LM-OSL curves, the fast component of the quartz OSL signal can be separated from the signals observed for mixed mineral grains in order to determine the equivalent dose (D_e). The medium component underestimates the D_e for old samples, and this is attributed to its thermal instability. A method was proposed to evaluate the D_e values for the fast component and medium component by analyzing the D_e as a function of stimulation time.

Three kinds of source traps (i.e. shallow, medium and deep sources) for thermal transfer in quartz were identified. The shallow source is thermally unstable below 260°C and is mainly related to the main OSL trap. The medium source is the primary charge source (peak ~300°C). The deep source is dominant at higher temperatures. Two kinds of OSL traps were identified as accepting the charges from the medium and deep sources. These OSL traps have different thermal stabilities and associated sensitization processes from those of the main OSL traps. A method was proposed to correct for thermal transfer effects for young samples based on the linear relationship between the initial and final parts of the thermally transferred OSL signals in repeated heat/OSL measurement cycles.

A new isochron method involving measurement of the IRSL signals from K-feldspar grains of different size was proposed. It is based on the observation that the IRSL signal due to the internal dose does not appear to fade. The consistency between the isochron ages and quartz ages for 12 sediment samples from different geological settings suggests that the isochron method can be used to overcome anomalous fading. It can also be used to avoid problematic effects from changes in environmental dose rate. It was successfully applied to a lacustrine section showing significant changes in environmental dose rate due to a recent uptake of radioisotopes. The validity of the method is also tested using single grain IRSL measurements on K-feldspar grains.

Optical dating using quartz was applied to the Holocene lacustrine and fluvial sediments at the Dagouwan section in the Sala Us River bank, Mu Us Desert. The results indicate that the Holocene Optimum occurred between ~8.3 and ~5.0 ka ago. After ~5.0 ka ago, the Holocene Optimum terminated and the climate became dry again. The Sala Us River began to cut through the underlying Quaternary sediments after ~2 ka ago with a down-cutting rate of ~3-4 cm/year. The drainage of the Sala Us River accelerated the disappearance of the lake water and the deterioration of the local environment. However, impacts from human activities also play an important role during the last 2 ka.

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Thesis Title: Post-glacial history of sea-level and environmental change in the southern Baltic Sea
Grade: PhD
Date: March 2007
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A new palaeoenvironmental record of the post-glacial history of the southern Baltic Sea (~14 ka to present) is presented. During this period, large water level and salinity changes occurred in the Baltic Basin due to opening and closing of connections to the North Atlantic. Previous attempts to establish a detailed chronology for these palaeoenvironmental changes have been conducted mainly in coastal settings, where organic material for ^{14}C dating is abundant. Many of these records are, however, discontinuous due to large water level fluctuations. In the relatively deep water of the Arkona Basin (45 m deep) in the southern Baltic Sea the sediment record is expected to be more or less continuous, but lack of organic material for ^{14}C dating has impeded previous studies.

Here, palaeoenvironmental change in the Arkona Basin is reconstructed on the basis of geochemical, sedimentological, mineral magnetic and palaeontological investigations. Additionally, independent physically based chronological control is, for the first time, obtained using Optically Stimulated Luminescence (OSL) dating on fine quartz sand from a ~10.86 m long sediment core. Tests of luminescence characteristics confirmed the suitability of the material for OSL dating and the ages agree well with the available AMS ^{14}C ages on shells; in contrast, bulk sediment ^{14}C ages are generally ~1000 years too old. Stratigraphic marker horizons in this deep basin are now absolutely dated, allowing comparison and testing of existing models of post-glacial Baltic Sea regional development.

Glacial varved clay was deposited during the Baltic Ice Lake stage and a sand layer representing the Baltic Ice Lake drainage to the North Atlantic is dated to ~11.6 ka. This event is followed by a period of low water level and enhanced influence from the Oder River. A period of very rapid sedimentation occurs between ~10.9 and ~10.4 ka and is attributed to the Ancylus Lake transgression. A first anomalous slightly brackish water inflow is recorded at ~9.8 ka, but there is no clear evidence for fully brackish conditions until ~6.5 ka. At that time, the lithologic change to clay gyttja represents a distinct shift in the circulation mode, with the onset of a high-productivity, brackish circulation system in the southern Baltic. Post-depositional diffusion of sulphur from the clay gyttja most likely explains the presence of greigite (Fe_3S_4) concretions in the underlying silty clay unit.

With this new chronology an anomaly appears between the classical model of the Littorina transgressions with brackish conditions starting ~8.5 ka, supported by studies in coastal lagoons, and our first clear brackish/marine influence occurring as late as ~6.5 ka based on studies performed in the deeper basins. This implies that the circulation system of the present Baltic Sea, with fully brackish conditions and the Danish-German Straits as the dominant inflow areas, only started from ~6.5 ka onwards.

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Thesis Title: Holocene evolution of hypersaline lake: Lagkor Tso, Western Tibet
Grade: MPhil
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Tibet contains numerous saline lakes, the history of which records the effects of global climatic change. One such lake, Lagkor Tso, was chosen for a pilot study. This study demonstrates that the OSL dating technique is suitable for dating regressive paleoshoreline terraces using an appropriate sampling strategy to collect representative backwash deposits. Lake retreat preserves the inter-tidal to supra-tidal beach facies undisturbed since their deposition, matching and fulfilling the fundamental principle of optical dating to determine when the paleoshoreline sediments were last exposed to sunlight.

Luminescence signal characteristics are diagnostic to OSL age accuracy and precision and should be studied site by site. Analysis of the preheat tests, SAR internal checks, dose recovery tests and $D_e(t)$ plots allows qualitative differentiation between well-dated results and unreliable data. $D_e(t)$ plots are also shown to be an effective and convenient tool to check sediment sample bleaching conditions such that routine application on OSL age analysis will be less time-consuming but more precise.

Dating of evaporitic salt bed sediments is, however, problematic. Enriched Sr content in the salt results in significant uncertainties in dose rate estimations because this element is radioactive but its contribution to radiation dose is not detectable using the facilities available. The limited thickness of datable sandy layers within the salt beds further complicates the dose rate estimations with the spatially heterogeneous radiation field problem.

Optically stimulated luminescence (OSL) dating on quartz using the single-aliquot regenerative-dose (SAR) protocol from seven regressive paleoshoreline deposits shows that the lake level was ~130 m higher than present at 5.5 ± 0.2 ka. Lake paleoenvironment reconstruction using Landsat 7 satellite images and GIS tools (MacDEM, ENVI and MapInfo) reveals a pan-lake (~3272 km^2) connecting Lagkor Tso, Zabuye Caka and Taro Tso were established at that time. Wetter periods should have been persisted prior to ~5.5 ka as higher lake levels are present above the highest terrace dated in this study. Lake regression took place thereafter in two phases: gradual lake level drop of ~25 m between 5.5 ± 0.2 ka and 3.7 ± 0.2 ka, followed by a rapid level descent of ~31 m between 3.7 ± 0.2 ka and 3.3 ± 0.1 ka. This abrupt climate change from wet to very dry conditions that occurred at ~ 5 - 3 ka is comparable to similar climate change events observed elsewhere in Tibet, China and other parts of the world.

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Thesis Title: Improving the chronologies of British Holocene lake sediments using a combined geomagnetic and optically-stimulated luminescence dating approach: a case study from Crummock Water
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This research investigated lake sediments from the Crummock Water of the British Isles in order to reconstruct late Glacial to Holocene environmental change. For dating the lake sediments optically-stimulated luminescence (OSL) and the palaeomagnetic secular variation (PSV) records were used. The magnetic properties of the lake sediments and the associated catchment soils were also investigated to reconstruct the source area of the lake sediments at different time intervals.

The fine silt quartz fraction of the lake sediments was used for optical dating. A standard SAR protocol was applied to measure equivalent doses. High resolution low level gamma spectrometry was used to determine radionuclide activity from which annual dose rates were derived. The optical ages of the three samples from the late Glacial silty clay are in agreement with their stratigraphic positions. Ten optical ages were obtained for the Holocene organic mud. Two of them are overestimated due to insufficient OSL resetting. The insufficient OSL resetting was caused by increased water turbidity due to human activity for one sample and rapid sediment reworking without being exposed to light for the other. The other eight optical ages are in agreement with radiocarbon ages. Based on the chronology reconstructed from the optical ages and radiocarbon ages, the timing of three well-known Holocene events was obtained. These events are the start of the Holocene, the 'Elm Decline' and the late Holocene human activity imprint. The results suggest that the OSL signal of the majority of the lake sediments was sufficiently reset prior to deposition. However, the PSV record recovered from the Crummock Water sediments was unreliable due to sediment disturbance caused by coring.

The comparisons of magnetic properties of the lake sediments and the catchment soils suggest that the dominant source area of the lake sediments changed several times during the Holocene. At the beginning of the Holocene the sediment input from bedrock and late Glacial till rapidly deceased, most probably in response to catchment stabilization due to vegetation recovery and soil formation. The catchment remained relatively stable during the Holocene until ca. 1,100 a when human activity induced significant surface erosion and down-cutting erosion. Alongside with the two processes, pedogenic ferrimagnetic minerals and the parent material were massively transported into the lake.

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The overall aim of this thesis was to investigate the usefulness of luminescence dating as a tool to establish reliable absolute chronologies for those sediments which provide a record of the earth's climate, especially during cold and dry periods. This research focused on the sandy infill of frost wedge structures in Flanders and on loess from China. In the first part of this thesis quartz-based optical dating was used to establish an absolute chronology for these two sediment types. The second part of this thesis focused on testing the ability of two alternative luminescence techniques to date loess samples beyond the quartz optical dating range.

The potential of applying quartz SAR OSL dating to the sandy infills of relict sand wedges and composite-wedge pseudomorphs in Flanders (Belgium) was first investigated. Only those wedges that showed

evidence of having been, either exclusively or to a very large degree, filled with sand (primary aeolian infill) were selected for optical dating. Based on the luminescence chronology it was concluded that thermal contraction cracking and infilling with aeolian sediment appears to have been commonplace in Flanders during the Late Pleniglacial (MIS 2); more specifically during the Last Glacial Maximum (LGM, ~23-18 ka) and the transition period between the LGM and the start of the Late Glacial (~14 ka). This study also revealed the presence of two significantly older wedge levels, with a younger (MIS 3) wedge inset into an older (MIS 6) wedge; this clearly illustrates the often complex lithostratigraphy of periglacial sediments in the Belgium lowland and highlights the risks of misinterpretations of past periglacial processes in the absence of an absolute chronology.

High resolution quartz SAR OSL dating was then applied to three sites (Zhongjiacai, Le Du and Tuxiangdao) in the western part of the Chinese Loess Plateau. In total, sixty-two optical dates were obtained ranging from ~12 to ~75 ka. The age-depth patterns at all three sites revealed that loess accumulation in the western part of the CLP had an episodic character and large variations in sedimentation rate within and between sites have occurred. Moreover, a convincing sedimentary hiatus between ~20 and ~30 ka was identified at the Tuxiangdao site; this was undetected in previous proxy-record and dating studies and clearly illustrates the importance of high-resolution absolute dating studies for palaeoclimatic research on Chinese loess. Unfortunately, due to the relatively high dose rates (~3 Gy/ka) of this material, it would appear that the quartz OSL age range is rather limited, probably up to only ~40-50 ka (~120-150 Gy). Another method was thus needed to date older loess successfully.

Two other approaches to luminescence dating, one based on quartz and the other on feldspar, were tested to investigate their potential to extend the age range of the luminescence dating of (Chinese) loess. The reliability of a different single aliquot protocol was tested; this used isothermal thermoluminescence (ITL) signals from quartz. Despite the fact that the shape of the growth curve suggests that much higher doses could be measured than with OSL, it seems that the D_e values obtained with ITL are overestimates. The protocol employed also failed the dose recovery test, overestimating the dose given prior to any heating; this was explained by a sensitivity change which occurred when the first heat treatment was applied to measure the natural signal. It was shown that one way to circumvent this sensitivity change is to use a multiple aliquot approach (the single aliquot regeneration and added (SARA) dose procedure) in which doses are given prior to the measurement of the ITL signal. The origins and the dosimetric characteristics of the ITL signal were also investigated into more detail for quartz extracted from several other sediments and it was concluded that some initial sensitivity change is common in quartz.

The accuracy and precision of IRSL dating using sand-sized K-feldspar grain was tested on an Eemian coastal marine deposit in Denmark, with well-known independent age control (~125-130 ka). The uncorrected feldspar ages severely underestimated (by ~30%) both the quartz ages and the independent age control. Using a site-averaged fading rate (g value = 3.66±0.09%/decade) to correct the optical ages of all samples provided good agreement between the average fading-corrected K-feldspar age (120±3 ka random uncertainty; ±6 ka total) and the independent age control (~125-130 ka); Nevertheless, this result is not considered significantly different from the quartz age (114±4 ka; ±7 ka total).

Because of these encouraging results on a known-age site, it was decided to apply IRSL dating with anomalous fading correction to old (> ~70 ka) Chinese loess samples from two sites (Luochuan and Dongchuan) for which quartz OSL was thought to be inappropriate (see above). We showed that anomalous fading of the IRSL signal from polymineral fine-grains extracted from Chinese loess is ubiquitous and an overall average g value for these samples of 3.10±0.13%/decade was obtained. At both sites, the quartz OSL ages are always lower than the fading-corrected IRSL ages; the latter are also in better agreement with the pedostratigraphic age control (~75 and ~130 ka). Based on a comparison of the quartz OSL ages with the pedostratigraphic age control and the fading-corrected IRSL ages it is concluded that quartz OSL dating of Chinese loess from these sites should be restricted to samples not exceeding ~40-50 ka (~120-150 Gy). For IRSL dating using polymineral fine-grains with anomalous fading correction comparison with pedostratigraphic age control would suggest an upper dating limit of probably ~100-120 ka (up to ~300 Gy uncorrected dose). Ages older than this should be considered minimum ages.

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Letters

Blue light stimulation and Linearly Modulated Optically Stimulated Luminescence

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We address here issues raised by Huntley (2006) on the use of Linearly Modulated OSL (LM-OSL, Bulur, 1996) and blue light stimulation in OSL measurements, namely 1) CW-OSL vs. LM-OSL, and the significance of 2) wavelength shift during LM-OSL, and 3) Raman scattering. We restrict our discussion mainly to quartz as both LM-OSL and blue light stimulation have been used widely for this dosimeter; nonetheless, feldspars are discussed when required.

1. CW-OSL and LM-OSL analysis

We agree with Huntley (2006) that CW-OSL contains the same physical information as LM-OSL. However, we argue that LM-OSL may be better suited for curve fitting analysis for extraction of trap parameters.

We first summarise evidence that the assumptions for the arithmetically transformed CW-OSL data to be consistent with true LM-OSL (Huntley, 2006) are indeed met for quartz; a transformation is achieved by scaling of both the luminescence and the time axis in the CW-OSL so as to obtain peak shaped data that are similar to LM-OSL (e.g. Bulur, 2000; Poolton et al., 2003). We then briefly discuss the problems inherent in the mathematical analysis of both CW-OSL and transformed CW-OSL data.

(i) Is there an apparent change in the measured photoionisation cross-section of quartz with the excitation light intensity ?

Such an effect cannot be determined conclusively from OSL measurement alone as the signal decay depends on both trapped charge eviction and its subsequent retrapping and/or recombination. However, for a first order system (one trap, one centre and negligible retrapping) a constancy of photoionisation cross-section will imply a linear change in OSL decay rate with the excitation light intensity. This relationship has been tested for blue light stimulation of quartz (Bulur et al., 2001). No dependence of photoionisation cross-section on excitation intensity was observed up to 50 $mW.cm^{-2}$.

The above can also be tested by comparing LM-OSL with a linearly transformed CW-OSL. Close correspondence between such curves has been observed for quartz (Jain et al., 2003, Poolton et al., 2003).

Alternatively, one can compare the decay rates obtained from CW-OSL and LM-OSL for the same maximum excitation intensity (Kuhns et al. 2000)., The data of Kuhns et al. (2000), obtained using green light emitting diodes (LEDs), apparently suggest that there may be a difference between cross-sections derived by applying first-order solutions to CW-OSL and LM-OSL data. Jain et al. (2007) point out that the difference observed by Kuhns et al. (2000) may have arisen from the presence of a peak-shaped isothermal TL (ITL) signal underlying both the CW-OSL and LM-OSL signals due to an insufficient preheat (162°C) followed by an elevated temperature measurement (127°C). This isothermal signal is observed as the LM-OSL curves not starting from zero for near zero stimulation light intensity, and an apparent fast component (in fact peak shaped ITL: see Jain et al., 2007) observed in the LM-OSL but not in the CW-OSL signal. Such a signal can be observed when holding the aliquot at the same temperature without shining light onto it.

It is worth noting that, unlike quartz, NaCl does not show a linear change in decay rate with blue light stimulation intensity (Bulur et al., 2001).

(ii) Evidence for non first-order kinetics in quartz OSL?

In addition to the evidence presented above, i.e. a good agreement between CW-OSL and LM-OSL (blue light stimulation at or above 125°C), the dose response of LM-OSL suggests that the fast, medium, and two slow components in quartz follow first-order kinetics (Singarayer, 2002). The decay rate (or peak position) of these components did not depend on the dose (i.e. trapped charge concentration), and, moreover, their dose response curve could be well described by a single saturating exponential. The fast

OSL component of quartz measured using IR stimulation, resulting in an orders of magnitude lower detrapping rate compared to that for blue light stimulation, also shows first order decay (Singarayer and Bailey, 2003; Jain et al., 2005).

The response after thermal annealing is observed to be more complex (i.e. non first-order) for the medium and slow components; but this may partly reflect thermal lag during sample heating.

One can thus suggest that there are insufficient grounds to invoke non first-order kinetics for the dominant components in quartz OSL as long as stimulation temperatures are sufficient to prevent known competition from the 110 °C TL traps (Murray and Wintle, 1997).

(iii) How does analysis of LM-OSL compare with that for CW-OSL ?

Since the main OSL components in quartz behave in a first-order manner, it can be inferred that the physical separation of the linearly superposed components in the LM-OSL and CW-OSL signals will be the same. This can be shown easily if one considers the change in trapped electrons per incident photon (instead of per unit time as is usually done). Thus, for first order:

$$\frac{-dn}{d\Phi} = \sigma.n \qquad \text{Eqn 1}$$

where n is the trapped electron concentration, Φ defines the number of excitation photons per unit area (fluence), and σ the photoionisation cross-section. The variation in n (from n_0 to n) with photon fluence Φ can then be described as:

$$n = n_0 \exp(-\sigma.\Phi)$$

If there are two components X and Y, then

$$\frac{n_X}{n_Y} = \frac{n_{X0}}{n_{Y0}} \exp[(\sigma_Y - \sigma_X)\Phi]$$

For a given OSL measurement, n_{X0}/n_{Y0} and $(\sigma_Y - \sigma_X)$ are constant; therefore, for a given photon fluence the ratio of the light output from any two components will be constant, no matter how that fluence was achieved in time (assuming that Eqn. 1 is true as argued earlier). In the time domain, however, different shapes of luminescence intensity can be achieved by defining the time dependence of fluence, or more specifically the fluence-rate or flux ($=d\Phi/dt$), i.e., $d\Phi/dt = f(t)$, but the actual overlap of the signals will not differ for a given fluence. For a better measurement of one component in the presence of another, the difference in cross-sections $(\sigma_Y - \sigma_X)$ needs to be increased; this can be achieved using different stimulation wavelengths and/or temperatures.

Thus, there is no extra physical information in an LM-OSL signal (or any other signal obtained by changing the photon flux through time) than in a CW-OSL signal and, as discussed above, a transformation of CW-OSL to provide an output with peaks should give the same visual information as LM-OSL.

One can also ask whether there is any fundamental advantage in analysis of LM-OSL as compared to the transformed CW-OSL.

Analysis of exponential decays is a mathematically ill-posed problem (see review by Istratov and Vyvenko, 1999). An experimentally determined OSL curve with superposition of first order components can be defined as:

$$f_{\exp}(t) = \sum_{i=1}^{n} A_i \exp(-b_i t) + B + \xi(t)$$

where A_i and b_i are the amplitude and decay constants of n discrete components in the transient (e.g. CW-OSL signal). $B \geq 0$ is a baseline offset and $\xi(t)$ is a noise component. A more general case can be defined using a spectral function $g(b)$ for a continuous trap distribution; this can be reduced to a sum of n delta functions for discrete traps.

In the analysis of first-order OSL (e.g. quartz) the purpose of such multi-component analysis is to determine A and b as these quantities give information on the relative concentration and photoionisation cross-sections of each trap. However, there is a fundamental limit to the maximum resolution obtainable by such analysis. Two or more exponential decays can be derived from a transient (OSL decay curve) only if the ratio of their decay constants is greater than the resolution limit.

It remains to be investigated mathematically if analysis of LM-OSL is any less ‘ill-posed’ than the analysis of CW-OSL. However, it can be shown that analysis of LM-OSL should be better than that of the transformed CW-OSL. This is because the presence of error (noise) in the data further narrows the resolution limit. Noise $\xi(t)$ leads to a family of $g(b)$

out of which there is only one true solution (Istratov and Vyvenko, 1999). Thus, the resolution of any transformed CW-OSL data to peak shape will be poorer than LM-OSL because of error propagation inherent in the transformation.

Similarly, the actual derivation of trap parameters from the OSL data is generally achieved by non-linear least squares analysis (e.g. Levenberg - Marquardt algorithm). We believe that such analysis is more robust for multiple peaks (LM-OSL) than for multiple exponentials (CW-OSL) and, as stated in the previous paragraph, the fitting of LM-OSL will be superior to the fitting of transformed CW-OSL because of noise propagation in the latter. We, therefore, think that LM-OSL may perhaps be the most suitable method for signal analysis.

(iv) Time economy and the 'background' in LM-OSL and CW-OSL

CW-OSL gives a most time efficient measurement of the signal. However, for the same final fluence LM-OSL takes only twice as long as CW-OSL.

If no incident scattered light is detected, then the background in the CW-OSL and LM-OSL, will be almost constant with time, while it will increase linearly in the corresponding transformed CW-OSL. If there is some light breakthrough, then the background will increase linearly in the LM-OSL also. In either case the background can be measured and subtracted from the data; this is strongly recommended.

2. Does any wavelength shift during stimulation significantly affect the LM-OSL analysis?

Huntley (2006) mentions that 'excitation cross-section is exponentially dependent on the photon energy'. Presumably the author does not mean this literally as such a dependence is physically not possible. The cross-section for deep traps is likely to have a maximum as a function of photon energy (e.g. Lucovsky, 1965, Jaros, 1977). For some part of the photon energy range, the function may approximate to an exponential decrease or an exponential increase.

It is known that the LED spectrum changes slightly during use. However, this has not been documented before for the blue LEDs in the Risø reader. We present here the measured spectra for blue light stimulation as the intensity was ramped from 0 to 50 $mW.cm^{-2}$ in 600 s. Instantaneous measurements were made every sixtieth second. It is seen that a) there is no change in the shape of the spectra, and b) the peak wavelength decreases rapidly by about 3 nm in the first 10 $mW.cm^{-2}$, and then decreases more slowly by about 3 nm from 10 to 50 $mW.cm^{-2}$ (Fig. 1) The total change in the peak wavelength is about 6 nm (Δ E = 0.03 eV).

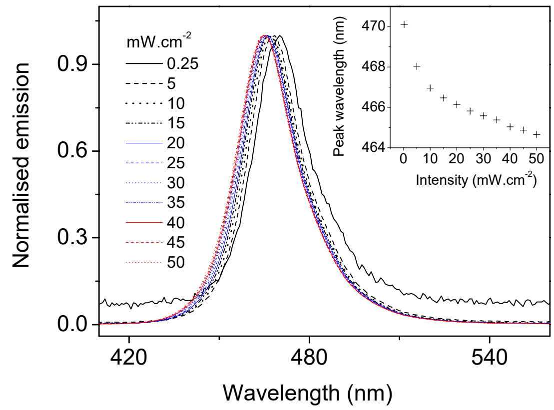

Figure 1: *Blue LED (NICHIA NSPB 500S) emission spectra measured during linear ramping from 0 to 50 $mW.cm^{-2}$ in 600 s. The emission is achieved using four blue LED clusters in the Risø stimulation head, with each cluster consisting of seven LEDs and a 2.5 mm thick Schott GG-420 at the front. The spectra were recorded using a symmetrical crossed Czerny-Turner imaging spectrometer with a focal length of 101 mm, slit width of 25 microns, a ruled grating with a density of 300 lines/mm. The spectrometer, a QE65000 from Ocean Optics, is equipped with a Hamamatsu S7031-1006 FFT-CCD back-thinned detector.*

The fast and the medium OSL components are removed very quickly; under 600 s stimulation from the blue LEDs, they would be removed before the intensity reaches 10 $mW.cm^{-2}$ (shift < 3 nm). For slower components a maximum shift of 6 nm can be expected during stimulation; the effective shift is more likely to be <3 nm because little stimulation of the components occurs below 10 $mW.cm^{-2}$. Such small shifts in excitation wavelength could cause < 5% variation in fast and medium component cross-sections (based on data in Singarayer, 2002). However the blue LED spectrum is rather broad (FWHM = 30 nm), and effects of shifts of the order of few nanometers are not likely to resolved in the experimentally obtained cross-sections.

We conclude that slight wavelength shift during LM-OSL using Risø reader configuration does not invalidate the analysis. A wavelength shift will also occur in CW-OSL as the diodes heat up during stimulation. In any case, it may be more appropriate to use a spectral function of decay constants (see section 1) rather than discrete values in CW-OSL decay shape analysis, since the excitation spectrum is broad.

3. Is there a significant presence of Raman scattered photons in blue light stimulated luminescence ?

Raman scattering is an inelastic scattering process. The scattered photon can have either higher (anti-Stokes) or lower energy (Stokes) than the incident photon; this energy difference equates to the differences of the vibrational and rotational energy-levels of the molecule. In crystals, only specific photons are allowed by the lattice structure, so Raman scattering can only appear at certain frequencies.

Raman scattering is a rare event with a typical efficiency of 10^{-6} to 10^{-7} (Böer, 1990, page 413). At room temperature, Raman scattering in the anti-Stokes mode is generally much weaker than that in the Stokes mode. As a result, the main difficulty of Raman spectroscopy is separating the weak inelastic scattered light from the intense Rayleigh scattered light - even with laser stimulation one has to use holographic diffraction gratings and multiple dispersion stages or Raman notch filters to achieve an appropriate degree of rejection of laser light.

The issue for discussion here is whether there occurs a significant background in the anti-Stokes measurement from Raman scattering during blue light stimulation. Huntley (2006) states that ‘for this reason I favour the use of green LEDs until someone proves that Raman scattering of blue photons by quartz is not significant’. No doubt there will be some Raman scattered photons from the dosimeter and the system components when stimulated not just with blue light but also with yellow, green, red etc., since Raman scattering, unlike fluorescence, can occur at any wavelength below the resonance wavelength (a special case is Resonant Raman Scattering). Moreover, the efficiency of this process is strongly dependent on the frequency of the excitation light; for example, blue light will cause more scattering than green or red light.

However, the important question is whether these scattered photons enter our UV detection window (Hoya U340) and is the intensity sufficient to be of any significance in our OSL measurements. We examine this question both theoretically and experimentally. The focus of this examination is blue light stimulation (470±30 nm and Schott GG-420 filter) in conjunction with UV detection using a Hoya U340 filter (Bøtter-Jensen et al., 1999) as this is the most commonly used configuration for blue light stimulated luminescence from quartz and feldspar (for example, see any volume of the last three LED conference proceedings).

(i) Theoretical considerations

An important characteristic of Raman scattered light is that it is frequency-shifted i.e. with respect to the excitation frequency, but the magnitude of the shift is independent of the excitation frequency; the shift is constant in energy or frequency (or wave number). Therefore in wavelength units, the anti-Stokes photons move closer to the stimulation light with a decrease in the stimulation wavelength. For example, if we take an arbitrary Raman shift of 1200 cm^{-1}, then the anti-Stokes scattered photon will be at 489 nm for stimulation at 520 nm ($\Delta\lambda$= 31 nm), 445 nm at 470 nm ($\Delta\lambda$= 25nm), and 382 nm at 400 nm ($\Delta\lambda$= 18 nm). Thus, although, the intensity of the scattered light increases strongly, the wavelength of the scattered light moves closer and closer to that of the incident light for more energetic excitations. Therefore the problem of rejection of Raman scattered photons, if significant, may not be as bad as it may appear; various sharp edge-filters are available to achieve this.

Raman scattering from feldspars

Huntley et al. (1989, Figure 2) ascribe an anti-Stokes Raman origin to a broad, featureless, rising signal between 550 to 600 nm after laser stimulation at 632.8 nm (He-Ne laser, 10 $mW.cm^{-2}$) in their study of OSL emission spectra of feldspars. This signal did not show any decay between 100 and 400 s stimulation, and was, therefore, interpreted to arise from Raman scattering from feldspars. However, ***the spectrum of this signal typically lacks any characteristic Raman peaks.*** Other possible origins for this signal were overlooked in the paper. For example, the emission can arise from a very slowly decaying OSL signal (a measurement of thermally zeroed sample would have shown that), or scattered light from the system (a blank measurement would have clarified that), or quite simply an instrumental error (e.g. parasitic laser light). The argument for Raman scattering is not supported. Raman scattering vs. OSL origin can be checked from the temperature, time (relaxation) and/or wavelength dependence of the signal, as well as a comparison of Stokes and Anti-Stokes emissions.

Even if one were to assume that the origin of the broad rising signal with wavelength limit of 550 nm (for 632.8 nm excitation) is Raman scattering (Figure

2 of Huntley et al., 1989), the implications for blue light stimulation are not so severe. For example, based on this limit, the anti-Stokes Raman scattered photons will not occur at wavelengths smaller than 420 nm for excitation at 470 nm (excitation peak), and wavelengths smaller than 400 nm for excitation at 440 nm (higher energy side of the excitation spectrum; see figure 1).

Raman scattering from quartz

Several Raman spectra are available for SiO_2 in both amorphous (silica glass) and crystalline phases (alpha and beta quartz) for different temperatures and pressures. Raman spectra of both these materials show well defined peaks. For example, silica glass at 1 bar pressure is characterised by a relatively strong diffuse band at 440 cm^{-1} with two relatively sharp bands at 492 and 605 cm^{-1}. There are very weak features at 1060 and 1190 cm^{-1} (Hemley et al., 1986). In the case of crystalline α quartz, there are several strong peaks between 100 to 450 cm^{-1} and relatively weak peaks thereafter (Fries and Claus, 1973). Scott and Porto (1967) examined the Raman spectrum of quartz excited at 488 nm (80 mW). No mention of any continuum is made by these authors. Similarly, Chio et al. (2003) have examined the Raman spectra of alpha quartz grains of various sizes. The Stokes and anti-Stokes spectra between 400 and 600 cm^{-1} recorded with a source excitation of 488 nm at 25 and 150 mW do not show any sign of a continuum background on either side. (Fig. 1 and Figs. 9 & 10).

We have calculated the anti-Stokes Raman photon spectrum for blue LED stimulation (470±30 nm, 50 $mW.cm^{-2}$) using an efficiency of 10^{-7} and a Raman shift of 450 cm^{-1} (Fig. 2a). We chose this wave number as the limit of the relatively strong Raman peaks from α quartz (Fries and Claus, 1973). Fig. 2b shows that most of the Raman scattered photons will be swamped by the broad spectrum of the blue diodes, and that they do not pose any apparent problem for detection below 400 nm. The scattering because of other strong Raman modes below 450cm^{-1} in quartz will be intermediate between the two cases presented in Fig. 2. (This is only a crude demonstration to show that the effect is not significant - the actual Raman spectra will be somewhat skewed since the efficiency varies strongly with the frequency of the excitation photons. A further simplification was made by making a trivial (for this purpose) assumption there is no broadening of the emission line).

A variety of short-pass filters are available with OD > 6 in the blocking range (that is a reduction by $>10^6$); these can allow easy rejection of any Raman photons in the detection window.

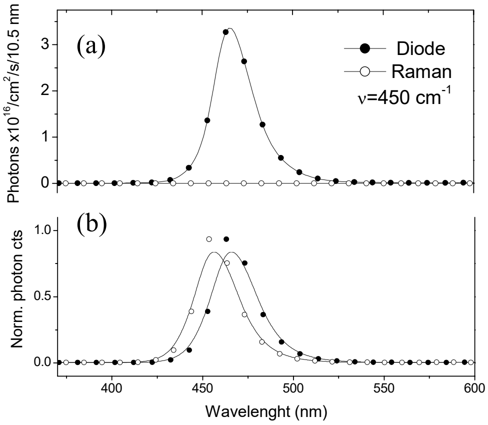

Figure 2: *a) Measured blue light photon spectrum (derived from figure 1) and the calculated Raman scattering spectrum (for assumed single emission line and an efficiency of 10^{-7} at each excitation wavelength) using a Raman shift of 450 cm^{-1} for quartz. The photon flux was calculated for an integral intensity of 50 $mW.cm^{-2}$. b) Data from a) plotted after normalisation by the peak counts.*

To take a different example, we refer to the quartz pulsed OSL measured by Denby et al. (2006) and Tsukamoto et al. (2007) using the same blue LEDs. The rise and fall time of the signal are adequately described by a single lifetime of about 40 μs; this number was in good agreement with the values published using green light (525 nm) stimulation (see Chithambo and Galloway, 2000). If Raman scattering were significant it would have affected the analysis of the rise time data (i.e. 'light on' signal) but not the 'light off' signal. This is because Raman scattering is almost instantaneous (e.g. picosecond or shorter time scales), while radiative OSL recombination occurs on microsecond time scales. Similarly, if Raman scattering emission was overlapping with the broad OSL emission then the problem may be more serious for blue light than for green light. Good agreement between the rise and fall time constants, and the similarity of lifetimes for the radiative relaxation using blue and green light suggests that Raman scattered photons in the detection window, if any, are not likely to be important.

Excitation of the quartz grains at 470 nm (excitation peak) and observation at 380 nm (emission peak) corresponds to an anti-Stokes shift of 5040 cm^{-1}. ***We do not expect any background due to Raman scattering at this wavelength.***

In summary, the above considerations are sufficient to discount any significant background due to Raman scattering in the blue OSL from quartz or feldspars in the defined measurement configuration. Nonetheless, we test this by direct measurement from the substrate, and quartz and feldspar samples.

(ii) Experimental data using the blue LEDs in the Risø reader

We measured scattered light from blue light stimulation (LEDs at 470 ±30 nm, 50mW.cm^{-2}; + Schott GG-420 filter; see Bøtter-Jensen et al., 1999) in the Risø TL-DA15 reader using an empty stainless steel cup at various temperatures. Measurement was made using a photomultiplier tube placed over a 7.5 mm thick, broad band-pass filter Hoya U340. The measured count rate changed from ~100 s^{-1} to ~200 s^{-1} when the light was switched on at room temperature (Fig. 3a). This increase may be due to Rayleigh and/or Raman scattered photons from the reader and the disc into the detector. No detectable increase in the light intensity was observed by increasing the temperature of the discs from RT to 250°C (Fig. 3a). This implies that a) the contribution of light from the stainless steel cup alone is very small, or b) the detected light is not of Raman origin, or c) a stainless steel cup does not show Raman scattering (see e.g. Melgarejo et al., 2000).

Irrespective of the exact mechanism, one can conclude that background contribution from the reader and the sample substrate is insignificant compared to the OSL signal from quartz, and that it is independent of the measurement temperature.

We then tested for any scattered photons from quartz and feldspar grains from a sediment sample (972505). These grains were heated at 700°C for 1 hour to remove as much trapped charge as possible. Subsequently the grains were placed in stainless steel cups and OSL measured at different temperatures. The results for 125°C stimulation are shown in Fig. 3b. The count rate when the light is switched on is similar to that observed from the blank cup (Fig. 3a). No significant variation in the count rate was observed for stimulation temperatures between 50 and 200°C (data not shown) suggesting that the observed counts are not from Raman scattering. The OSL after 1 Gy dose and preheat to 260°C for 10 s from the same aliquots is shown in Fig. 3c together with the signal from unirradiated heated quartz (taken from Fig. 3b). The difference in the initial signal from the irradiated and the unirradiated heated aliquots is about three to four orders of magnitude.

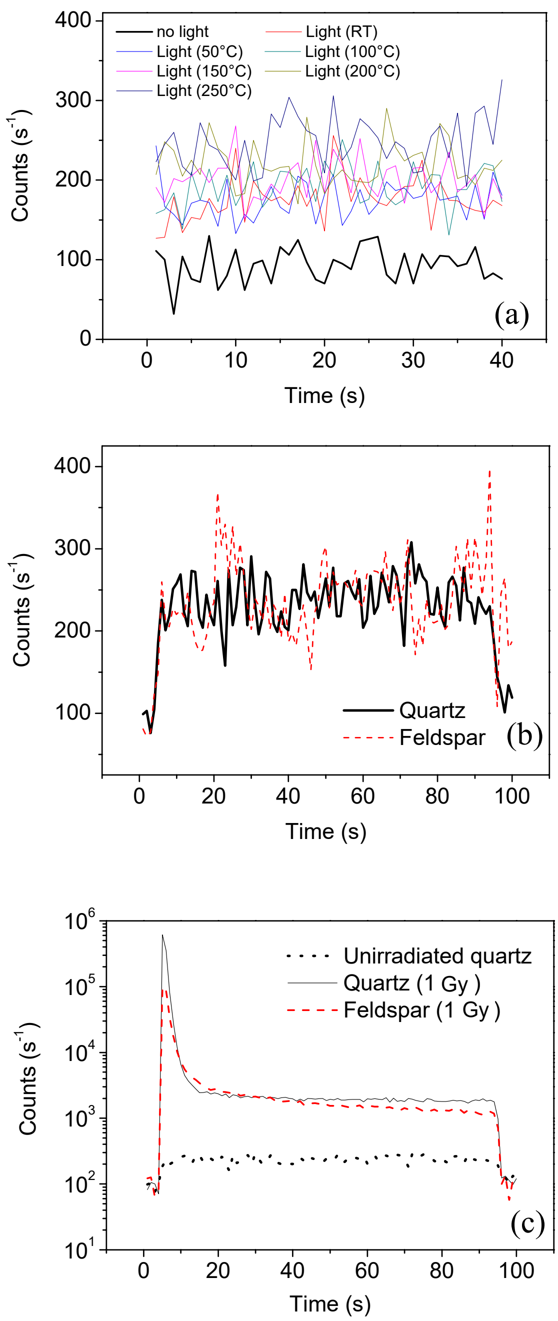

Figure 3: *a) Counts detected from a blank stainless steel cup at different temperatures (RT = room temperature) with or without blue light stimulation (470 ± 30 nm). b) Counts obtained from a quartz and a feldspar aliquot (sediment sample 972505) during blue light excitation. The grains were previously heated at 700°C for one hour to remove trapped charge. c) OSL response from the same aliquots after a 1 Gy dose and preheat for 10 s at 260°C. All measurements are made in the Risø TL-DA15 reader.*

We conclude that our experimental data shows excellent agreement with our theoretical reasoning that Raman scattering will not be significant for quartz and feldspar when using blue LEDs in the conventional Risø reader measurement configuration.

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Response to Jain and Lindvold

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Constant vs varying excitation intensity
As I pointed out, data taken with constant excitation can be transformed into data that would be obtained using excitation that increased linearly with time, provided certain conditions apply. One test that the conditions apply is a suitable comparison of data taken with both methods, and I gave a reference to an example of a test that failed. Jain and Lindvold refer to two examples where they state that correspondence was observed. In the first, Jain et al. (2003) state "The results showed a good match between the two for the samples reported here (data not shown)"; what we need to know is whether or not the matches were within experimental error; if not, the conditions referred to above were not satisfied. In the second example, that of Poolton et al. (2003), three samples were analyzed using a total of 14 fitting parameters, of which only seven are listed in Table 1. Comparisons of three of the parameters obtained using the two methods are in clear statistical disagreement; it may well be that the two largest disagreements (over 30 %) are the result of non-linearity of the PM tube as suggested, but that is not proven. For two other parameters one cannot say whether or not there is statistical agreement because of the way the figures are presented. No comparison is provided for the remaining parameters. Thus neither paper makes a suitable test for the thesis.

The example I gave of a clear disagreement was that of Kuhns et al. (2000). Jain and Lindvold suggest that this was the result of the authors unwittingly measuring thermoluminescence. I feel very uncomfortable with this suggestion; it implies the authors had not done the proper control tests, and without any evidence from the authors this is unwarranted.

Jain and Lindvold suggest that analysis of transformed data taken with constant excitation will lead to a poorer result than analysis of data taken with excitation that increases linearly with time, because of noise in the data. I do not understand this and would expect the reverse to be the case. The crucial part of the data is that near the start of excitation; for constant excitation the signal to noise ratio will normally be quite large, and decreasing with time. When the excitation linearly increases with time, initially the noise will dominate because the signal starts at zero and increases linearly with time; as time progresses the signal to noise ratio will eventually become comparable to that at constant excitation.

In short, Jain and Lindvold do not establish that the use of a linearly increasing excitation intensity is better than or even as good as the use of a constant excitation intensity. It would seem that a comprehensive study is needed to establish which method is best, or, perhaps, that the two methods do give different results.

Raman Scattering
There are two issues here, our interpretation of certain data as due to Raman scattering and whether or not this may be significant with the use of blue light-emitting diodes.

Jain and Lindvold dispute our interpretation of what we called the "Raman continuum", a spectrum for which the intensity decreases exponentially with energy away from the energy of the excitation photons. Their main argument is that our spectrum "lacks any characteristic Raman peaks". This is not a valid argument since no Raman lines are expected in the range shown in Huntley et al. (1989, Fig.5). Further, Jain and Lindvold appear not to understand that an experimental physicist's greatest fear is that he or she is not measuring what he or she thinks he or she is measuring, otherwise we would not have been also criticized for not having done a variety of tests listed. This criticism is thus also not valid. We were in the habit of doing many control experiments, including most or all of those suggested by Jain and Lindvold, to make sure that we knew what we were measuring; the results of these experiments were usually not reported in the publications. One of these, the energy dependence, Jain and Lindvold could have checked, as we did, from the data shown in Fig. 5; it is about right (the intensity should change a factor of about e per 0.025 eV at room temperature). The exponential continuum has been observed previously in feldspars, along with the Raman lines; see for example figures 536 and 537 in Deer, Howie and Zussman (2001) or Figs. 11.2a and 11.2b in Smith and Brown (1988), and these also show about the expected energy dependence.

One of our first control experiments was to measure spectra from 2.14 eV to 2.31 eV using a 1.96 eV laser (He-Ne) for plasticine and Apiezon-Q (a black versatile mouldable firm reusable sealing compound); both of these showed an exponential energy dependence which initially puzzled us. These data

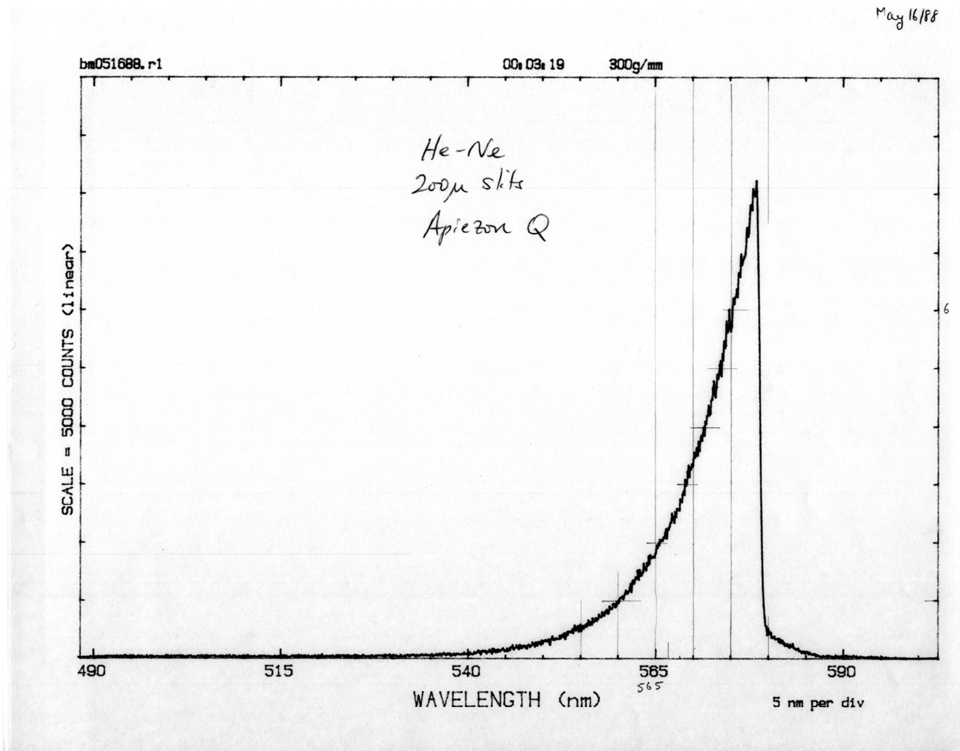

Figure 1: *Intensity vs wavelength for Raman scattering from Apiezon-Q using 1.96 eV (633 nm) excitation from a He-Ne laser. The spectrometer cut-off was at 580 nm*

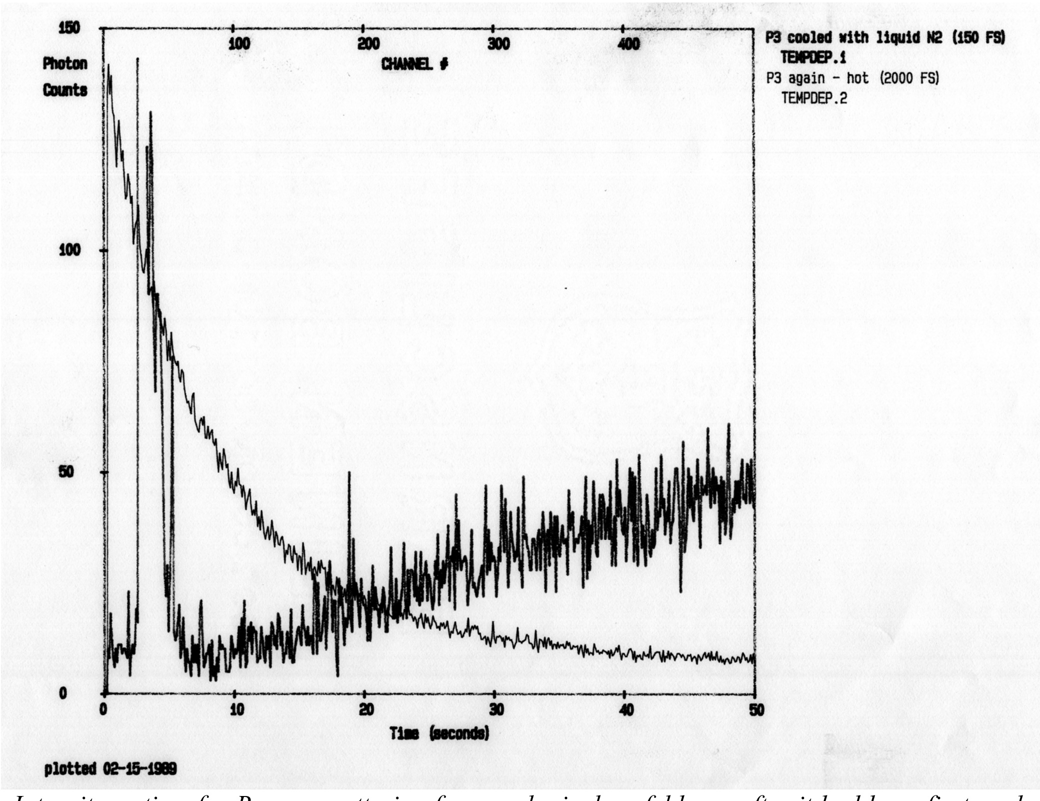

Figure 2: *Intensity vs time for Raman scattering from a plagioclase feldspar after it had been first cooled to liquid nitrogen temperature, showing the intensity increasing as it warmed, and then after it had first been heated on a hot plate, showing the intensity decreasing as it cooled*

were the motivation for our interpretation when we found the energy dependence to be about as expected for lattice scattering. Some of the raw data for Apiezon-Q are shown in the accompanying Figure 1. We also measured the plasticine with a 2.41 eV laser (Ar) and obtained a similar spectrum. In contrast, some black RTV (room temperature vulcanized) silicone on an aluminium disk gave nothing above background.

If our interpretation were to be correct there should be a very large temperature dependence, and we tested this using a sample chamber with a light-collection solid angle of ~ 0.96 sr. Samples were warmed or cooled and then quickly placed in the apparatus, where they slowly cooled or warmed to room temperature (hence we did not know the actual temperatures). Warming the plasticine on a hot plate increased the count rate over a factor of ~5 and cooling it in liquid nitrogen decreased the count rate a factor of ≥200 to background. We did a similar experiment with some feldspars, and again found a large temperature dependence; some data for a plagioclase are shown in Figure 2 (note the ordinate scales for the two data sets are different, being 150 and 2000 counts per 100 ms; the high count rate from 3-5 s probably occurred when the sample was loaded and light leaked into the chamber).

Jain and Lindvold have apparently missed our argument for the interpretation that was referred to and described in the accompanying paper by Godfrey-Smith et al. (1989) on zircons. Here, what we called the "Raman continuum" was ascribed to scattering from lattice vibrations in an imperfect crystal. Supporting evidence described was that the intensity had roughly the right energy dependence, a strong temperature dependence, and that it decreased with high-temperature annealing that improved the crystallinity.

Jain and Lindvold refer to the absence of any continuum in reports of Raman measurements on quartz and silica. Actually, Figure 1 of Hemley et al. (1986), to which they refer, shows a Raman spectrum of SiO_2 glass in which the background looks very much like our "Raman continuum", and has about the expected energy dependence.

All this fits in with the notion that the continuum arises from scattering from lattice vibrations in an imperfect lattice structure. Silica glass, plasticine and Apiezon-Q are disordered, feldspars are normally somewhat disordered, and zircons are often severely affected by radiation damage from internal U and Th decay; thus if our interpretation of the "Raman continuum" is correct one would expect it to be more intense for these minerals than for less disordered crystals such as quartz.

The reader will now be wondering what we found for quartz. We did measure quartz sand-sized grains and observed the continuum, but a control experiment showed that it arose from the silicone oil used to mount the grains. We also saw the low-energy tail of what we now know is the quartz emission band; from this tail we deduced that the emission band was not in the blue as we had anticipated, but in the ultraviolet where the spectrometer was insensitive due to the coatings on its many mirrors. We thus abandoned measurement of quartz with the Raman spectrometer.

I would welcome any evidence that our interpretation of the exponential continuum is incorrect. I would also welcome alternative suggestions as to an explanation of the observations. Although I have consulted books and experts on Raman scattering, I have not found the subject discussed in the literature and would welcome any references.

In order to discuss the relevance of Raman scattering it is simplest to discuss it in terms of energies. For those who wish to use wavelengths or wave numbers, the conversions are:

$E.\lambda = 1240$ eV.nm and $E/k = 1.24 \times 10^{-4}$ eV.cm,

where:

E = energy, λ = wavelength, and k = wave number

The largest Raman scattering energies are given in Table 1. I should emphasize that the figures given for the continuum are the largest reported values; because of the exponential energy dependence there is no fixed cut-off and the actual relevant value will depend on the conditions of the experiment; the higher the excitation power and the more sensitive the detector, the higher this energy will be.

The main portion of the emission band of quartz extends from 3.0 to 3.7 eV. Let us assume an experimental setup made to optimize the measurement of this band and ask what maximum excitation energy would lead to an absence of significant Raman scattering into this energy range?

Considering only Raman lines, the answer is 3.0 - 0.15 = 2.85 eV (435 nm). This energy falls in the range of likely emission from blue light-emitting diodes. If there is a significant Raman continuum then this energy would have to be lower.

Mineral	Line (eV)	Continuum (eV)	References
quartz	0.153	?	Shapiro et al. 1967
silica glass	≥0.15	>0.15	Hemley et al. 1986
feldspar	0.14	0.29	Smith and Brown, 1988 Deer, Howie and Zussman, 2001 Huntley et al. 1989
zircon	0.13	0.17	Godfrey-Smith et al. 1989
plasticine, Apiezon-Q	?	0.35	Us

Table 1: *Largest observed energy difference between excitation photon energy and Raman-scattered photon energy for several minerals*

There are two remedies for the problem. The first is to restrict the emission from the diodes; Jain and Lindvold indicate that they do this using Schott GG-420 filters, which have a cutoff at about 2.95 eV, depending on thickness. This, by itself, is clearly not adequate. Their second remedy is to use a filter in the measuring system that cuts out a portion of the quartz emission band; this Jain and Lindvold do using a Hoya U340 filter which cuts off sharply below about 3.15 eV. The difference between 2.95 eV and 3.15 eV is 0.2 eV. This would appear to be adequate to prevent measurement of any Raman lines, but one should be cautious because the cut-offs of the filters are not perfectly sharp and there is still the possibility of some overlap.

Jain and Lindvold argue another way that "Excitation of the quartz grains at 470 nm (excitation peak) and observation at 380 nm (emission peak) corresponds to an anti-Stokes shift of 5040 cm^{-1}. We do not expect any background due to Raman scattering at this wavelength." While this is so, it is not relevant because it ignores the fact that the emission bands of both the diodes and quartz are broad. What matters is the difference between the energies of the cut-offs of the U340 and GG-420 filters which is about 0.2 eV.

The numbers here are clearly critical; different filter combinations could yield a different conclusion, and only experimental tests will determine whether a particular combination is usable or not.

The situation for feldspar is different. The main emission for K-feldspar is in a band from 2.7 to 3.3 eV. If the measurement system incorporated a filter to encompass this then the excitation energy would need to be less than 2.55 eV (490 nm) or, if our measurement of a Raman continuum is considered, 2.4 eV (520 nm). Green or lower energy photons would be needed for excitation.

The experimental evidence provided by Jain and Lindvold that the effect is not significant for the quartz they tested and the particular set-up they used is reassuring. One does need to be alert however, because there may be situations for which the effect is significant. Reduction of their high background might do it. The use of different blue diodes or different filters could do it. So could a different quartz or quartzite or some other mineral, particularly one with a low emission intensity. In what may be an extreme case, ten years ago Olav Lian and I decided to measure a phytolith in a new Risø machine with green excitation from a filtered Xenon lamp; my recollection is that we observed about 200 counts/second above background, independent of time and a radiation dose. I attributed this to scattering from lattice vibrations in this non-crystalline material.

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Response to Huntley

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We find several errors in Huntley's reply:

1) Huntley relies on Kuhns et al. (2000) to argue that LM-OSL may yield different parameters than CW-OSL. LM-OSL by definition should originate from the origin (0, 0). All plots in the above study fail this requirement and therefore cannot be relied upon for comparison.

2) Huntley misquotes Poolton et al. (2003) by saying that 14 parameters were used for fitting. As can be seen in that paper, samples 1 and 3 used 10 free parameters and sample 2 used 12. The slow component is identical or varies by 5%, while the medium component by 15%. One should consider S/N effect while assessing precision.

3) Huntley claims a 'continuum' in Si-glass at >0.15 eV (his Table 1) based on Hemley et al. (1986, Fig. 1). However these are Stokes shifted spectra (pers. com. Hemley). The energy dependence discussed by Huntley (i.e. due to thermally populated excited levels according to the Boltzmann distribution) cannot by definition generate continuum in the Stokes mode. In fact, the claimed continuum in these results arises due to 'diffuse scattering'. We suggest caution in use of the term Raman scattering (RS); it is a precise effect with definite predictions.

4) The choice of three commercial putty-like products (Apiezon Q, Plasticine and Black RTV) is inappropriate for comparison since these have no lattice, the exact chemical composition is proprietary, and the constituents (dispersed clay particles or carbon black) mainly generate multiple- or Rayleigh scattering.

5) Huntley advocates significant Raman scattering by relying on the tails of excitation and emission spectra. Our calculations show that only one scattered photon in 10 billion incident photons will be detected by the PMT in the antiStokes mode, therefore tails are unlikely candidates. Moreover, Huntley's result of 0.29 eV shift from feldspar (his Table 1) would predict significant RS photons observed through a U340; this was not seen in our experimental data (Figs. 3(a) and (b) in our previous letter).

References

Hemley, R. J., Mao, H. K., Bell, P. M., Mysen B. O. (1986) Raman spectroscopy of SiO_2 glass at high pressure. *Physical Review Letters* **57**, 747-750.
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Poolton, N. R. J., Bøtter-Jensen L., Andersen, C. E., Jain, M., Murray, A. S., Malins A. E. R., Quinn, F. M. (2003) Measuring modulated luminescence using non-modulated stimulation: ramping the sample period. *Radiation Measurements* **37**, 639-645.

ENGLISH HERITAGE

EH Research Department Reports Series

Since January 2006, technical reports commissioned by the English Heritage Scientific Dating Service have been issued in the Research Department Reports Series *(EH Res Dep Rep Ser)*, which replaces the former Ancient Monuments Laboratory (AML) and Centre for Archaeology (*CfA*) Reports Series. These are usually interim reports, making available the results of specialist investigations in advance of full publication, and their conclusions may have to be modified in the light of information not available at the time of the investigation. The list below details reports on luminescence dating issued in 2005–07.

Summaries of all the reports are available through the EH Research Department Reports Database, accessible online at:

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A small charge is made for copying (4p per page) and there is a minimum charge of £1.50. Outside the EU postage costs an extra £2.50.

J-L Schwenninger, Optically stimulated luminescence (OSL) dating of coversand deposits from Flixborough, Lincolnshire. *CfA Rep* **8/2005.** 22pp.

A series of samples was collected from two trenches near Flixborough in Lincolnshire for OSL. The dates were obtained from sand-sized quartz grains and palaeodose determinations were made using an SAR protocol. The environmental dose rate for each sample was calculated using the results obtained by neutron activation analysis (NAA) and *in situ* gamma-ray spectroscopy measurements. The concentrations of radioactive elements were above detection limits and the samples and their luminescence characteristics were generally found to be close to optimal for obtaining reliable luminescence age estimates.

P S Toms, Luminescence dating for the Bletchingley excavations, Surrey. *CfA Rep* **9/2005.** 24pp.

Three sediment samples and six burnt flints obtained from section A11 of the Bletchingley excavations were submitted for OSL and TL dating, respectively, by English Heritage. An attempt to quantify the accuracy of all luminescence age estimates was made using signal analysis methods to detect partial resetting of datable signals prior to sample interment, and through consideration of the influence of varying moisture content and cosmic dose rate over the burial period. Optical dating evolved a chronology of sedimentation, not necessarily continuous, from *c.* 32 ka (30,000 BC) through to *c.* 2.8 ka (800 BC). Three flints were excluded from the study owing to evidence of insufficient heating prior to burial. The remaining flints, located in close proximity to each optical dating sample, generated age estimates of *c.* 7 to 12 ka (5000 to 10,000 BC) consistent with age expectations premised upon microliths recovered from equivalent levels across the site. However, a significant inversion in age between the lowermost optical dating sample and underlying flint sample was recorded. After considering the accuracy of De and dose rate estimates for both sample types, this anomaly was attributed to displacement of the flint sample from its primary context by anthropogenic activity or gravitational effects coupled with low adhesion afforded by the sand matrix within which all the flint samples were located. Similar displacement for all the flint samples that have yielded age estimates in this study cannot be dismissed. The juxtaposition of Mesolithic burnt flints and Iron Age sediments and charcoal in the uppermost dated unit evidences a period of land surface stability and repeated human occupation.

J-L Schwenninger and E J Rhodes, Optically stimulated luminescence (OSL) dating of fluvial sediments from a Middle Palaeolithic site at Lynford Quarry, Norfolk. *CfA Rep* **25/2005.** 25pp.

This report presents details of the application of OSL dating to sediment samples collected during the excavation of a Middle Palaeolithic open-air site in Lynford Quarry near Mundford, Norfolk. The dates were obtained from sand-sized quartz grains and palaeodose determinations were made using a multi-grain SAR protocol. The environmental dose rate for each sample was calculated using the results obtained from instrumental neutron activation analysis (INAA) and *in situ* gamma-ray spectroscopy measurements.

H M Roberts and A J Plater, Optically stimulated luminescence (OSL) dating of sands underlying the gravel beach ridges of Dungeness and Camber, south-east England, U.K. *CfA Rep* **27/2005.** 84pp.

Holocene sands underlying the gravel beach ridges of Dungeness and Camber were dated using optically stimulated luminescence (OSL) applied to coarse (sand-sized) quartz grains. The 39 sand samples dated proved sufficiently sensitive and responsive to enable well-resolved dating using the SAR measurement protocol. The OSL chronology for the sub-gravel sands of the Dungeness foreland places the early formation of the underlying shoreface at about 5000 years ago in the region of Broomhill, with ages decreasing progressively eastwards to approximately 2000 years ago beneath Denge Marsh, and 1000–600 years ago under the present ness.

J-L Schwenninger, E J Rhodes, M R Bates, R M Briant, and F Wenban-Smith, Optically stimulated luminescence (OSL) dating of Quaternary deposits from the Sussex/Hampshire Coastal Corridor. *EH Res Dep Rep Ser* **20/2006**. 50pp.

A total of 43 samples were collected from different sites across the West Sussex coastal plain, the Western and Eastern Solent, the Test Valley, and the Isle of Wight for optically stimulated luminescence (OSL) dating. The dates were obtained from sand-sized quartz grains, and palaeodose determinations were made using a single aliquot regenerative-dose (SAR) protocol. The environmental dose rate for each sample was calculated using the results of neutron activation analysis (NAA) and *in situ* gamma-ray spectroscopy measurements. The concentrations of radioactive elements were nearly always above detection limits and the samples and their luminescence characteristics were generally considered to be suited for OSL dating.

G A T Duller and H M Roberts, Swale/Ure Washlands: single-grain optically stimulated luminescence (OSL) measurements of fluvial and fluvioglacial sediments. *EH Res Dep Rep Ser* **31/2007**. 16pp.

Eight samples of fluvioglacial origin and one from a Holocene fluvial deposit were collected from the area around Ripon, with the aim of providing chronological constraints on the deglaciation of the area at the end of the Devensian. The depositional environments are such that there was a concern that not all the mineral grains in the sediment may have been exposed to daylight at deposition. Therefore, luminescence measurements were made on single sand-sized grains of quartz. The signals from these were generally very dim, with only very few grains (0.9%–2.2%) giving detectable optically stimulated luminescence (OSL). In spite of rigorous sample preparation to extract pure quartz, investigations demonstrated that many of these OSL signals originated from non-quartz minerals, probably feldspar inclusions. After rejecting grains with these signals, only 0.1–0.6% of grains remained for the eight fluvioglacial samples, and this was insufficient to allow an age to be determined. For the one fluvial sample a slightly higher proportion (1.0%) of grains was accepted. Statistical analysis was problematic because of the low recovery of suitable grains, but the results broadly agreed with independent age control.

E J Rhodes, Barford Road, St Neots, Cambridgeshire: Optically stimulated luminescence dating of single grains of quartz from sedimentary fills of two cursus monuments. *EH Res Dep Rep Ser* **32/2007**. 59pp.

Fifteen sediment samples forming two vertical sequences, one located in the fill of each of two cursus monuments at the site of Barford Road, St Neots, Cambridgeshire were dated using new luminescence methods based on the Optically Stimulated Luminescence (OSL) from single grains of quartz. From the main suite of results it is concluded that grains showing signs of incomplete zeroing are relatively rare, though more common in basal fill samples. Most samples have a significant grouping of single-grain ages which is likely to represent the depositional age of the sediment. Grains providing significantly younger apparent ages are present in many samples, especially closer to the surface, and probably represent the effects of post-depositional root activity or other bioturbation processes. A novel approach based on the radiocarbon calibration programme OxCal was developed and applied to provide age estimates for the single grain measurements. The age estimates derived in this manner had relatively high uncertainties, but suggest that the lowermost fill of both cursus monuments began to be deposited in the early to mid 5th millennium BC, and the uppermost samples for both structures were laid down around the 3rd millennium BC.

J-L Schwenninger, J Williams, J Aram, J Hambly, and J Rackham, Welton-le-Wold, Lincolnshire: optically stimulated luminescence (OSL) dating of Pleistocene glacial tills and interglacial gravels. *EH Res Dep Rep Ser* **36/2007**. 26pp.

A series of ten samples were collected for optically stimulated luminescence (OSL) dating from exposed faces and boreholes at a disused quarry near the village of Welton-le-Wold in Lincolnshire. The reinstated former sand and gravel pit is a designated geological Site of Special Scientific Interest (SSSI) due to the presence of an extensive sequence of glacial tills overlying thick deposits of silts, sand, and gravel containing Palaeolithic artefacts and faunal remains. The site is recognized as being of national interest to our understanding of Middle/Lower Palaeolithic human occupation of the region and of critical importance for establishing the glacial history of Eastern England. Much controversy has surrounded the dating of this Pleistocene sequence, and the recent re-exposure of key quarry faces provided an opportunity to reassess the stratigraphic record and apply novel sampling methods and dating techniques.

J-L Schwenninger, M R Bates, R M Briant, and F Wenban-Smith, Further optically stimulated luminescence (OSL) dates of Quaternary deposits from the Sussex/Hampshire Coastal Corridor. *EH Res Dep Rep Ser* **55/2007**. 23pp.

A series of 14 samples were collected from different sites in the Sussex/Hampshire coastal corridor for optically stimulated luminescence (OSL) dating. The results complement a series of optical dates presented in a previous study funded by EH through the ALSF scheme in 2003. OSL age estimates were obtained from sand-sized quartz grains and palaeodose determinations were made using a single aliquot regenerative-dose (SAR) measurement protocol. The environmental dose rate for each sample was calculated using the results of elemental analysis by ICP-MS and occasionally by *in situ* gamma-ray spectroscopy measurements. The concentrations of radioactive elements were well above detection limits and the samples and their luminescence characteristics were generally considered to be well suited for OSL dating.

J-L Schwenninger, D R Bridgland, A J Howard, and T White, Pleistocene sediments from the Trent Valley: optically stimulated luminescence (OSL) dating. *EH Res Dep Rep Ser* **57/2007**. 29pp.

A total of 33 samples were collected from 16 different sites within the Trent Valley for dating by optically stimulated luminescence (OSL). Luminescence age estimates were obtained from sand-sized quartz grains and palaeodose determinations were made using a single aliquot regenerative-dose (SAR) measurement protocol. The environmental dose rate for each sample was calculated using the results of elemental analysis by ICP-MS and *in situ* gamma-ray spectroscopy measurements. The concentrations of radioactive elements within the sediments were well above detection limits but the quartz used for dating was often characterized by low sensitivity to laboratory induced irradiation. This problem combined with the common occurrence of contaminant feldspar minerals provided challenging conditions for luminescence dating. Despite these limitations, meaningful age estimates could be obtained for the majority of samples and the results provide a much improved and robust chronological framework for terrace development and landscape evolution of the Middle and Lower Trent Valley.

J-L Schwenninger, F Wenban-Smith, M R Bates, and R M Briant, Fluvial sediments from the Medway Valley: optically stimulated luminescence (OSL) dating. *EH Res Dep Rep Ser* **96/2007**. 22pp.

A total of 27 samples collected from Pleistocene aggregate deposits in north Kent and southeast Essex were used for dating by optically stimulated luminescence (OSL). The samples originated from fluvial terrace deposits associated with the river Medway in the Medway Valley north of Maidstone, the Hoo peninsula, and the southeast quarter of Essex, up to Clacton-on-Sea. The OSL age estimates were obtained on sand-sized quartz grains and palaeodose determinations were made using a single-aliquot regenerative dose (SAR) measurement protocol. For each sample the environmental dose rate was calculated from the concentrations of radioactive elements derived by ICP-MS analysis using a fusion sample preparation method. The concentrations of uranium, thorium, and potassium were well above detection limits and the samples and their luminescence characteristics were generally considered to be well suited for OSL dating.

R M Bailey, N P Branch, and J Stallard, North Park Farm Quarry, Bletchingley, Surrey: optically stimulated luminescence (OSL) dating of a Mesolithic archaeological site, Stage 1. *EH Res Dep Rep Ser* **98/2007**. 15pp.

Eight Optically Stimulated Luminescence (OSL) dates were obtained from the Mesolithic site at North Park Farm Quarry, Surrey, to provide a chronological framework for natural and cultural events. The OSL measurements indicate that redeposited Lower Greensand material accumulated prior to Mesolithic activity between c 764-500,000 years ago and around 24,000 years ago. This process continued during the period of human activity as shown by the results from below and above an in-situ Mesolithic hearth.

H M Roberts, Gwithian, Cornwall: optically stimulated luminescence dating of sands from a Bronze Age archaeological site. *EH Res Dep Rep Ser* **103/2007**. 16pp.

Two windblown sand units found at the Bronze Age site at Gwithian, near Hayle, West Cornwall, were dated using optically stimulated luminescence (OSL) applied to coarse (sand-sized) quartz grains. The quartz proved sufficiently sensitive to enable well-resolved dating using the Single Aliquot Regenerative dose (SAR) measurement protocol.
The OSL ages are indistinguishable within errors, showing that the two sand units were deposited in relatively rapid succession approximately 3500 years ago, with only a brief period of stabilisation due to cultivation in between. The OSL ages are in agreement with independent evidence from radiocarbon dating of intervening and overlying stratigraphic units.

Conference Announcement

12th International Conference on Luminescence and Electron Spin Resonance Dating

Peking University, China

18-22nd September 2008

Peking University invites you to the *12th International Conference on Luminescence and Electron Spin Resonance Dating* (LED 2008), to be held at the campus of Peking University, Beijing on 18 – 22, September, 2008. The conference will be sponsored by the National Natural Science Foundation of China, Peking University, Chinese Academy of Sciences and China Earthquake Administration.

LED 2008 continues the conference series which began in Oxford in 1978 and follows the tradition of more recent meetings in Rome (LED 1999), Reno (LED 2002) and Köln (LED 2005). It will bring together experts in the field of trapped charge dating from all over the world. The topics will range from fundamental studies of the physical basis of trapped charge dating, through advances in equipment technology and analytic procedures, to applications in dating Quaternary deposits and archaeological material. Presentations will include both oral and poster contributions. A few invited lectures will provide an overview of the latest developments in the field.

A conference web-page provides regular updates: http://led2008.pku.edu.cn.

Location

The conference will be held at the Overseas Exchange Centre of Peking University in Beijing. Mean annual temperature in Beijing is about 20°C for September. Beijing Capital International Airport serves both international and domestic flights. Connections to Peking University, which is located in the north-western part of the city, are readily available.

Pre-conference excursion (13-17 September 2008)

A five-day pre-conference excursion to the spectacular Loess Plateau will be organised by Xulong Wang (Institute of Earth Environment, Chinese Academy of Sciences) and Gongming Yin (Institute of Geology, China Earthquake Administration). It will start in Xian and include a visit to the Terracotta Warriors which were dated by luminescence 20 years ago. Further details will be available in the 2nd Circular and on the conference web-page. The cost of the excursion (including accommodation, food and flight to Beijing) will be in the range of € 450~500.

Conference fees

Professionals	€ 380 (Early)/430 (Late)
Students	€ 180 (Early)/230 (Late)
Accompanying persons	€150

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Important Dates

Early Registration in order to obtain lower conference fee: ***March 15th, 2008***

Registration for Pre-Conference Excursion : ***May 15th, 2008***

Reservation of Accommodation : ***May 15th, 2008***

Submission of Abstract : ***May 30th, 2008***