ISSN 2693-0935

Ancient TL

A periodical devoted to Luminescence and ESR dating

Department of Physics, East Carolina University, 1000 East 5th Street, Greenville, NC 27858, USA
http://ancienttl.org

2021, Volume 39 No. S

Special Issue: LED2021 Abstracts

13th – 17th September 2021

Ancient TL

Started by the late David Zimmerman in 1977

Ancient TL

This Special Issue of *Ancient TL* contains abstracts of oral and poster presentations submitted to the **LED2021**. The **16th International Luminescence and ESR Dating Conference** was held online Sept 13-17th 2021. All abstracts for which presentations had been uploaded to the **LED2021** webpage and for which the first authors gave consent for publication were included in this Special Issue.
Abstracts are organized by session number and are listed in the same order as in the conference programme.
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O.1-3: Non-first-order kinetic models in rock surface dating

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Luminescence-depth profiles in rock surface dating are generally described assuming first-order kinetics for electron detrapping (Sobahti et al., 2012). This assumption is perhaps reasonable for quartz, but feldspar is generally understood to follow non-first-order kinetics. In this study we employ (i) a localised recombination model (Jain et al., 2015) and (ii) a general order kinetics model (Chen and McKeever, 1997) to develop new analytical expressions for luminescence-depth profiles in rocks assuming no irradiation during bleaching. Using simulated data, we first investigate how sensitive various parameters (e.g. the light attenuation coefficient) are to the choice of kinetic model. We then explore whether incorrect model assumptions affect the (i) estimates of exposure age/erosion rate, or (ii) reconstruction of residual luminescence signal at the rock surface prior to irradiation. The latter builds on the model for multiple events proposed by Freiesleben et al. (2015).
Experimental data were derived from several granite samples exposed to daylight and to artificial broad-spectrum or monochromatic light sources. Some samples were subsequently irradiated with gamma rays to simulate a burial scenario. The kinetics determined from IRSL stimulation curves are consistent with those determined from measured luminescence-depth profiles. We use both simulated and experimental data to conclude that accurate ages can only be obtained if the correct kinetic model is used.

Keywords Rock surface dating; non-first order models; General order model; fading model; exposure dating.

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O.1-4: Exploring the use of luminescence techniques for dating volcanic glasses

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Tephras are significant isochronic markers in the stratigraphic record and have played a key role in reconstructing paleoenvironmental and archaeological histories worldwide [1]. Despite burgeoning research focused on tephra characterization and statistical correlation techniques, there are still few techniques that allow for the direct dating of tephra, particularly below the lower age limit of K/Ar and Ar/Ar dating methods (≈120 ka). The glass component in tephra shows considerable potential for thermoluminescence (TL) dating. The use of this fine-grained constituent can allow for both distal and proximal ash deposits to be dated, providing an excellent opportunity for tephrostratigraphic correlation over large distances. Moreover, unlike phenocrystic quartz, the glass component is ubiquitous throughout tephra deposits. In this study, we test different TL approaches on the 4-11 µm volcanic glass constituents of three independently dated primary tephras collected from pluvial shoreline deposits in the Western United States. By comparing against independent age control, we demonstrate the utility of both UV-blue (320 to 450 nm) and red (590 to 650 nm) TL emissions for dating volcanic glasses using single aliquot regenerative (SAR) dose techniques.

We find that both UV-blue and red TL emissions from the volcanic glass are dim but reproducible and show no evidence for significant sensitivity changes occurring between the natural TL and the first test dose during the SAR protocol. Fading tests on the blue TL signal show that g-values range from 1.2 ± 1.1 to 3.1 ± 1.3 %/decade and are statistically consistent with zero at 2σ for the red TL. Bleaching experiments suggest that both blue and red TL signals are sensitive to light exposure, with sensitivity corrected signals declining by ≈60% and ≈40% over a 2-hour period, respectively. For all three tephras, both the UV-blue (fading-corrected) and red SAR-TL ages are fully consistent with age expectation. These successful results demonstrate the effectiveness of TL techniques for determining the eruption ages of tephra deposits in primary position between ≈1.5 and at least 30 ka.

Keywords Thermoluminescence; tephra; tephrochronology; red TL; volcanic glass

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O.1-5: A preliminary study on the ESR signals characteristics of recrystallized carbonate in southwest China

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There are strong fault activities in carbonate rock area of southwest China. Due to the lack of suitable materials for dating, it is a great challenge for the age dating of the tectonic activities in such area. Fortunately, we found a thin layer of recrystallized carbonates on the bedrock fault surface and there are scratches of fault activity on the surface of recrystallized carbonate, which indicated the recrystallized carbonate formed by the heat of friction generated during fault activity. Therefore, it is a direct product of fault activity and was formed at the same time as the fault movement. Theoretically, the heat generated by friction (higher than 200 ℃ usually) on the bedrock fault surface during fault activity can completely anneal the ESR signals of the recrystallized carbonate to zero. So it is an ideal material for the chronology of fault activity in carbonate rock area using ESR method.

Carbonate is one of the main materials used for ESR dating. In fact, the ESR method was applied to the dating of carbonate material as early as the 1970s, and a great deal of carbonate ESR studies have been carried out subsequently. Until now, the ESR signals characteristics of marine carbonates (e.g. coral, mollusc shell, foraminifera) and speleothems (e.g. stalactite and stalagmite) is well known including signals features, dose-response, thermal behaviour, stability etc., but there are very few studies related to the continental carbonate rocks and their recrystallized carbonates, which are essential for ESR dating using the recrystallized carbonates in carbonate rock area.

In this study, we investigated the ESR signals characteristics of recrystallized carbonates, calcite veins and limestone bedrock collected from Napo city, Guangxi Zhuang Autonomous Region, China, and the following results were obtained: (a) Multiple ESR signals are present in carbonates: g=2.0006 and g=2.0040 signals are observed in all three kinds of samples and g=2.0057 is present only in calcite veins and limestone bedrock samples. (b) g=2.0057 is not sensitive to artificial γ-irradiation. (c) g=2.0040 increases with irradiation, but does not fit any of the growth patterns (including linear or exponential), so the signal is not suitable for dating. (d) g=2.0006 is the best dating signal, which responds well to irradiation and increases exponentially with irradiation doses (0~2000 Gy), and the saturation dose D_0 ranges from 1200 to 2500 Gy, corresponding to the upper dating limits of 900 to 2400 ka BP.

Keywords: ESR signal; recrystallized carbonate; carbonate rock area; fault activity; southwest China

O.1-6: Luminescence dating of diatoms: an attempt

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Luminescence characteristics of 1) natural diatomite collected from Lake Ashenge, Ethiopia, and 2) diatom frustules extracted from two lacustrine profiles from 1) Mahanadi basin (3 samples) and, 2) Vembanad wetland, Kerala (4 samples), India were measured in a newly established Luminescence Dating Laboratory (LumDL) of our Institute. Before making the luminescence measurements, the absence of any inorganic luminescent minerals is confirmed using FE-SEM, EDX, XRD and Raman spectroscopy.

We observed a prominent unstable glow peak at ~ 80°C at the heating rate of 2°C/s and a broad glow peak afterwards. The TL measurements were done using U-340 filter. This broad glow peak was optically bleachable and it lost 99 % of its induced luminescence in 2 hours of solar exposure. Reproducible decay curves were measured using blue stimulation (UV emission) at 50°C after preheating the irradiated diatomite to 200°C. The growth curve saturates beyond the dose value of 650 Gy ($2.D_0$) and a lower g-value (1.5 ± 2.6 % per decade) indicates no significant fading.

Palaeodoses of fine polymineral grains (4-11 μm) and diatom frustules were measured using IRSL (blue emission) and OSL (UV emission) signals respectively. There is a contrasting observations on the values of 1) alpha dose efficiency (a-values) and, 2) luminescence signals' fading rate between the diatom frustules from different geographical locations. Alpha efficiency of diatom frustules from Mahanadi basin was underestimated by 50 - 60 % than the fine polymineral grains whereas Vembanad wetland, Kerala samples shows that there is no such difference between them. Diatom frustules from Mahanadi basin exhibited no fading whereas Vembanad wetland, Kerala samples exhibited a greater value (10.2 % per decade) compared to that of fine-grain polyminerals (7.4 % per decade). A detailed methodology and results will be discussed in the conference.

Keywords: Diatoms; Frustules; Luminescence dating; Diatomite

P.1-1: Thermoluminescence of aquamarine

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Thermoluminescence of aquamarine, the cyan variety of beryl ($Be_3Al_2(SiO_3)_6$) is reported. From a dosimetry point of view, beryl is of interest as some of its luminescence features resemble those of quartz [1]. Measurements made at 1 °C s^{-1} after irradiation to 10 Gy show a prominent glow peak at 75°C and three secondary peaks at 113, 188 and 306 °C respectively. The pale blue hue of aquamarine is ascribed to presence of Fe-related cations within its matrix. By way of comparison, beryl intentionally doped with Fe shows strong thermoluminescence emission between 300 and 400 nm [1] studied here. Kinetic analysis of the main peak is performed using the initial rise, peak shape, whole glow peak, curve fitting and variable heating rate methods show that the peak follows first order kinetics, its activation energy is of the order of 1 eV and has a frequency factor of ~ 10^{12} s^{-1}. The peak fades with delay between irradiation and measurement, the factor within 600 s of irradiation being 14%. The dose response of the main peak is linear within the first 10 Gy but tends towards sub-linearity as the dose is further extended to 100 Gy.

Keywords: Beryl; thermoluminescence; kinetic-analysis; dose-response, fading.

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P.1-2: Dependence of the LM-OSL peak shape on trap filling and trap emptying - Comparison with TL

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Linearly modulated optically stimulated luminescence (LM-OSL) is a technique which can be used in OSL research and applications. The LM-OSL bell shape is the elementary basic component of several complex experimental LM-OSL curves and has its own unique properties. These properties are poorly studied relative to the theoretical end experimental literature existing for the corresponding Thermoluminescence (TL) peaks. The stimulation modes of TL and LM-OSL differ greatly, so it could be ideal to study the effects responsible for electron trap filling or trap emptying. This could also extend our knowledge for TL and OSL phenomena.

The theoretical process was simulated using the existing known model of two localized levels, an isolated electron trap (T) and a recombination center (R), commonly referred to as the one trap – one recombination center model (OTOR). The simulation process was conducted by numerically integrating the OTOR model equations using Python. Python is under an open-source license and has become very popular due to the vast number of open libraries used for mathematical analysis and data processing.

In the present work, the properties of LM-OSL and TL peaks were investigated and compared, theoretically and experimentally; specifically, the peak shape as a function of dose, the maximum intensity (I_{max}) and the stimulation time where reaches its maximum intensity (t_{max}). The aforementioned properties were compared to, the TL intensity caused by heating rate alteration and the temperature where a TL peak reaches its maximum intensity (T_{max}). For example, T_{max} shifts to lower temperatures as the dose increases.

Finally, we tried to verify that the shift of a second order kinetics LM-OSL peak maximum (I_{max}) as a function of dose, is not observed after trap filling (irradiation) but it is observed in the residual intensity after the trap is partially emptied either by thermal or by optical bleaching [1].

Keywords: Linearly modulated optically stimulated luminescence; One trap one recombination center model; Simulation; Open source; Python;

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P.1-3: Recombination pathways in a BeO yielding two main dosimetric TL peaks

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Beryllium oxide (BeO) is a well-established dosimeter and is highly used as medical, environmental, and personal dosimeter, due to its atomic number being close to that of tissue. The most common type of BeO is fabricated by Thermalox, having the commercial name Thermalox 995 BeO (BeO_T), and yields one main Thermoluminescence (TL) dosimetric peak at the dosimetric region between the temperatures of 100-250^{o}C. However, a new type of BeO ceramic, originating from a Turkish private company, is called BeO_R (Radkor) and yields two separate TL peaks at the dosimetric temperature region of 100-300^{o}C.

The aforementioned BeO_R dosimeter was studied extensively by Aşlar et al. [1] with a plethora of techniques, which besides TL and optically stimulated luminescence (OSL) include electron spin resonance (ESR), scanning electron microscopy (SEM) coupled with energy dispersive x-ray spectroscopy (EDX) and x-ray diffraction analysis (XRD). Moreover, the same team conducted some experiments on a variety of the luminescence dosimetric properties of BeO_R, such as dose-response, minimum detectable dose, thermal stability and quenching, reproducibility, and bleaching.

On the other hand, Polymeris et al. [2] concentrated on the recombination pathways during the readout stage regarding four different known dosimeters, including the BeO_T. It is known that these pathways can be either delocalized, via the conduction band, or localized, involving tunneling through an excited state of the trapped electrons. These authors have proposed a series of experiments in order to compare the value of the activation energy of each peak and to distinguish its recombination pathway, by including the fractional glow technique (FGT), an isothermal decay signal (PID) and the peak shape methods (PSM).

The main aim of the present study is to use the methodology that is proposed by Polymeris et al. [2] in order to generate some experimental data for the case of both main dosimetric peaks of BeO_R. By conducting the three series of experiments, it is possible to calculate the activation energy of both main dosimetric peaks at different scenarios and thus being able to compare them. The second aim of this study, as the protocol suggests, is to distinguish the pathways that are present in the BeO_R dosimeter. With this analysis, a very surprising phenomenon arises, as it seems that in the thermal stimulation stage, the first peak follows the general delocalized model, while the second is of the localized nature.

Keywords BeO_R; FGT; PID; PSM; Recombination pathways

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P.1-4: Phototransferred thermoluminescence of topaz

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We report the phototransferred thermoluminescence of topaz induced by 470 nm blue LEDs. The thermoluminescence glow curve recorded at 1°C/s following beta irradiation to 20 Gy shows three prominent peaks at 48, 128, and 264 °C, and a weak-intensity peak at 420 °C. These peaks are labelled peak I, II, III, and IV respectively. Peak I is reproduced under phototransfer after any preheating between 70 and 220 °C. No PTTL was observed at peaks II – IV. A study of the influence of preheating temperature on the PTTL intensity of peak I confirm that only the electron trap corresponding to peak I acts as an acceptor. Further investigation of the other peaks not acting as PTTL peak between 70 and 400 °C shows no signal for peak II and a weak-intense peak IV. However, for peak III, the dependence of its intensity on preheating temperature is suggestive of competition effects. This is addressed in this report. A study of illumination time dependence of PTTL intensity for peak I following preheating to 78 and 178 °C to remove peaks I and II also shows that electron traps for peak I act as an acceptor. The time dependence profiles of PTTL intensity of peak I are modelled by a system of an acceptor and donors. Kinetic analysis of PTTL peak I using the Hoogenstraaten method shows that its activation energy is 0.71 eV. This PTTL peak was found to be affected by thermal quenching with an activation energy of 0.45±0.02 eV. The dose response of the PTTL peak following preheating to 78 and 178 °C shows a supralinear behaviour between 1 and 100 Gy. The influence of delay between irradiation and measurement for PTTL peak I shows that the peak fades rapidly after 600 s. This suggests that topaz can be exploited as a thermoluminescence dosimeter under phototransfer.

Keywords Phototransfer; thermoluminescence; competition effects; thermal quenching.

P.1-5: Thermal stability of radiation-induced organic radicals in chibaite

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Silica clathrates have a framework structure with cage-like voids occupied by guest species and are very similar to gas hydrates which contain molecule compounds enclosed within cage-like structures of solid-state water molecules. Chibaite is a natural analogue of gas hydrate structure II with larger cages than that of melanophlogite isostructural to gas hydrate structure I. It suggests that the cage in chibaite can store propane and isobutane together with methane and ethane as guest molecules. Chibaite was found in marine sediments of Early Miocene age (Hota Group) at Arakawa, Minami-boso City, Chiba Prefecture, Japan [1]. It occurs in quartz veins ranging from a few mm to 1 cm thick in tuffaceous sandstone and mudstone. Although chibaite should crystallize after marine sedimentation, it is not clear when it formed. If organic radical species like methyl radicals in silica clathrates are thermally stable in geological time scale, electron spin resonance (ESR) dating could be applied to evaluate the formation age. To obtain a reliable ESR age, it is necessary to assess a thermal stability of the radical species in chibaite. Propyl radicals and *tert*-butyl radicals might be formed and stored in the clathrate cage because they are potentially stable in the large cages. In this study, we have conducted to measure the radicals in natural clathrate of chibaite by ESR to clarify whether radical species are observed in chibaite and how stable they are.

We gently crushed chibaite samples with a mortar into several particles about 1 mm in diameter, some of which were irradiated by gamma-rays from a source of ^{60}Co. After isochronal annealing for 15 min at temperatures of 150, 180, 210, 240, 270, 300, 330, 360, 390, and 420 ºC, ESR signals for each portion were measured at room temperature using the X-band ESR spectrometer. Methyl and *tert*-butyl radicals were observed in the untreated samples. Gamma irradiation caused an increase in the signal intensity of *tert*-butyl radicals for every sample, whereas the signal intensity of methyl radicals apparently unchanged. During annealing experiments, the integrated intensity of *tert*-butyl radicals increased from 180 ºC up to 240 ºC and decreased above 240 ºC up to 300 ºC. In contrast, the intensity of methyl radicals decreased from 180 ºC up to 240 ºC and increased above 240 ºC up to 300 ºC. We have performed isothermal annealing experiments at various temperatures to make sure the detailed correlation among these radicals. In this presentation, we will show the results obtained in isothermal annealing experiments and discuss the possibility of ESR dating using characteristic radicals detected in chibaite.

Keywords: silica clathrate, chibaite, electron spin resonance, radical species, thermal stability

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P.1-6: Thermoluminescence and defect studies of $SrAl_2O_4$ phosphor synthesized by solid state reaction method

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Recently, some rare-earth doped strontium aluminates have been investigated due to their thermoluminescence properties and their high potential for application in radiation dosimetry using the TL technique [1-3]. Even though this material exhibits interesting luminescence properties, few studies have been performed on the defects responsible for the TL emission of these materials.
In this work, strontium aluminate (SAO) nanophosphor was synthesized by the solid-state reaction method. The structure analysis of the sample was carried out using a Rigaku MiniFlex 600 diffractometer (XRD) with Cu-K_α radiation at room temperature. The sample diffractogram was analyzed using the MATCH program for phase identification. The results of XRD characterization show predominant presence of strontium aluminate nanophosphor.
In order to obtain SAO pellets, the sample was crushed in an agate mortar for 2 hours to turn it into a fine powder, and then pellets with mass of 50 mg and a diameter of 6 mm were obtained at a pressure of 0.7 ton/cm^2. TL glow curves of SAO pellets irradiated in the range 1 Gy up to 11 Gy with a gamma source (Co-60) show three peaks, a very intense peak at 250 °C, and two peaks of lower intensity at 142 °C and 325 °C. Effect of UV irradiation was also studied on these SAO pellets by irradiating with a xenon UV source for 10 to 90 seconds. Two TL glow peaks at 150 and 272 °C was recorded in the samples. TL intensity was found to increase with UV dose. The kinetic parameters of the TL peaks were calculated for the SAO nanophosphors. The TL reading was performed using 4 °C/s of heating rate. All TL measurements were carried out at room temperature.
Electron Paramagnetic Resonance (EPR) studies have been carried out to identify the defect centers induced by gamma irradiation and also to identify the defect centers involved in the TL process in $SrAl_2O_4$. Two distinct centers contribute to the observed spectrum at room temperature. Center I exhibiting a four-line hyperfine splitting is identified as an O^- ion. O^- ion is associated with the high temperature TL peak at 326 °C. An eight-line spectrum with a *g*-value of 2.0068 is attributed to a F^+ center (singly ionized oxygen vacancy). This center relates to the 142 °C TL peak.

Keywords Thermoluminescence; EPR; Defect Centers; strontium aluminates; Solid state reaction

Acknowledgments This work was partially supported by CONCYTEC-FONDECYT, Peru, in the framework of the call E038-01 (Process number 037-2019)

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P.1-9: Kinetic analysis of the main peak of the thermoluminescent glow curve of α-Al_2O_3

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In this work, the kinetic parameters of the main thermoluminescence (TL) peak of pure alumina (α-Al2O3) samples irradiated at different doses are reported. The TL behavior is analyzed as a function of dose. The pellets were irradiated at different X-ray doses using a 6 MeV linear accelerator (LINAC), in air at room temperature, located at the Instituto Medico de Alta Tecnología (IMAT) in Monteria city. The TL reading of the samples was performed on a Bicron® TLD 4500 system. The Initial Rise (IR), Peak shape (PS), Whole glow peak (WGP) and Curve fitting (CF) methods were used to carry out a detailed kinetic analysis. Analysis of the TL shows that the alumina arrays contain more than one type of trap due to several points of maximum luminous emission intensity in the TL glow curve. The glow curves of the pure alumina samples exhibited a total of three glow peaks with the main peak located between 160 and 170 °C. The kinetic parameters (activation energy E, frequency factor s and order parameter b) of the main peak of the TL glow curve are independent of the radiation dose received by the material. Physical processes involved in the emission will be discussed. Dosimetric properties such as dose response and reproducibility are also reported. The dose response of the main peak is linear within the first 10 Gy. After seven identical measurements at the same dose, the results showed an uncertainty of 2.3% suggesting the potential of α-Al2O3 as thermoluminescent dosimeter.

Keywords: Al_2O_3; thermoluminescence; kinetic-parameters; dose-response; reproducibility

P.1-10: Investigating quartz OSL signal characteristics using EMCCD imaging

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Optically stimulated luminescence (OSL) signals from individual quartz mineral grains are frequently used for equivalent dose determinations in luminescence dating. Typical measurements using Risø luminescence readers involves individual grains being mounted on single grain discs with signals stimulated using a focused XY laser system incorporating a solid state laser beam [1], and luminescence is detected via a photo multiplier tube. Notably, when compared to the blue LED arrays typically used for multi-grain measurements, the power density of the green laser is much higher, resulting in a comparatively more rapid stimulation of single grain signals. Whilst single grain dating of quartz has become a routinely used means of dating, intra- and inter-sample variability in individual quartz OSL signals has been reported. These variations include the number of grains yielding a signal and signal intensity [2], D_0 [3], the presence and proportion of different components [4], and thermal stability [5]. At least some of this variability has been attributed to variation in the effective stimulation power delivered by the laser system during the measurement sequence [6]. However, the degree of intrinsic variation in single grain quartz OSL signals, both within and between quartz sediment samples, has yet to be fully quantified.

In contrast, electron multiplier charge coupled devices (EMCCD) offer an alternative means of detecting luminescence. Imaging rather than a photo multiplier tube is used for the detection and recording of signals, with the benefit of allowing the measurement of multiple thermal and optical signals at a single grain scale. Whilst imaging currently offers lower detection sensitivity in comparison to a laser system, it does allow stimulation using LEDs, which circumvents variability in the effective stimulation power delivered by the laser system. The lower stimulation energy of the LEDs allows signal stimulation at a slower rate, which benefits some mathematical treatments such as curve deconvolution [6]. In this paper, we use an EMCCD system to explore signal characteristics, such as composition of components, D_0, and dose response curve form, using a range of quartz sediment samples to assess intra- and inter-sample variability of quartz OSL signals.

Keywords Quartz; OSL; Components; Saturation; EMCCD.

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P.1-11: A systematic multi-technique comparison of two reference quartz samples

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Further developments in OSL dating, especially in thermochronometry, using quartz are impossible without establishing the nature and basic parameters of defects responsible for the luminescence of this mineral. Ideally, such basic investigations are carried out on reference quartz samples using multiple methods to characterize traps and luminescent centres. These samples should also be well described from the mineralogical point of view regarding petrogenesis and geochemistry. Finally, analyses should be repeated in several laboratories to verify the obtained results.

Recently, we proposed the Fontainebleau (FB) quartz as a reference sample. First luminescence and geochemistry results of this material, involving multiple laboratories, were presented [1, 2]. Here we propose an additional quartz reference sample, the 'Silver Sands of Morar' (Scotland, UK), originating from the bank of an active estuary. The sediment is approximately 8-9 ka old and has been reworked frequently by fluvial and marine processes. Several tests performed on both reference samples show that luminescence sensitivities differ significantly. The intensity of the 110 °C TL peak for 100 grains of the FB sample is 10 000 cts K^{-1} Gy^{-1} , while in the case of the Morar (MO) sample, it is 50 cts $K^{-1}Gy^{-1}$. A similar significant difference is observed for the initial blue OSL intensities (10 000 cts $s^{-1}Gy^{-1}$ and ~10 cts $s^{-1}Gy^{-1}$, respectively). Differences became less significant for TL at higher temperatures, e.g., in the range 250–300 °C: TL intensities amount to ca 30 cts $K^{-1}Gy^{-1}$ and 10 cts $K^{-1}Gy^{-1}$, for the FB and MO samples. The shapes of TL curves for both samples differ mainly above 300 °C, where the signal for the FB is much weaker than for MO. A severe difference is also observed in the LM-OSL characteristics. While for the FB sample, the fast OSL component dominates, the signal of the MO sample is dim at the beginning, giving way to intense slow components.

In this contribution, we present details of the TL and OSL and TR-OSL results that provide insight into the character of the recombination process in both samples.

Keywords thermoluminescence; optically stimulated luminescence, OSL dating; quartz

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P.1-12: Thermoluminescence of natural quartz grains beside Huguangyan Maar Lake

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In order to investigate the relationship between the thermoluminescence (TL) characteristics and the irradiated history of natural quartz crystals, quartz grains size of 40 - 60 μm were selected from the volcanic ash beside Huguangyan Maar Lake [1] (E110°17'29'', N21°8'52'') in Zhanjiang City. After annealing at 450 centigrade for 10 minutes, the thermoluminescence characteristics of quartz particles were measured. The TL trap parameters were calculated using the general order kinetics [2], and the parameters are consistent with those of the quartz crystals extracted from the sandy soil samples near Nags Head (W75°39'38'', N35°56'36'') on the east bank of USA. The thermoluminescence peaks above 200 centigrade of natural quartz are about 260, 320 and 370 centigrade, and the trap energies corresponding to the three TL peaks are about 1.34, 1.44 and 1.51eV.

Annealing processes below 450 centigrade for quartz grains has little effect on TL sensitivity when irradiated history dose of quartz grains is less than the saturation dose. When the irradiated history dose exceeds 1000 Gray, annealing processes at 450 centigrade will increase the TL sensitivity.

The peak position of the TL glow curve changes slightly with the increasing of irradiated dose of quartz grains [3], which corresponds to a slight decrease in the average activation energy of the TL trap. This result indicates that the energy of a thermoluminescence trap is not a single value, but an energy distribution.

Keywords Quartz; Thermoluminescence; Sensitivity; Trap

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P.1-13: The functionalization of the quartz surface: A new proposal to stabilize the E'1 center and ESR dating of marine sediment

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Electron spin resonance dating (ESR) was first introduced to geology science in 1975. The quartz is useful for ESR dating. The E'1 center can measure the number of unpaired electron spins in crystalline quartz and determine the dose equivalent. However, the E'1 center presents one component ghost or also known as component thermal. The component ghost can act as one interference of the signal of the E'1 center. This work reserves to consider a model of functionalization of the quartz surface where the atoms of surface oxygen are on to a proton. The E'1 center was used to determine the equivalent dose of eight marine sediment samples collected from the coast of Brazil. The annual dose determined by gamma-ray spectroscopy. The results obtained at the E'1 center ranged from 3 to 28 thousand years. Therefore, quartz surface functionalization is a promising method to stabilize the E'1 paramagnetic defect in quartz.

Keywords ESR dating; E’1 center; marine sediment; quaternary; functionalization.

P.1-14: Radiation sensitivity characteristics of quartz ESR signals under high temperature baking by volcanic lava flow: Example of Datong China

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Quartz is one of the most important materials for ESR dating method. Therefore, it is necessary to study and understand the behaviour and characteristics of quartz ESR signals. In order to evaluate their radiation sensitivity under natural high temperature baking, samples heated at different temperature degrees by lava flow have been collected for ESR study (concerning Al, Ti-Li, Ti-H and E' paramagnetic centers) from lacustrine strata covered by volcanic flows at Yujiazhai, Datong, Northern China. The analyses show that the radiation sensitivity of the Ti-Li signal increases significantly with the temperature of the lava flow and is proportional to the increasing baking temperature. On the other hand, the radiation sensitivities of the E' and the Ti-H centers firstly increase, then decreases with increasing baking temperature.

Keywords: quartz; electron spin resonance (ESR); radiation sensitivity; baking effect; lava flow

Session 2:
Insights into feldspar luminescence processes

Oral Presentations

	Presenter	Title
2	Vasilis Pagonis	Standardizing the computerized analysis and modeling of luminescence phenomena: new open-access codes in R and Python
3	Monika Devi	TL and OSL trap correlation studies to understand the luminescence mechanism in feldspar
4	Svenja Riedesel	Time-resolved analysis of blue and yellow-green IRSL emissions - Insights into charge recombination and radiative relaxation in chemically and structurally different alkali feldspars
5	Mayank Jain	Exploring the potential of green light excitation for measurement of infrared photoluminescence
6	Melanie Bartz	Does chemical weathering change luminescence of feldspar?

Poster Presentations

	Presenter	Title
1	Georgios S. Polymeris	Athermal fading studies in thermoluminescence signal of 10 different K-feldspar samples; fading rate versus TL glow curve temperature analysis and correlation to structural state characteristics
2	Markus Fuchs	Further investigations on infrared-radiofluorescence (IR-RF) emissions
3	J.M. Kalita	Thermally assisted-optically stimulated luminescence from deep electron traps in microcline
4	Marine Frouin	Further investigations into IR-RF and IR-PL
5	Geoff Duller	Imaging single grains of feldspar: luminescence variability and implications for dating

O.2-2: Standardizing the computerized analysis and modeling of luminescence phenomena: new open-access codes in R and Python

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In this presentation, we describe a new initiative for the development of open-access codes in R and Python, to be used for computerized analysis and modelling of luminescence phenomena. The purpose of this broad initiative is to help in the classification, organization and standardization of the computerized analysis and modelling of a wide range of luminescence phenomena. Although a very significant number of such open access codes is already available in the literature, there is a lack of common standardization and homogeneity, which we hope to address in this initiative [1].
The new open-access codes are grouped in six broad categories of thermoluminescence (TL), optically stimulated luminescence (OSL), infrared stimulated luminescence (IRSL), excitation spectra (ES), dose response (DR) and time-resolved (TR) codes. In each of these categories, we present codes based on (a) delocalized transitions involving the conduction/valence bands and (b) localized transitions based on proximal interactions between traps and centers, and (c) semi-localized transitions based on a combination of localized and delocalized transitions.
While many previously published codes for thermally and optically stimulated phenomena are based on the empirical general order kinetics and on first order kinetics, the new codes in R and Python are based on physically meaningful kinetics described by the Lambert W function. During the past decade, the Lambert W function has been shown to describe both thermally and optically stimulated phenomena, as well as the nonlinear dose response of TL/OSL/ESR in dosimetric materials ([2],[3]).
In the case of time-resolved signals, we provide deconvolution codes and models based on a variety of dosimetric materials (quartz and Al_2O_3:C etc), while for the analysis of excitation spectra we present deconvolution codes based on the sum of Gaussian or Lorentzian functions.
Special attention is given to IRSL signals, which are of great importance in luminescence dating applications. Specific deconvolution codes are presented for TL signals in feldspars, which are based on localized luminescence models and random distributions of defects in these materials [4].
The new open access codes will be available on GitHub for users to download as individual R/Python codes, as well as a single zipped folder. The presentation will demonstrate our proposed classification and organization of the codes, which we hope will be a useful tool, especially for newcomers to the field of luminescence dosimetry.

Keywords computerized analysis; luminescence processes; deconvolution of signals; open-access R codes; Python

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O.2-3: TL and OSL trap correlation studies to understand the luminescence mechanism in feldspar

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Quartz and feldspar are the two natural and ubiquitous minerals used for luminescence dating. Quartz has proved itself a reliable chronometer, but due to its low saturation dose, the dating range has been limited to 100-200ka. Whereas feldspar has a higher saturation dose with an extended dose range promise, but it suffers from anomalous fading. So far, several mechanisms for luminescence in feldspar are proposed [1], but still, it require further refinements. A better understanding of the mechanism is needed to circumvent the problem of fading.

The present study tries to identify and characterize the traps playing a role in OSL (Optically stimulated luminescence) and their link with traps responsible for TL (thermo-luminescence). The study investigates emission from different stimulation lights and its corresponding effect on the TL glow curves to understand the trap dynamics of k-feldspar. The preliminary results suggest that green and blue stimulations at 50°C affect the TL traps up to 400°C. Moreover, Infrared stimulation (IRSL) at 50°C mainly affects the ~410°C TL peak. Although green and blue lights having much higher energies are expected to probe the deep traps, it is found that the traps probed by these stimulations are shallower than the IRSL (50°C). The preliminary results also suggest that green, blue, and violet (GBV) lights probe almost similar traps and share some common traps with IR. Further, we are trying to investigate the effect of violet stimulation on the TL traps. As the violet light has significantly higher energy than blue and IRSL, it is expected that it can probe the IRSL and more deeper traps. The relevant results will be presented at the conference.

Keywords: feldspar; anomalous fading; post-IR IRSL; shallow traps; deep traps.

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O.2-4: Time-resolved analysis of blue and yellow-green IRSL emissions - Insights into charge recombination and radiative relaxation in chemically and structurally different alkali feldspars

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Luminescence emissions and their lifetimes are the result of radiative relaxation of electrons at specific lattice defect sites and can thus give information on the type of defect and luminescence production involved. Here we investigate lifetimes determined using time-resolved (TR) luminescence of the blue (~410 nm) and yellow-green (~550 nm) emissions of chemically and structurally different alkali feldspars using pulsed infrared (870 nm) stimulation.

In luminescence dating of feldspars, the blue luminescence emission is commonly investigated. This emission has been hypothesised to originate from a hole centre located on Al-bridging O ions [1, 2]. It has been shown that the intensity of this blue luminescence emission, as well as the shape of the thermoluminescence curve and infrared stimulated luminescence (IRSL) fading rate, can be altered by artificially disordering the Al,Si framework of feldspars [2]. However, it is unknown if these observed changes in the blue emission are solely the result of an increase in the number of related hole centres, or whether the physical characteristics of this type of defect are also modified.

Although the yellow-green emission is rarely used in luminescence dating, the emission is of interest as it has been assigned to Mn^{2+} substituting for Ca^{2+} in plagioclase feldspars [3] and is thus thought to indicate the presence of such feldspars. However, emission resulting from this type of defect should show lifetimes on a scale of several milliseconds, but much shorter lifetimes have been observed as well [4,5], implying that a different type of defect may occur in some feldspars [3]. Furthermore, this yellow-green emission has also been found in single-phase microcline [2] which is surprising if it is associated with substitution for Ca^{2+}. Thus, the source of the yellow-green emission is currently unclear.

To explore potential sources of the blue and yellow-green emission, we investigate a range of chemically and structurally different feldspars, including K- and Na-feldspar endmembers, perthites and artificially disordered specimens. The TR-luminescence measurements are performed using a conventional post-IR_{50} $IRSL_{225}$ protocol and can thus be directly linked to luminescence processes routinely measured in retrospective dosimetry using alkali feldspars.

Keywords Feldspars; time-resolved luminescence; radiative relaxation; IRSL; crystal defects

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O.2-5: Exploring the potential of green light excitation for measurement of infrared photoluminescence

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Since the first report of the discovery of infrared photoluminescence (IRPL) in feldspar in LED 2017 at Cape Town, this signal has been used to understand the physical mechanisms involved in feldspar luminescence and its potential has been tested as a dating tool. Basic investigations involve understanding the electron trapping centre by site-specific probing: characterising the different trapping states and their response to heat or excitation wavelength, as well as establishing the relationship between traps and feldspar mineralogy/composition [1, 2]. IRPL has not just provided new information on the electron trap but also on the nature of the OSL/IRSL recombination process [3]. New applications in archaeology and Earth science involve IRPL sediment dating [4], rapid high-resolution imaging of luminescence-depth profiles [5, 6], and understanding of light propagation through rock fractures [7].

One fundamental challenge in the measurement of IRPL signals is that the detection and excitation wavelengths are in close proximity to each other in the near infra-red domain. Appropriate filtering in combination with gating of the detection is required to minimise the signal contamination from the excitation light. The challenge, however, becomes severe in imaging where the CCD detectors cannot be operated fast enough in a pulsed mode. To find a solution to this measurement problem we investigate here on the applicability of green light sources (532 nm) for IRPL measurements. Kumar et al. [1] have recently reported that green light represents the ground state to the conduction band transition of the main dosimetric trap in feldspar. Thus, green light could in principle be used to measure the trap, while still retaining the important high sensitivity characteristic of IRPL. Our study focusses on the efficiency, bleachability, signal-to-noise ratio and the dose recovery potential of green light induced IRPL. We will present preliminary results obtained from a known-age sample.

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O.2-6: Does chemical weathering change luminescence of feldspar?

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Chemical weathering alters the chemical composition of mineral grains, and it follows that trapped charge dating signals of silicate minerals may also be progressively modified. In this study, we artificially weather three feldspar samples under different chemical conditions to understand the effect of feldspar partial dissolution on their luminescence properties. We conducted time-series experiments with five time points (0, 4, 96, 240, and 720 h) using two extracting solutions: (1) oxalic acid (pH 3, 20 °C), an organic acid with chelating abilities, and (2) aqua regia (pH <1, 40 °C), a mixture of strong acids creating aggressive acid hydrolysis conditions. These two solutions were chosen to approximate some of the changes, which may occur in weatherable minerals over long time scales under natural conditions.

We investigate (i) the concentration of solutes in the extracting solutions (ICP-OES), (ii) changes in feldspar surface morphology (SEM), and (iii) subsequent changes in feldspar luminescence in the UV (~340 nm) and blue (~400 nm) thermoluminescence (TL) and infrared stimulated luminescence (IRSL) emission bands. Time- and spatially-resolved luminescence analyses at the multi- and/or single-grain levels are carried out to gain insights into the dose response, saturation, anomalous fading, and thermal decay characteristics of the feldspars. In general, aqua regia has a larger effect on feldspar dissolution compared to that of oxalic acid. For both solutions, concentrations show only minor feldspar dissolution after 720 h with <5% of total Al, Si, Na, and Ca being extracted and passing into solution, while Mn and Fe were extracted by 5-8%. Our results show that TL and IRSL intensities change slightly with increasing weathering time, but that the feldspar luminescence properties are otherwise unmodified.

Keywords feldspar; chemical weathering; IRSL; TL

P.2-1: Athermal fading studies in thermoluminescence signal of 10 different K-feldspar samples; fading rate versus TL glow curve temperature analysis and correlation to structural state characteristics

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Athermal fading (hereafter AF) of thermoluminescence (TL) signals is the term adopted for the rapid decay of luminescence at room temperature, instead of the stability expected for it according to standard luminescence kinetic models. Even though athermal fading is a common malicious effect in all luminescence signals in feldspars, it has been extensively studied in reference materials such as Durango apatite from Mexico, a naturally occurring luminescent material that yields the effect intensely.

This paper reports an extended study of athermal fading in the TL signal of 10 different pure K-feldspar samples from North Greece. 9 different fading/storage times ranging from prompt measurements up to 50 days were applied. Athermal fading was found to be ubiquitous for the TL signal of all feldspars. The remnant signals are defined as the ratio of the TL signal remaining after storage time t, over the corresponding signal promptly measured at a given zero-time, t_0. Two different fading rates were calculated, namely the value of g-factor which describes the luminescence signal loss in terms of percentage per decade of time as well as the g_{50}-factor which describes the fading rate when the signal has been decreased by 50%.

Both aforementioned fading factors were calculated using a differential analysis over the entire TL glow curves in steps of 10 °C and were eventually plotted versus glow curve temperature; a similar approach has been previously presented by the same authors for the case of Durango apatite [1]. The analysis indicated that fading factors yield maximum values within the temperature range between 200 and 330 °C, with a tendency to decrease with increasing temperature along the rest glow curve. As the various K-feldspar samples of the present study belong to three different groups (microclines, sanidines and orthoclases), possible correlation is studied between the fading factors and specific structural parameters of alkali feldspars, such as the probability of Al-cation to occupy specific sites in the forming tetrahedra and the volume of the unit cell.

Keywords athermal fading; thermoluminescence; K-feldspars; fading rate.

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P.2-2: Further investigations on infrared-radiofluorescence (IR-RF) emissions

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Unlike in the commonly used optically stimulated luminescence dating methods, stimulating minerals with ionising radiation can also result in a luminescence signal. The radiofluorescence (RF) emission of K-feldspar centred at 865 nm is the basis of the infra-red RF (IR-RF) dating method [1]. This emission has been shown to yield a thermally stable signal bleachable in nature, which requires no correction for anomalous fading. Using a single aliquot regenerative dose (SAR) procedure measured at elevated temperatures [2], the signal displays a late-saturating dose response. Together with a recent approach to account for sensitivity changes [3], the method allows for relatively high equivalent doses in the kGy range to be determined, making this method particularly suitable for older samples.

Despite the recent improvements, some aspects still need to be addressed before this technique can be applied routinely [4]. More detailed work is required to characterise the bleaching and possible fading behaviour of different samples. More fundamental questions still include, for example, to what extent the dose response curve obtained in the laboratory corresponds to the natural one.

Further consideration also needs to be given to the emissions from neighbouring peaks emitted in the IR-RF of K-feldspar (e.g., at 710 and 910 nm), as presented here. Depending on the signal intensity proportions, these emissions could contaminate the targeted signal and need to be accounted for. Additionally, the neighbouring emissions can vary substantially with sample mineralogy, a factor often overlooked in dating of K-feldspar. A better understanding of the total IR-RF signal composition could help answer some of the open questions and pave the way for a more reliable dating procedure for Middle Pleistocene sediments.

Keywords luminescence dating; age range extension; feldspar; mineralogy; fading

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P.2-3: Thermally assisted-optically stimulated luminescence from deep electron traps in microcline

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Microcline ($KAlSi_3O_8$) is a naturally occurring K-rich mineral belonging to the feldspar family. Stimulated luminescence properties of microcline have mostly been studied using thermoluminescence (TL), optically stimulated luminescence (OSL) and infrared-photoluminescence (IR-PL). These methods stimulate electrons from shallow and intermediate-energy electron traps which are typically accessible up to 500 °C. There are a few other reports concerning phototransferred thermoluminescence (PTTL) which suggest the presence of deep electron traps beyond 500 °C in microcline [1]. However, in the literature direct experimental evidence of such deep electron traps is rare. Concerning this aspect, we report thermally-assisted optically stimulated luminescence (TA-OSL) of microcline collected from Sri Surya Pahar hill in Assam state, North-Eastern India (latitude: 26°6'31" N, longitude: 90°42'27" E).

To study the luminescence associated with deep electron traps in microcline, a beta-irradiated sample is first heated to 500 °C at 1 °C/s to deplete all electron traps accessible up to this temperature (see Fig. 1(a)). Thereafter, the sample is illuminated by 470 nm blue- or 870 nm infrared light at various temperatures between 30 and 300 °C and TA-OSL associated with deep electron traps is recorded. Experimental results confirm that the sample produces TA-OSL (Fig. 1(b)). The intensity of TA-OSL increases with the measurement temperature. The TA-OSL decay curves measured under both illuminations consist of two components. The intensity of TA-OSL measured by blue light is relatively higher than that measured under the infrared light. The activation energy of thermal assistance corresponding to optical stimulation by blue light is found to be 0.21±0.02 eV whereas that corresponding to the infrared light is 0.04±0.01 eV. Under both illuminations' conditions, the TA-OSL intensity shows sublinear growth in intensity between 100 and 1000 Gy. A fading study shows that the TA-OSL intensity measured by blue light illumination fades by 11% whereas that measured by the infrared light fades 27% in 43200 s. The results suggest that the luminescence associated with deep electron traps could be useful for natural dosimetry and dating.

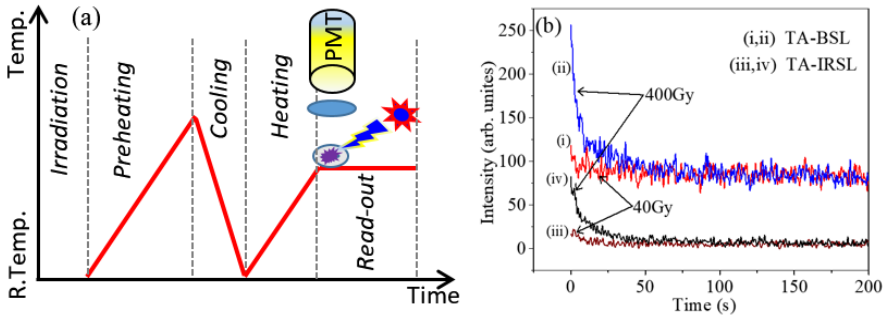

Fig. 1: (a) Experiment illustration, (b) TA-OSL decay curves measured at 300 °C

Keywords Microcline; Deep electron trap; Thermally-assisted optically stimulated luminescence (TA-OSL); Dose response; Fading.

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P.2-4: Further investigations into IR-RF and IR-PL

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K-feldspar as a dosimeter is receiving increasing attention because of its useful luminescence properties. In particular, the dose response curve of its infrared-stimulated luminescence signal extends to significantly higher doses than the optically stimulated luminescence signal of quartz, allowing us to date sedimentary deposits up to 500,000 years. Exciting new developments suggest that it may be possible to extend this age limit even further [1] using an infrared-radiofluorescence signal (IR-RF,[2]). However, uncertainty surrounding the upper age limit remains and further studies on known-age samples are required, which is the main objective of this work.

In the present study, a high sensitivity spectrometer was coupled to the Risø TL/OSL reader to measure IR-RF emission spectra of multigrain K-feldspar aliquots of known-age sediment and volcanic tuff samples. IR-RF spectra reveal at least five peaks centered at ~500nm, ~700nm, ~865nm, ~880nm and ~950nm and the magnitude of these peaks appears to be sample/dose dependent. We further investigated the effect of bleaching and preheat/measurement temperature on the peaks in order to better understand the dynamic range of the IR-RF signals and to evaluate the saturation level of the dose response curves. The results are compared with infrared photoluminescence (IR-PL) dose response curves obtained using a recently proposed protocol [3]. The potential correlation between the IR-RF and IR-PL signals and the chemical composition of individual K-feldspar grains will also be discussed.

Keywords K-feldspar, infrared-radiofluorescence, infrared photoluminescence, dose response curve.

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P.2-5: Imaging single grains of feldspar: luminescence variability and implications for dating

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A novel spatially-resolved attachment for the Risø luminescence reader based on that described by Duller et al. [1] is used to measure the infrared photoluminescence (IRPL) emitted by single grains of feldspar separated from geological sediments. Combined with the EMCCD imaging system designed by Kook et al [2], this system makes it possible to obtain measurements of TL, IRSL, pIR-IRSL and IRPL from the same grains, thus making it possible to explore the relationships between these signals for each grain.

Single grains of feldspar from a suite of samples from New Zealand with independent age control [3] are analysed. IRSL, pIR-IRSL and IRPL signals are used to determine equivalent dose, and the results compared. The relationships between different luminescence signals are explored, along with their response to different thermal treatments. Substantial variability in response to thermal pretreatment, and variability in D_0, are seen from one grain to another. Systematic patterns in the data are explored which could allow for improvements in the reproducibility of single grain feldspar analyses.

Keywords infrared photoluminescence IRPL; temperature dependence; dose response curve; New Zealand

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Session 3:
Advances in instrumentation and dose rate determination

Oral Presentations

	Presenter	Title
1	Chauhan Naveen	A Revised Protocol for Violet Stimulated Luminescence (VSL) Dating to Extend the Dating Range using Quartz
2	Neda Rahimzadeh	A comparative study of sand- and silt-sized quartz fractions for MAR-VSL dating using loess-palaeosol deposits in southern Germany
3	Michel Lamothe	Post-isothermal method for circumventing anomalous fading: testing the protocol for Holocene to Mid-Pleistocene well-dated sediments.
4	Helen M. Roberts	Determination of equivalent dose from mixed mineralogy samples without heating: implications for portable field instruments
5	Gwynlyn Reinette Buchanan	Testing the limits of infrared radioflourescence dating: investigating the bleaching duration and temperature parameters on the Luochuan Loess sequence, Chinese Loess
6	A. K. Singhvi	How robust are SAR single grain paleodoses: the role of sensitivity changes?

Poster Presentations

	Presenter	Title
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2	Maryam Heydari	Bayesian data analysis for spatially resolved luminescence measurements
3	Thomas Kolb	Testing the potential of a standardized growth curve approach for improving the reliability and applicability of fading correction
4	Tobias Lauer	Yellow stimulation of feldspar at low temperatures – testing a new dating approach
5	Elizabeth Chamberlain	A case against subtracting a laboratory residual dose for feldspar single-grain luminescence dating
6	Junjie Zhang	A simplified multiple-aliquot protocol to extend the dating limit of K-feldspar pIRIR signal to 600 ka
7	Andrew Ivester	An approach to test for IRSL full bleaching on deposition: The 3ET method
8	Nina Ataee	Isolating a VSL signal suitable for dating: investigating different thermal pretreatments and signal integration limits
9	Pontien Niyonzima	Testing the potential of quartz violet stimulated luminescence for dating of Brazilian fluvial sediments
10	Alicia Medialdea	VSL as a tool for extending the age range: suitability of the SAR protocol up to 400 Gy
11	Prachita Arora	Testing the applicability of VSL, TT-OSL and TT-VSL on modern sediments
12	Alan Cresswell	Quartz Age Extension Applied to SE Asian Cover Sands
13	Piotr Palczewski	SAR TM-OSL protocol - tests of the suitability of the technique for dating sediments
14	Shin Toyoda	ESR dating of sea-floor hydrothermal barite: use of the regenerative dose protocol
15	Verónica Guilarte	ESR dating of Quartz using different measurement temperatures: performance evaluation of different cryogenic systems based on He and N2 and their

		influence on dose
16	Amber Hood	The minimum extraction technique: an update on methodological developments
17	Maria Jesus Alonso	In which extent exothermic reactions during sample preparation may impact luminescence and ESR signals measured in quartz?
18	Gloria I. López	Heat and Cold Stress on OSL samples: A word of caution regarding field and lab extreme conditions
19	Atul Kumar Singh	A new and effective method for quartz-feldspar separation for OSL dating
20	Sam Woor	Improving the effectiveness of heavy liquid density separation in isolating K-feldspar grains using alluvial sediments from the Hajar Mountains, Oman
21	Konstantina Prevezanou	Implementation of expressions based on Lambert-W function in deconvolution and dose response phenomena using Python

O.3-1: A Revised Protocol for Violet Stimulated Luminescence (VSL) Dating to Extend the Dating Range using Quartz

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Quartz is considered to be most useful mineral for luminescence dating due to its stable and fast to bleach luminescence signal. However, the dating range using it is limited to 50-100 ka due to its low saturation doses (~200 Gy). Several signals of quartz such as TT-OSL, red luminescence have been explored but these suffer from issues of inheritance, bleachability, sensitivity changes and reproducibility. Recently the use of Violet Stimulated Luminescence (VSL) has been proposed and this was explored in the present study that tests the suggested protocol for measurement using VSL and characterized the VSL signal. The VSL curve component deconvolution was done to understand the changes in signal characteristics during violet light exposure. The results indicated that the components sensitivity is significantly affected by violet light exposure and thus suggested use of regenerative protocols is inappropriate. Additionally, the regenerative protocol had the saturation doses comparable to existing standard blue light-based OSL-SAR protocol, thus applicability of regenerative protocols is precluded.

Further, the work explores the applicability of additive dose protocols and optimized the parameters as preheat temperatures, irradiation dose and time duration for measurements. The protocol was successfully applied for geological samples with independent age controls and results are in agreement. Further the doses as high as 400 Gy, which is ~ 2 times the existing limit of SAR OSL doses were successfully estimated. The presentation will discuss the earlier protocols, their shortcomings, the new optimized protocol, optimization of parameters, aspects of sensitivity changes and the results.

Keywords: Quartz; Violet Stimulated Luminescence (VSL); Age Extension

Acknowledgement: HR and AKS acknowledges the DST-YOCP grant for supporting this work.

O.3-2: A comparative study of sand- and silt-sized quartz fractions for MAR-VSL dating using loess-palaeosol deposits in southern Germany

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Violet stimulated luminescence signal (VSL), which examines traps deeper than those accessible by the blue light, is believed to have the potential to extend the possible age range of quartz luminescence dating to the full Quaternary period. For sand-sized quartz, Ankjærgaard (2019) reported a good agreement between VSL ages and independent chronology up to ~900 ka for the loess-palaeosol sequence of the Luochuan section using the multiple aliquot regenerative dose (MAR) protocol [1]. However, a recent study on silt-sized quartz showed that the MAR standardised growth curve (SGC) from the same region (Luochuan section) can only reproduce the natural dose response curve (DRC) shape up to ~250 Gy, resulting in a significant age underestimation beyond ~100 ka [2]. They concluded that the different shapes of the natural and MAR DRCs caused this age underestimation and suggested that the linear growth of the laboratory generated MAR DRC in the high dose region could be a laboratory artefact, which does not exist in nature [2].

Several comparative studies on the quartz blue OSL signal for different grain size fractions revealed different growth patterns of DRC for different fractions, which also leads to age discrepancies [3]. Hitherto, there has not been any direct comparison between different grain size fractions from a same sample for the VSL signal. Therefore, the aim of this study is to assess the VSL dose response pattern using quartz with sand-sized (63-100 µm) and silt-sized (4-11 µm) grains. In addition, the natural signals of quartz samples are measured to construct semi-natural DRC for both fractions and compares it to the laboratory-generated DRC in order to test their similarity. Nine quartz samples of both fractions from a loess-palaeosol sequence in southern Germany were used for MAR VSL dating. All samples benefit from a good age control provided by reliable quartz OSL ages and fading corrected feldspar $pIRIR_{225}$ ages [4].

Our observation in VSL is similar to previous studies on the blue OSL signal; showing a lower D_e value and a higher characteristic saturation dose for the silt-sized fraction. For the younger deposits (<50 ka), the VSL ages for the sand-sized fraction are overestimated while the VSL ages of the silt-sized fraction are consistent with the reference ages. However, for the older sediments (>50-150 ka), both fractions give VSL ages consistent with the reference ages. The cause of the observed age discrepancy will be discussed.

Keywords VSL; MAR protocol; Quartz; Grain size; Loess

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O.3-3: Post-isothermal method for circumventing anomalous fading: testing the protocol for Holocene to Mid-Pleistocene sediments

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Anomalous fading (AF) is at the source of age underestimation commonly observed in optical dating of sediments when using feldspar luminescence. Post-isothermal laboratory induced luminescence (pIt-IR) has been recently shown to be a promising approach to circumvent this issue. The pIt-IR protocol probes easily bleachable traps and therefore measures an equivalent dose (D_e) that is not dependent on time elapsed since irradiation, hence the argument about its capability to circumvent AF. In the pIt procedure, one measures two IRSL signals, first from an IR stimulation at low temperature (i.e. IR_{50}) followed by a second one, at a higher temperature (i.e. IR_{225}). The concept is to measure two signals that fade at different rates, followed by a succession of thermal treatments carried out before the measurement of the laboratory-induced IR_{50}/IR_{225} luminescence. One thus determines which thermal treatment shall yield the same D_e for both signals. It is argued that this D_e is the true total radiation dose received by the feldspar minerals in nature, more properly known as the palaeodose (P). In the case of well-bleached samples, this methodology yields ages that mostly agree with their stratigraphic constraints, even though the low temperature IR_{50} signal may still exhibit considerable fading.

The pIt-IR protocol has been tested and mostly validated for a series of well-dated sediment samples, ranging from Early Holocene to the Mid-Pleistocene. These samples are from sedimentary sequences of variable facies and from geological terrains of various age and nature. The available experimental data reveal that the main limitation to the application of the pIt-IR methodology resides in the overlooked higher luminescence residual for the pIt-IR_{225} component at deposition. This residual remains in the dated trap during geological time and may induce an unwanted overshoot in the amplitude of the paleodose reached in the environment, and a consequent age overestimation. Nevertheless, this issue is mostly limiting the potential of the pIt-IR method for dating Late Pleistocene to Holocene samples for which the level of residual may represent half of the pIt-IR_{225} component in the natural luminescence signal. Laboratory measurements of modern samples from marine, eolian, fluvial, lacustrine and glaciofluvial samples allow assessing the amplitude of this issue for stratigraphically older samples, up to at least 225 ka.

Keywords Anomalous fading, K-feldspars, sediments, Post-isothermal luminescence, residual, age overestimation.

O.3-4: Determination of equivalent dose from mixed mineralogy samples without heating: implications for portable field instruments

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There is a growing interest in the use of portable instruments for the measurement of luminescence signals directly in (or near) the field, and such instruments have been involved in a variety of applcations [1]. Incorporation of an ionising radiation source would provide the opportunity for in situ calibration of the luminescence signals from such field instruments, and hence potentially also for rapid field determination of equivalent dose (D_e). In a laboratory setting, samples are typically given a thermal treatment following exposure to ionising radiation, to remove thermally-unstable charge prior to measurement of the luminescence signal(s). However, in a field instrument the capacity for such heating is technically challenging, particularly if reproducible heating is desired for samples taken directly from the field. For this reason, measurement protocols for the determination of D_e in the field may need to take place at ambient temperature, without heating.

Furthermore, measurements in the field would be made using unprepared, mixed-mineralogy grains. A number of measurement protocols designed to separate the signals from quartz and feldspar have previously been proposed [e.g. 2, 3, 4], but for a field instrument such measurements would need to be deployed at ambient temperature. This paper builds upon previous work which examined strategies for the determination of D_e from unheated quartz separates [5, 6], by assessing the determination of D_e from unprepared, mixed-mineralogy grains without heating. Measurements are made within the laboratory, but the findings have implications for the design and deployment of portable field instruments.

Keywords quartz feldspar polymineral; OSL; IRSL; infrared photoluminescence IRPL; unheated sediment

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O.3-5: Testing the limits of infrared radioflourescence dating: investigating the bleaching duration and temperature parameters on the Luochuan Loess sequence, Chinese Loess Plateau

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The Luochuan loess-palaeosol sequence on the Chinese Loess Plateau is a well-documented sequence spanning over 2 Ma, that has served as a proving ground for many trapped charge dating techniques for example: post-infrared infrared stimulated luminescence (pIRIR) [1], electron spin resonance (ESR) [2] and violet stimulated luminescence (VSL) [3]. This study evaluates the infrared radioflourescence (IR-RF) signal from course grained feldspar on 10 samples from the loess-palaeosol sequence with depositional ages ranging from~25 ka to~900 ka [4]. Initial work tested 6 samples using the RF_{70} protocol [5] with a bleaching duration of 1500s using UV-LEDs, which resulted in consistent and significant underestimation across all but the youngest sample. The bleaching duration between the natural and regenerated IR-RF measurements was increased to 20,000 s and tested on 10 samples. The 5 samples younger than 300 ka (~1250 Gy) were consistent with the independent ages while the samples older than 300 ka once again significantly underestimated the ages. Natural and laboratory dose response curves were constructed, and they revealed significantly different curves in the case of the shorter bleaching duration, but consistent curves in the case of the longer bleaching duration. In an attempt to extend the dateable range of RF_{70} on this sequence, based on one sample older than 300 ka, measurements were done at a range of preheat and measurement temperatures from 40 °C to 200 °C. The intensity normalised regenerated curves trend toward the natural dose response curve shape with increased temperature and become consistent with it at 200 °C. However, the D_e results at these temperatures continue to underestimate the ages significantly, suggesting that the samples older than 300 ka may be in saturation.

Keywords: Infrared Radioflourescence; bleaching; temperature; Loess; Luochuan.

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O.3-6: How robust are SAR single grain paleodoses: the role of sensitivity changes ?

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During 2011, a refinement in the most used SAR protocol was proposed to account for sensitivity changes during the preheat and recording of natural OSL signal [1]. This study demonstrated that significant sensitivity changes occur during the preheat and read out of natural OSL and these are not accounted for in the currently used SAR protocol. These unaccounted for sensitivity changes lead to a systematic offset in ages and a larger dispersion in paleo-dose. Based on the general observation that the OSL signal is correlated to 110°C TL glow peak of quartz, a natural correction factor (NCF), which is the ratio of a laboratory dose induced, 110˚C TL peak of sample, as received and after preheat and OSL read out was developed. It's use led to reduced dispersion and generally lower paleodose values. It also helped deal with the samples with natural signal well above the regenerated growth curves.

As a logical corollary, sensitivity changes in single grains (SG) OSL were examined [2]. As anticipated, large sensitivity changes were seen, implying that SG-SAR ages suffer similarly from unaccounted-for sensitivity changes and that at least some, if not all of the SG ages would need a revision. In general, the brighter grains had an NCF closer to unity compared to dull grains. This study examined the possible use of a sensitivity filter that could serve as a routine criterion for the use of single grain measurement. Analysis of SG paleodoses based on their signal-to-noise ratio (S/N=R) for R >3, R >10, R >50 and R >100 suggested large variations and implied that currently produced SAR-SG ages may not always be correct. Comparison of paleodoses with different R with control samples suggest that SG paleodoses with R >100 may perhaps be more appropriate for dating.[3]. The results and implications for routine SG dating will be discussed.

This study was supported by DST-Science and Engineering Research Board Year of Science Chair Professorship to AKS.

Keywords Optically Stimulated Luminescence; Thermoluminescence; Quartz; Single grain dating; Sensitivity change

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P.3-1: Can we automate TL MAAD analysis?

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In the context of our work on the application of the Bayesian approach to luminescence dating, we are interested in the relationship between the equivalent dose (De) and the luminescence measurements. Can a numerical simulation be enough to obtain an equivalent dose from luminescence measurements without requiring human choices? In the present communication, we are focusing on the multiple aliquot additive dose (MAAD) TL. The investigation of MAAD protocol is more complex than SAR OSL. The number of assumptions involved (determination of the plateau, choice of normalization, comparing the first-glow and second-glow growth curves, ...) is important. The basic model imposes: correction by normalization; linearity; plateau.

Several approaches can be proposed.
1 - channel by channel approach
The idea is to measure the De for each channel based on the method used in SAR-OSL. This type of modelling is not satisfactory from the point of view of the processing time or the choice of parameters (in particular the plateau).

2-approach by defining the plateau
This idea has been proposed in [1]. The plateau bounds [Ti, Tf] are taken as variables. Tf is sampled from a uniform distribution between 250 °C and 550 °C, then draw Ti from a uniform distribution between 250 °C and T2. After defining Ti and Tf, the other variables are taken as integrating between these two bounds. Convergence should tend to values of Ti and Tf corresponding to the plateau. This model works for cases without normalization, but still causes problems when normalization is introduced (simulation under WinBugs)

3- slice sampling approach
We therefore sought to develop a new approach based on the Slice sampling method [2]. This type of sampler is already applied for optimizing OSL age models [3]. In this case, we use it to select temperature. Each TL glow curve represents a temperature distribution for a given disk. The Slice sampler defines a common domain (slice) for all these curves and a temperature included in the slice is drawn. The selected temperature is then introduced in a larger model in order to estimate the linear growth curve whose other parameters are selected according to a Gibbs sampler [4].

Keywords MAAD TL; numerical simulation; Slice sampling

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P.3-2: Bayesian data analysis for spatially resolved luminescence measurements

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Developing statistical models in luminescence dating using Bayesian inference is rather forward-thinking. Bayesian inference has become popular for data analysis because of its dynamic performance, processing all parameters simultaneously instead of analysing them separately. Notably, in the hierarchical Bayesian model, the outcome is a consequence of the interaction between the measured data and every estimated parameter. Thus, the Bayesian output is believed to be more consistent with the original data. Over the past decade, several Bayesian models have been proposed to improve the precision and accuracy of the dose estimate for natural minerals (grains) using multi-grain or single grain measurements.

Spatially resolved measurements offer several advantages over conventional single grain measurement (e.g., unravelling the micro-dosimetry issue and allowing for applications of a broader range of signal measurement protocols with various stimulation and detection spectra [1,2,3]). Unfortunately, unwanted light contributions from surrounding grains to each individual grain (optical crosstalk), cannot be fully negated by increasing distance [1,2,3] and it is the main drawback hampering a broad application. In addition, unstable background signal can give rise to an additional source of uncertainty which needs to be verified and subtracted from the obtained grains' signal. Recently a Bayesian approach was proposed to tackle optical crosstalk in spatially resolved measurements through an imaging system [1]. Our contribution advances from there.

In this study, we attempt to employ the Bayesian inference to minimise the impact of unstable signal background and optical crosstalk. We first determine a set of reliable prior distributions which can sufficiently describe the contribution of light originating from the background and the surrounding grains to the signal of individual grains. The likelihood function containing the measurement data after exporting to the single curve data also will be estimated. This model will be first applied to a dose-recovery experiment using calibration quartz to evaluate the validity of selected prior distributions. In a final step, we apply the model to natural samples to estimate the natural dose for individual grains.

Keywords Bayesian modelling; Spatially resolved measurements; EM-CCD imaging; Optical crosstalk

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P.3-3: Testing the potential of a standardized growth curve approach for improving the reliability and applicability of fading correction

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Following a general trend in palaeo-environmental research, a considerable and still growing number of luminescence dating studies have been focussing on sediment archives providing information on environmental conditions far beyond the last glacial-interglacial cycle. This trend caused a revival of feldspar minerals as dosimeters. As a consequence, the long-known but still poorly understood problem of anomalous fading and various correction methods are gaining increasing importance. In order to cope with the challenge of anomalous fading, several new measurement protocols aiming at reducing or completely avoiding fading were proposed. However, these approaches are either still experimental (IR-RF), have only been applied to a limited number of natural samples (pIT-IR) or are the subjects of still ongoing scientific discussions on how the obtained results have to be interpreted (pIR-IR).

After all, anomalous fading remains a severe problem for feldspar-based luminescence measurements, and fading correction will thus be of crucial importance for reliable age calculations. However, determining fading rates is time-consuming. Moreover, some of the proposed correction methods [1, 2] require fully-constructed dose response curves (DRCs) to accurately constrain D_0- and saturation values, which is indispensable for mathematically accurate corrections. Recording such DRCs requires the consideration of high-dose points for a large number of aliquots, corresponding to long-lasting measurement times that can hardly be realized in routine dating applications.

The L_nT_n method proposed by [3] might provide a promising solution for this problem. Based on the standardized growth curve (SGC) approach, the weighted mean of re-normalised L_n/T_n values is projected onto a SGC to estimate the final D_e of a sample. Since only a limited number of fully-recorded DRCs are required for constructing the SGC, this approach might offer the possibility of applying fading correction procedures to large numbers of aliquots using sample- or site-specific SGCs. Here, we present results obtained from a comprehensive study assessing the potential of improving the reliability and practical implementation of SGC-based fading correction procedures. Our performance test includes different measurement protocols which were applied to various natural samples covering different sedimentary environments and revealing a variety of fading rates.

Keywords
Fading correction; standardized growth curve (SGC); L_nT_n method; performance test

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P.3-4: Yellow stimulation of feldspar at low temperatures – testing a new dating approach

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Dating methods are crucial to study the timing of past shifts in climate and palaeoenvironment including their influence on early human dispersal. Terrestrial sediment archives play also a key role to decipher human-environmental interactions. Luminescence dating is often used to establish chronological frameworks for terrestrial sediment archives and so called pIRIR protocols, in which the feldspar signal is stimulated at elevated temperatures after depleting the IR50 signal, are mostly applied to date sediments yielding an already saturated or generally problematic quartz luminescence signal. These elevated temperature measurements often show no or negligible fading but dose residuals can be problematic and lead to age overestimation what is especially relevant for Holocene or Upper Pleistocene sediments. Ongoing research is now testing the potential of a post-IR yellow stimulated feldspar signal [1], now measured at low temperatures to overcome the problem of dose residuals. First studies on the approach, in which a yellow stimulated feldspar signal is measured at 50°C following an IR-bleach (named hereafter pIR-YOSL), show that the pIR-YOSL approach seems very promising to date Quaternary sediments.

The new approach was already tested on various samples for which age control is available spanning from modern to Middle-Pleistocene age and here, these first results are presented on a poster dealing with dose response, saturation and bleachability of the pIR-YOSL signal.

Keywords yellow stimulated luminescence; low temperature

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P.3-5: A case against subtracting a laboratory residual dose for feldspar single-grain luminescence dating

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Evaluating the degree of signal resetting is critical for luminescence dating of Holocene-aged deposits. This is particularly important for slow-to-bleach feldspar post-infrared infrared stimulated luminescence (pIRIR) signals which may not be completely zeroed in nature, even by full sunlight exposure. It is common practice to test the degree to which pIRIR signals can be zeroed through laboratory bleaching in a solar simulator providing high-intensity light exposure at rates of 5-6 times natural sunlight. Such tests quantify 'unbleachable' laboratory residual doses which may be subtracted from modeled equivalent doses for paleodose estimation. Yet, the mechanism yielding unbleachable residual doses is unclear. This phenomenon is hypothesized to link to retrapping of liberated charge spurred by the high-energy part of the light spectrum that exists in nature and may be enhanced in laboratory sources [1,2].

We conducted an experiment to test the degree of pIRIR-150 signal bleaching accomplished by laboratory versus natural-sunlight stimulation. The experiment was performed on a late-Holocene-aged (~1.2 ka) glaciofluvial sample of 180-250 µm feldspar sand (paleodose = 5.97 ± 1.41 Gy) from the Northern Patagonian Ice Field, Chile. Prior work determined a low-temperature single-grain feldspar (pIRIR-150) protocol showed negligible-to-no fading and, combined with a minimum age model, was optimal for dating these deposits. We exposed one fraction of the sample in a SOL2 simulator for 24 hours and exposed another fraction to natural sunlight conditions for 115 hours in a rural outdoor environment, free of artificial light and sheltered from wind, in Wisconsin, USA. These two conditions provide comparable bleaching opportunities yet under different intensities and likely somewhat different spectra. We then measured the remaining post-exposure doses of the two fractions using the pIRIR-150 single-grain protocol. Results showed that sunlight was more effective than the SOL2 in resetting the pIRIR-150 signal although neither method completely reset all grains. An arithmetic mean of the single-grain equivalent doses yielded values of 2.18 ± 0.10 Gy for the laboratory-bleached fraction and 1.71 ± 0.08 Gy for the sunlight-bleached fraction. Yet, some grains of both fractions were completely zeroed. The unlogged minimum age model returned values of 0.66 ± 0.10 Gy for the laboratory-bleached fraction and 0.10 ± 0.14 Gy for the sunlight-bleached fraction indicating that enough grains can be reset in nature to obtain an accurate paleodose without subtraction of a laboratory residual. In all, these results suggest that some feldspar grains may be predisposed to bleach more completely than others and high-intensity laboratory stimulation aiming to mimic sunlight is not a suitable substitute for determining the bleachability of grains under natural conditions. We infer that minimum age models applied to single-grain pIRIR datasets preferentially weight not only the grains that received the most sunlight exposure prior to deposition, but also those most readily reset. Based on our results, we strongly advise against subtracting laboratory residual doses from young heterogeneously bleached sediments.

Keywords Bleaching, Holocene, pIRIR, Residual dose, Solar simulator

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P.3-6: A simplified multiple-aliquot protocol to extend the dating limit of K-feldspar pIRIR signal to 600 ka

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The post-infrared infrared stimulated luminescence signal (pIRIR) from K-feldspar shows significantly less athermal fading than the conventional IRSL signal [1], thus it has been widely used for dating Quaternary deposits. With the single-aliquot regenerative-dose (SAR) protocol, the characteristic saturation dose (D_0) of the pIRIR signal increases with the size of test dose, and it is mostly in the range of 200-500 Gy [2], which makes the pIRIR dating protocol only applicable to samples with equivalent doses (D_es) up to 1000 Gy. Li et al. (2013) demonstrated that these relatively small D_0 values were due to the pre-dose effect in the SAR protocol, and proposed a multiple-aliquot regenerative-dose (MAR) protocol, applying a high-temperature heating treatment between the regenerative dose and test dose to remove the effect; the D_0 increased to ~ 800 Gy [3].

In this study, we propose a simplified MAR protocol, applying the 80-180 °C thermoluminescence (TL) response to a small dose (~ 5 Gy) for normalization between aliquots. The low-temperature TL signals were measured both before (TL1) and after (TL2) the natural signal (L_n) or regenerative-dose signal (L_x) measurements. Two coarse-grain (63-100 µm) K-feldspar samples from units L2 and L4 (with expected D_es of 450±50 Gy and 1340±150 Gy, respectively) from the Chinese Loess Plateau were tested with the multi-elevated-temperature (MET) pIRIR protocol using signals up to 290 °C. With the SAR protocol, the D_e of the MET-pIRIR$_{290}$ signal from the younger sample was 413±14 Gy, consistent with the expected D_e; while the D_e of the older sample was 942±58 Gy, which was significantly underestimated. With the MAR protocol, the D_es of the two samples were 440±41 Gy and 1321±105 Gy respectively when the TL2 was applied for normalization, consistent with the expected D_es. However, the MAR D_es were significantly underestimated when applying the TL1 normalization. Mass normalization showed that the bleached aliquots used to build the dose response curve had lower sensitivity in the TL1 compared to the natural aliquots. However, after the measurements of L_n or L_x, all the aliquots showed an identical sensitivity in the TL2, with no pre-dose effect. Polymineral fine grains (4-11 µm) were tested with this MAR protocol, but it was not successful, as the 80-180 °C TL signal has a contribution from quartz, which has a significant pre-dose effect.

With this TL normalization method, the D_0 values of all pIRIR signals at different stimulation temperatures are 850-1000 Gy, having the potential to date samples with D_e values up to 2000 Gy (i.e. ages up to 600 ka).

Keywords: K-feldspar; pIRIR; multiple-aliquot; TL normalization

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P.3-7: An approach to test for IRSL full bleaching on deposition: The 3ET method

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Feldspar pIRIR age estimates can be adversely affected by incomplete bleaching, making the most recent depositional event difficult to identify with certainty. In standard single grain pIRIR protocols, depositional events are often defined by consistent modes or minima in De distributions. However, such an approach may assume that the contributing grains are fully bleached; in some situations, the resulting age estimate might not accurately reflect a true depositional event. A new protocol offers an additional way to assess the completeness of bleaching of a grain by testing patterns of consistent De values measured at three elevated temperatures (3ET). Measurements at increasing temperatures (50, 125, and 225 ^{o}C) isolate signals from traps progressively more difficult to bleach. Consistent De estimates at any two IRSL measurement temperatures, or at all three, suggest a single bleaching event of sufficient duration to fully depopulate the traps involved. Incompletely bleached grains with inconsistent De values across temperatures will lack a 3ET "plateau" and can be filtered out of the analysis. The resulting subset of fully bleached grains can more reliably suggest true depositional ages, subject to assessment of fading.

To expedite processing of the large data sets produced by the 3ET protocol, we developed code using Python along with open-source software packages for data analysis and visualization. In a Jupyter Notebook environment we used pandas data analysis library and Plotly graphing package to apply the 3ET filter and to render the resulting data in interactive visualizations. These graphics can be output as HTML and posted on the web to enable data exploration. Examples of interactive visualizations of 3ET datasets demonstrate a range of capabilities of these software utilities.

Using this approach, the 3ET protocol was tested on a sequence of stepped fluvial terraces in the Kekerengu region of New Zealand as part of a larger project to reconstruct regional seismic history. Where standard pIRIR apparent ages are somewhat inconsistent or ambiguous, 3ET age estimates produce generally consistent apparent ages both within and across terraces. These initial results suggest that the 3ET method can be useful in situations where standard pIRIR apparent ages are adversely affected by incomplete bleaching.

Keywords pIR-IRSL; 3ET; bleaching; data visualization; Python.

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P.3-8: Isolating a VSL signal suitable for dating: investigating different thermal pretreatments and signal integration limits

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Violet stimulated luminescence (VSL) is one of a number of novel luminescence signals with the potential for extending the dose range for dating quartz. The signal was first described by Jain in 2009 [1] and has since been investigated in a number of papers, but our understanding of its origin and behaviour remains unclear [e.g. 2, 3].

This study has two parts. First, we use a single quartz sample from Zambia to explore in detail the variability in the form of the VSL decay curve after different thermal pretreatments. The most appropriate thermal pretreatment is identified as that which minimizes the contribution of OSL components to the VSL signal. Using the selected preheat conditions, we investigate the VSL dose response curve and the variability in the calculated D_e value (or the recovered dose in dose recovery experiments) when integrating different parts of the VSL signal. For dose recovery, unheated discs prepared from a sample with a coarse grain quartz OSL D_e of 1.34 ± 0.05 Gy [4] were bleached in the SOL2 solar simulator before being given a laboratory beta dose to recover. Five different given doses (15, 100, 400, 1600, 3200 Gy) were recovered using three aliquots for each set of measurements. The success of the dose recovery experiments varied from one aliquot to another depending upon the part of the signal that we integrated for constructing our dose response curve; however, by avoiding the rapidly decaying early part of the VSL signal it was possible to obtain good dose recovery ratios within uncertainties of unity for doses greater than 15 Gy.

In the second part, we used the knowledge gained from the detailed analysis of the sample from Zambia to assess the VSL characteristics of other samples, including those from other regions, and samples with different ratios of OSL signal components.

Keywords VSL; dose recovery; D_e; signal integration limits; preheat.

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P.3-9: Testing the potential of quartz violet stimulated luminescence for dating of Brazilian fluvial sediments

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Brazil hosts widespread fluvial quartz-rich deposits recording landscape changes during the Quaternary. The optically stimulated luminescence (OSL) techniques have been applied to determine sediment deposition ages, but they are not suitable to obtain ages beyond the late Pleistocene (100-200 ka) and potassium feldspar is lacking in most deposits due to intense weathering. In the present study, we investigated the post-blue violet stimulated luminescence (VSL) signals of quartz from fluvial terraces from Pantanal wetland (Western Brazil), Paraná River basin (Southeastern Brazil) and Amazon River basin (central and eastern Amazonia). These samples are representative of major fluvial systems of Brazil with expected equivalent doses (D_e) ranging between 14 Gy to 868 Gy. Under preheat temperatures in the 200-340°C range and blue stimulation at 125°C, the natural VSL signal is absent in all samples, including samples with D_e beyond OSL saturation. The natural VSL signal appears in some samples when a lower preheat at 160°C is used, indicating that possibly the VSL signal in the studied samples is unstable over geological time scales. We estimated equivalent dose (D_e) and two characteristic doses ($D_{0,1}$, $D_{0,2}$) of samples that showed natural VSL signal using a single aliquot regenerative dose (SAR) protocol and multiple aliquot additive doses (MAAD) and multiple aliquot regenerative doses (MARD) protocols. For a well bleached sample from Paraná River basin, with OSL D_e = 14.0 ± 0.3 Gy and characteristic dose of the second exponential function ($D_{0,2}$) = 146.4 ± 13.9 Gy, the VSL SAR protocol estimated D_e = 44.30 ± 2.80 Gy for regenerative doses in the range of 500–2500 Gy when the dose response curve (DRC) is fitted with exponential plus linear function. Basic assumptions of the single aliquot regenerative dose (SAR) protocol, recycling ratio and recuperation were tested. The VSL SAR protocol poorly recovered a large (500 Gy) laboratory dose, with the mean values for the calculated-to-given dose ratio between 0.6 and 1.8. This poor behavior indicates that VSL SAR poorly reproduces the natural dose growth. The SAR VSL signal exhibits DRC with characteristic dose (D_0) about ~ 104 Gy, which is relatively low compared to previous works (e.g. Ankjaergaard *et al*., 2016; Ankjaergaard, 2019). Applying MAAD protocol on the same sample, characteristic dose ($D_{0,2}$) of ~805 Gy was estimated when the (DRC) is fitted with the double exponential functions, also lower than the value of D_0 value reported from Chinese loess samples ($D_{0,2}$ = 1334 Gy) (Ankjaergaard *et al*., 2016). The present study also shows that the behavior of VSL signal appears to be sample dependent, indicating the need for further investigations on behavior of VSL signals of samples from different depositional systems.

Keywords: Violet Luminescence Dating; Natural dose response curve; Multiple Aliquots Additive Dose; Fluvial sediments; Quartz.

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P.3-10: VSL as a tool for extending the age range: suitability of the SAR protocol up to 400 Gy

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The Optically luminescence dating (OSL) plays a key role in understanding landscape evolution by providing the necessary chronology to define long term patterns. With this aim, extending the age range covered by this technique has been one of the main focuses in method development over the past years. Promising results in this respect have been observed when using violet stimulation instead of the standard blue or green for dating sedimentary material [1]. Despite the great potential of violet stimulated luminescence (VSL), which forces a luminescence response from quartz that saturates at higher doses than conventional OSL [2], VSL still shows the difficulties for defining a reliable dose response curve in the high dose range (>500 Gy) using the well-stablished SAR protocol.

In this study we apply VSL to study the tectonic activity in south-east Spain, dating a suite of samples with burial ages up to 300 ka (400 Gy). Attempts to use conventional OSL on this material showed that all measured natural doses were above the saturation of the SAR-defined dose response curve. In contrast, the VSL response of these samples saturates beyond the burial doses. The suitability of the protocol has been tested by measuring artificially given doses in the range of interest. The SAR measurements allow the recovery of the given doses and conclude that the measured burial doses in that same range are reliable. VSL therefore, makes it possible to accurately date this suite of sediments which could not be dated with conventional methods.

Although it was not necessary for the purposes of dating these specific samples, the response to higher doses has also been studied. The previously reported tendency to underestimation of the natural (or artificially given) dose when applying the SAR protocol in the the high dose region (>500 Gy) [1] has also been observed in this case. The behaviour of different measurement protocols has been studied.

Keywords:
Violet stimulated luminescence (VSL); extended age range; SAR protocol; high doses.

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P.3-11: Testing the applicability of VSL, TT-OSL and TT-VSL on modern sediments

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To establish an absolute chronology for the Quaternary terrestrial sediments, the fast component dominant OSL has proven to be a reliable method. The upper limit of which is defined by its saturation dose beyond which the luminescence signal does not increase with burial time. In order to extend the upper age range of quartz luminescence dating technique, various methods (e. g., VSL: Violet Stimulated Luminescence; ITL: Isothermal Thermoluminescence; RTL: Red Thermoluminescence; and TT-OLS: Thermally Transferred Optically Stimulated Luminescence) have been employed. Of these methods VSL and TT-OSL methods have already been useful in dating older sediments and their application for the modern sediments is still an ongoing research.

Towards this the present study is an attempt to use VSL (Violet stimulated luminescence) and TT-OSL (thermally transferred optically stimulated luminescence) for dating beach ridge sediments from the Godavari-Krishna basin. Along with these two signals, we also attempted a new signal i.e., thermally transferred violet stimulated luminescence (TT-VSL) after its characterization. These methods is believed to measure the luminescence from a deeper electron trap in quartz which is not accessible to the blue light, thus understanding of the source of these traps becomes important as well. For the present work, dose response curves of VSL, TT-OSL and TT-VSL have been measured using the SAR protocol. It is known that the trapping probability is increased due to harsh heating pretreatments and hence the usage of multiple aliquots method has been proposed [1,2]. In this study we observed that natural sensitivity correction factor (NCF = TL_1/TL_2) varies up to 0.6 where TL_1 and TL_2 are the thermoluminescence signals before and after the first thermo-optical (violet) treatment on the sample [3]. The observed increase in the sensitivity (~35%) of samples due to the first measurement can be corrected using NCF and thus enable us to work within SAR framework.

Keywords: Quartz; VSL; TT-VSL; TT-OSL; Beach ridges

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P.3-12: Quartz Age Extension Applied to SE Asian Cover Sands

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A significant feature of the soils of southeast Asia is a regionally extensive layer of generally sandy material, in some places 5m or more in depth. These distinctive red, quartz rich, cover sands are observed throughout Vietnam, Cambodia, Laos and Thailand, and also reported from upland areas of Myanmar and Malaysia, and even the Punjab. The origin of these sands is unclear, with explanations including late Pleistocene to Holocene aeolian (loess-like) deposits, marine or lacustrine sediments, and degradation of termite mounds. In many locations, these cover sands immediately overlay a tektite containing laterite layer. These tektites, known as the Muong Nong type, are associated with a large meteorite impact between 750 to 800ka in Indochina, within the border area between Thailand, Laos and Cambodia or the coastal waters of Vietnam. Sections of these cover sands at sites in Thailand, Laos and Vietnam have been investigated using field and laboratory profiling, and quartz SAR procedures. In some locations the sections consist of a layer of low sensitivity quartz with saturated signals overlain by a visibly indistinguishable layer of high sensitivity quartz with ages less than 35ka. Elsewhere, only the high sensitivity quartz is present, with age progression between ~10 and ~35ka, interpreted as consistent with aeolian deposition.

Further work has been undertaken to attempt to extend quartz luminescence dating for the older materials using Thermally Transferred Optically Stimulated Luminescence (TT-OSL) to access deeper traps that are expected to saturate at higher doses. Luminescence was recorded during sample heating and hold, giving thermoluminescence (TL) and isothermal decay (ID) data probing the transfer of charge from deep to shallow traps, in addition to TT-OSL measurements. These measurements have produced equivalent dose values of upto 300Gy, and ages of 100-150ka, for these older materials. The possibility that the associated traps may not be stable at environmental temperatures above 25°C is discussed.

Keywords Thermally Transferred Optically Stimulated Luminescence; Thermoluminescence; Isothermal Decay

P.3-13: SAR TM-OSL protocol - tests of the suitability of the technique for dating sediments

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The OSL measurement method based on optical stimulation while the sample is heated was used in the SAR procedure using quartz. The modified procedure was called SAR TM-OSL. The first encouraging results from using this protocol have been presented previously [1]. Here we demonstrate the usefulness of the new approach for a more significant sample set. Sediments used in the investigation are of different age and originate from various places in Poland (Pomeranian Lake District, Polish Plain, Upper Silesia and Silesian Lowlands). One part of them is eolian, and the other fluvial sediments. Values of equivalent doses obtained by the newly proposed protocol are compared with results of SAR protocol with blue diodes and another protocol using the light with a wavelength of 620 nm, also used in SAR TM-OSL.

The TM-OSL method was invented to separate the individual OSL components better. This method exploits the dynamic dependence of the optical cross-section on the temperature in the stimulation energies below the ionization threshold of a trap. The method allows obtaining the OSL curve in the form of a peak when measurement parameters: the stimulation energy, the heating rate and the photon flux density are appropriately selected for the trap to be optically emptied [2]. It was established that the favourable to stimulate the fast component selectively is the red light with a wavelength of 620 nm [3]. In SAR TM-OSL, the TM-OSL measurement with red light carried out from room temperature to 120 °C replaces the usual CW-OSL measurement with the blue light. The OSL signal reset is done during the stimulation with blue light in the temperature range from 120 °C to 200 °C.

When the red light is enough to stimulate the fast component in quartz, the question arises whether one can use the red light in a regular SAR measurement instead of blue light and thus determine the age based on the separated fast OSL component. As a result of preliminary studies, the conditions for performing such measurements were established, which led to correct results of the recuperation, the recycling and, first of all, the recovery tests for the calibration quartz sample. The protocol established in this way was also used to determine the equivalent dose for the investigated sediment samples. We will compare these results with the results obtained for the other two methods.
Acknowledgements: This work was supported by the National Science Centre, Poland, no. (2016/21/B/ST10/01867)

Keywords Sediment dating; Quartz, Thermally modulated OSL

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P.3-14: ESR dating of sea-floor hydrothermal barite: use of the regenerative dose protocol

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Barite ($BaSO_4$), one of sulfate minerals being common in areas of se-floor hydrothermal activities, is formed with a chemical reaction of barium ion (Ba^+) contained in hydrothermal fluid with sulfate ion (SO_4^{2-}) in the sea water. While it had been pointed out that the electron spin resonance (ESR) signal in barite might be used for ESR dating [1], it was shown that the SO_3^- signal is practically useful for dating of barite by sea-floor hydrothermal activities [2]. Conventionally, ESR dating of barite employs the additive dose method, where gamma ray irradiation enhances the signal intensities. The dose response is then extrapolated to the zero ordinate to find the equivalent dose given by natural radiation. In the additive dose protocol, the signal intensity increases significantly in younger samples, while the signal is almost saturated in older samples where the fitted saturating exponential curve would have less reliability, i.e., it may be questionable whether the equivalent dose is correctly calculated. In the present study, we tried the regenerative protocol for barite, which, in principle, has smaller errors and higher accuracy in obtaining the equivalent dose as the equivalent dose is estimated by interpolating the observed dose response. However, in this case, it is necessary show the protocol to erase the signal (such as heating) does not change the property in dose response (such as the sensitivity).

Barite crystals extracted from chimney samples at the Iheya, Gondo, Yoron site in the Okinawa Trough were heated at temperatures, 380-600 °C to erase the signal, and then gamma ray irradiation was performed at Takasaki Research Institute of Japanese Atomic Energy Agency. After that, ESR measurement was performed at room temperature with an ESR spectrometer (JEOL PX-2300) at Okayama University of Science Technology Center.

As a result, the initial sensitivity in the dose response, i.e., the slopes of the dose response line in the low dose region do not change with heating temperature except at 600 °C while the signal saturating level at the high dose region decrease above 420°C. The erasing temperature is one of the important factors in finding the appropriate regenerative dose protocol. The equivalent doses obtained by the additive dose method and by the regenerative dose method are compared.

Keywords Barite, ESR dating

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P.3-15: ESR dating of Quartz using different measurement temperatures: performance evaluation of different cryogenic systems based on He and N_2 and their influence on dose assessment

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Electron Spin Resonance (ESR) dating of quartz grains is based on the detection of various radiation-induced paramagnetic centres associated with defects present in the crystalline structure of quartz [1,2]. Among them, Aluminium $[AlO_4]^0$ and Titanium centres $[TiO_4/M^+]^0$ (M^+= Li^+ and H^+) have become the most widely used for geochronological purpose. However, unlike other materials, such as fossil tooth enamel, ESR signals of Al and Ti centres in quartz are not visible at room temperature, and measurements should be performed at very low temperature.

Previous works have shown a strong influence of temperature on the intensity and spectral resolution of the ESR signal from the Al centre [3]. The measurements of quartz are typically performed in most ESR dating laboratories using variable temperature units (VTU) based on liquid nitrogen (N_2), with a temperature ranges from 90 to 120 K. Other experimental setups, i.e. VTU based on liquid Helium and Finger Dewar filled with liquid N_2, allow to reach lower temperatures. However, these have been very rarely used for dating purpose.

To fill this gap of knowledge, we carried out a comparison study of three different temperature systems in order to evaluate their potential for quantitative ESR measurements: (i) a VTU using the evaporation of liquid Nitrogen (measurement temperature = 90-100 K), (ii) a VTU using the evaporation of liquid Helium (measurement temperature between 20 and 100K), (iii) a Finger Dewar, in which tubes are directly inserted into liquid N_2 (measurement temperature = 77 K).

Our comparative study investigates the measurement sensitivity, spectral resolution and measurement precision, as well as their influence on the equivalent dose (D_E) assessment, for both the Al and Ti centres and using each temperature system. Finally, other parameters, such as system stability over time, acquisition time and measurement cost will also be discussed.

Keywords: ESR dating; quartz grains; ESR dose assessment; temperature system; Finger Dewar.

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P.3-16: The minimum extraction technique: an update on methodological developments

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The minimum extraction technique (MET) is a sampling technique used for the extraction of OSL samples from museum materials in preparation for dating. The MET requires extraction of only a 2 mm x 4 mm core for analysis [1]. Owing to the extremely small sample yield from MET extraction, optimisation of associated sampling and measurement protocols are desirable.

This poster presents updates and results for new and ongoing methodological developments for the MET: dose rate measurements (including LA-ICP-MS for internal dose rate determination), improved sample yield and sample recovery.

By routinely reviewing and updating sampling and measurement protocols used in combination with the MET, it is possible to optimise the application of luminescence dating to museum materials whilst still upholding the aesthetic integrity of precious artefacts. It is hoped that such revisions and improvement will lead to an increase in OSL studies centred upon museum objects that are too often overlooked as suitable material for analysis.

Keywords Methodology; dose rate; minimum extraction technique; archaeology; museums.

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P.3-17: In which extent exothermic reactions during sample preparation may impact luminescence and ESR signals measured in quartz?

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Standard sample preparation procedures in ESR and OSL dating of quartz grains typically include chemical treatment with HCl and H_2O_2 to eliminate carbonates and organic matter, respectively. Exothermic reactions may occur during these processes, and the samples may be exposed to high temperatures (>50°C), potentially impacting both luminescence and ESR signals. Such impact has, however, been very little studied to the best of our knowledge.

Consequently, in the present work we aim to evaluate, and possibly quantify, the effect of heating resulting from exothermic HCl and H_2O_2 reactions on both the luminescence and ESR signals. For this purpose, two quartz samples (grains 100 – 200 µm) were selected: OUC11-02, from modern fluvial deposits in Morocco and, LM17187-4 collected from a 22 kyr old loess deposit from lower Ebro basin (N Spain). The latter was artificially bleached in a HÖNLE solar simulator during 24 hours before sample preparation Residual dose was evaluated on 3 multi-grain quartz aliquots prior to irradiation to ensure the total reset of the luminescence signal. Samples were then irradiated to 300 Gy using a Gammacell-1000 irradiator.

Gamma-irradiated quartz grains were mixed with either carbonates (100 – 200 µm) or activated charcoal powder, and then treated with HCl (32% and 10%) and H_2O_2 (35%), respectively. Two sets of experiments were performed: (i) under uncontrolled temperature conditions, and (ii) with an ice bath. The evolution of the temperature during the chemical reaction was monitored.

Finally, OSL and ESR measurements were carried out to evaluate the recovery of the given dose (300 Gy). OSL measurements include Single aliquot Regenerative-dose (SAR) protocol on small multi-grain aliquots. ESR analyses are based on the Multiple Centre approach and using the Multiple Aliquots Additive Dose procedure. The implications for Luminescence and ESR dating will be discussed.

Key words: Luminescence; ESR; sample preparation; Chemical treatment.

P.3-18: Heat and Cold Stress on OSL samples: A word of caution regarding field and lab extreme conditions

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Most of the success behind a reliable OSL age falls onto the appropriateness of sample collection, site selection, careful assessment of the depositional environment and judicious analysis of the mode of transport most likely to have effectively reset luminescence signals prior to deposition. Expert diligence is put into many logistical aspects of fieldwork prior and during sampling, and also during sample preparation in the laboratory.

Nonetheless, precautions related to sample handling during transport in the field and to the laboratory, as well as the temporary storage of OSL samples (on route and/or at the laboratory before any physico-chemical preparation is initiated) can easily be overlooked due to multiple reasons yet sometimes common mistakes, even by OSL specialists (e.g., inexperience, fatigue, stress, lack of time, scarce resources, reduced space, inappropriate transport, modest facilities, etc.). This is accentuated when field locations are remote, difficult to access, and under extreme weather conditions.

For instance, cryogenic weathering during burial is known to crack quartz grains as a result of freeze-thaw cycles resulting in a sensitization effect on the luminescence emission, potentially questioning the reliability of the natural dose estimation. Nonetheless, some studies have favourably shown the potential for OSL-dating frozen natural archives, despite their difficult bleaching and burial histories. Many sediments commonly exhibit partial bleaching. However, aeolian and coastal quartz sands commonly yield tight, Gaussian-like dose distribution, resulting in easily quantifiable D_E values. Sunlight or heat may tamper these results, partially or completely, leading to overly dispersed results.

After deliberately exposing previously studied, well-behaved beach/dune quartz-rich samples to different ambient to extreme temperatures (-4°C to 200°C), measurements depicted an extreme loss of OSL signal intensity and components during both heat and cold stresses, reaffirming the OSL signal characteristics temperature-dependence. Experiments were caried out under controlled laboratory (interior) settings, and also field (exterior) conditions, purposely recreating several possible scenarios.

This experimental study, to my knowledge the first to examine sample care under variable temperature conditions in field and laboratory settings, exalts the importance of sample handling after evidencing several real field and laboratory situations, e.g., samples accidentally bleached when left inside field vehicles, laboratory storage facilities or unprotected under direct sunlight (>50°C); deliberately frozen in freezer (<0°C) or left outside in extreme cold weather. A list of minimal handling recommendations is proposed to maximize care during transport and temporary storage of OSL samples and avoid accidental bleaching. Nonetheless, more experimental work is needed in terms of laboratory frost sensitivity and heat stress on both bulk samples and purified quartz separates. Last but not least, a better understanding of the thermal conductivity of certain sampling materials commonly used in OSL is also required.

Keywords OSL; frozen samples; extreme heat; field conditions; sample care

P.3-19: A new and effective method for quartz-feldspar separation for OSL dating.

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The major component of rocks and sediment samples are quartz and feldspar. The extraction of pure quartz from this mixture is important for the Luminescence dating. The separation of quartz from unwanted feldspar and other heavy minerals can be achieved by density separation [1]. This is followed by HF etching which usually removes the feldspar contamination from the quartz (if any left). But in some cases, this method is not successful, especially in the case of feldspar rich samples and samples with feldspar inclusions/intergrowth in quartz crystals. The separation of quartz and feldspar using an isodynamic separator has also been reported [1] for such samples but has some limitations.

Here, we report a new method that is quite effective in separating quartz and feldspar. The method is not newly invented was reported for the first time by [2]. However, we have done some modifications and have also tried to quantify the purity of separated quartz using different analytical techniques (e.g. ICP-MS, FE-SEM-EDAX). Two sets of samples were used, one from the Aravalli mountains which are quartz rich (quartzite derived) and the second one was from the glacial settings in the Himalaya. The heavy minerals were first removed using isodynamic separation. The obtained fraction was etched with 1%HF + 1%HNO3 for 24 hours. The mild HF removes the silicon from the outer layers of the feldspar as volatile fluorides but does not affect the quartz. This action of HF creates pits of few microns on the surface of the feldspar grains. A small amount of fine iron powder is added to the mixture and the mixture is shaken vigorously so that iron powder settles into the pits created on the feldspar grain. This mixture is then passed through the isodynamic separator, the feldspar grains with the iron powder behave as a magnetic mineral and are separated from the quartz. The obtained fractions of quartz and feldspar were analysed under the Scanning Electron Microscope (SEM), a visual interpretation shows that this process is very effective in removing the feldspar from the quartz. An EDAX measurement was also done on the quartz fraction of one of the samples and only the peaks of Si and O were observed. The absence of feldspar contaminations was cross-checked by the IRSL and ICP-MS measurements. The quartz rich samples from the Aravalli were free of any feldspar contamination after this step. The glacial samples from the Himalaya gave high IRSL and Aluminium content, and thus were considered feldspar contaminated and the above mentioned procedure was repeated once again to obtain almost feldspar free quartz from the Himalayan samples too. A systematic approach to clean the quartz will be presented in the meeting.

Keywords Feldspar contamination, IRSL, FE-SEM-EDAX, ICP-MS, Himalaya.

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P.3-20: Improving the effectiveness of heavy liquid density separation in isolating K-feldspar grains using alluvial sediments from the Hajar Mountains, Oman

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Developing chronologies for alluvial sediments in the eastern Hajar Mountains will tell us how hydrological regimes in the region have varied during the Late Quaternary, information critical to evaluating the opportunities and barriers to ancient human occupation of this landscape. Using conventional quartz optically stimulated luminescence (OSL) dating however is problematic for two reasons i) there tends to be a low abundance of quartz in the region and ii) many samples date beyond the limit of the quartz OSL signal. The use of K-feldspar signals offers a potentially powerful alternative for developing chronologies, however thus far, isolating K-feldspar which provide infrared stimulated luminescence (IRSL) signals amendable for dating has proven challenging.

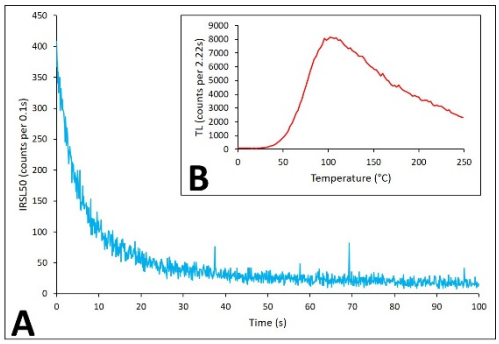

Figure 1. An example **A)** IR_{50} and **B)** TL signal from a 1 mm aliquot (~40 grains) of K-feldspar (<2.58 g.cm^{-3}), following a laboratory beta dose of ~ 100 Gy.

Following separation procedures in the laboratory, it is generally assumed that the <2.58 g cm^{-3} fraction is rich in K-feldspar mineral grains. However, it has been shown that for some samples, following heavy liquid density separation a mixture of mineral grains can remain [1]. These minerals can contribute to measured luminescence signals and may have properties undesirable for dating. In this study, initial measurements made on sediments from the <2.58 g cm^{-3} fraction, yielded IR50 signals with low levels of sensitivity (Figure 1), and post infrared infrared (pIRIR) signals which were either also low in sensitivity or were not detected, even after laboratory doses exceeding 250 Gy. K-feldspar pIRIR signals with low sensitivity have been reported in other alluvial settings [2], however further investigation into the mineralogical composition of the <2.58 g.cm^{-3} fraction is warranted in this environment, where sediments are drawn from an area which is geologically diverse and complex, and where K-feldspar ages have not yet been published. Using a combination of mineralogical characterisation techniques (e.g., XRD and thin section microscopy [2]) and signal analysis, we aim to identify the mineral grains currently isolated by standard laboratory preparation techniques and optimise K-feldspar isolation protocols. Improved understanding of the mineralogical composition of samples and more effective K-feldspar isolation will lead to improved reliability of age determinations, crucial for palaeohydrological reconstruction of south-eastern Arabia during the late Quaternary.

Keywords: luminescence dating; feldspar; mineralogy; density separation; pIRIR

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P.3-21: Implementation of expressions based on Lambert-W function in deconvolution and dose response phenomena using Python

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A research topic of major importance for Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) has been the method of Computerized Curve Deconvolution Analysis (CCDA). In TL, CCDA has been used to deconvolve the glow curves into the corresponding TL peaks and in OSL the decay curves into their corresponding components. Additionally, an important characteristic in these phenomena is the procedure of dose response, which describes the magnitude of the luminescence signal of a studied material, as a function of dose after a given exposure time. Therefore, to construct such a deconvolution tool, two factors needed to be met: a) selecting a suitable model along with the analytical expressions describing the TL/OSL curves and b) picking the proper software code. However, there are several models in scientific literature without a universally accepted analytical expression.

Kitis & Vlachos (2013) have proposed a different approach unifying the expressions that describe all types of stimulated luminescence, namely TL and OSL, into one 'master equation' with the use of the Lambert W function, including practical fitting parameters, such as maximum intensity I_m and the position corresponding to this intensity, either temperature (T_m) for TL or time (t_m) for OSL [2]. In addition, Pagonis et al., (2020) have reported an effective way to deconvolve all the dose response curves, including both the linear, but mostly supralinear or saturation regions by also using the Lambert W function. From a chronological dating point of view, this task could possibly result in an extension of the upper limit of the detectable age in archaeological but mostly in geological findings.

In this study, (a) deconvolution was performed for well-established stimulated luminescence phenomena, as well as (b) the new expressions for the dose response curves were applied on a variety of experimental curves; in all cases, using the Lambert W function implemented in Python. Python is under an open-source licence and has grown in popularity due to the large number of open libraries available for mathematical analysis and data processing, an ideal tool for curve deconvolution and fitting analysis.

Keywords CCDA; Dose Response; Stimulated Luminescence; Open source; Python;

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Session 4:
Advances in instrumentation and dose rate determination

Oral Presentations

	Presenter	Title
1	Elaine Sellwood	Equivalent dose determination using spatially resolved IRPL and IRSL
2	Matt Gunn	Optimisation of signal discrimination for measurement of the dose dependent IRPL signal in feldspar
3	Emmanuel Osunkwor	Microscopic variations in sediment dose rate: Comparison of measured and modelled dose distributions
4	Daniel Richter	Comparison of beta dose rates derived from Risø and LexCal calibration quartzes
6	Loic Martin	Advancing dosimetry for Dating Environmental Materials (ADDEM)

Poster Presentations

	Presenter	Title
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O.4-1: Equivalent dose determination using spatially resolved IRPL and IRSL

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Rock surface burial dating using optically stimulated luminescence face multiple challenges, including the need to separate minerals, unstable signals (e.g. fading), laborious sample preparation and establishing a reliable dose rate estimate. It has previously been demonstrated that spatially resolving OSL can overcome the need for separating out mineral fractions, speed-up sample preparation and measurement times, and provide high-resolution data where each mineral region can be investigated individually [[1], [2]. Such spatially resolved measurements have previously been used to reconstruct luminescence-depth profiles from naturally exposed rocks, using infrared photoluminescence (IRPL) and infrared-stimulated luminescence (IRSL) from feldspars [2], but applications have yet to explore IRPL and IRSL imaging for equivalent dose determination from buried rock samples.

Here, we use spatially resolved IRPL and IRSL for establishing equivalent doses from the buried surfaces of centimetre-scale rock samples. We adapt a regenerative-dose measurement protocol wherein we measure natural and regenerated IRPL and IRSL signals from three rock samples. The protocol also includes a test-dose normalisation step to monitor sensitivity changes, a preheat step to remove unstable charge and a bleaching step to supply background levels for IRPL. We reconstruct the natural luminescence-depth profiles on two samples with known initial exposure durations and known surface doses (200 or 500 Gy), and a final sample of unknown depositional history. Through establishing the response of IRPL and IRSL to dose, we are able to construct 2D maps of equivalent dose and burial age for each sample. We then map the rocks for their mineralogical compositions using micro-XRF measurements. Finally, we discuss how equivalent dose estimates correlate with factors such as mineralogy, grain size, rock texture, or sensitivity change.

Keywords Infrared-photoluminescence; IRSL; equivalent dose; rock surface dating.

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O.4-2: Optimisation of signal discrimination for measurement of the dose dependent IRPL signal in feldspar

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The new and recently reported [1] InfraRed PhotoLuminescence (IRPL) signal in feldspar offers a promising alternative to the well established OSL method to recover the absorbed radiation dose for dating purposes. The non-destructive readout using Stokes shifted photoluminescence offers the opportunity to carry out repeat measurements to improve the signal to noise ratio, and the steady state signal enables straightforward spatially and spectrally resolved measurements. However, the exploitation of the IRPL signal has been hampered by a large background signal, making the IRPL emission that is of interest for measuring absorbed dose difficult to discriminate.

A new IRPL detection attachment for the Risø luminescence reader has been developed which enables measurement of the IRPL emission with a signal to background at least two orders of magnitude higher than reported previously [2]. These improvements have been achieved through a combination of a bespoke optical design along with careful selection of filters and coatings. Key instrument design details will be presented along with instrument performance figures.

Keywords infrared photoluminescence IRPL; instrument development, signal optimisation

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O.4-3: Microscopic variations in sediment dose rate: Comparison of measured and modelled dose distributions

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Dose rate variations on a microscopic scale pose challenges in single grain dating and other applications. DosiSed and DosiVox [1] are powerful recent tools to model the dose absorbed by different materials in nonuniform media. The goal of our study is to validate the model calculations by comparing the results with measured dose distributions. We devised a set of mineral mixtures with well-defined properties such as grain size, mineral composition, and nuclide concentrations. Al_2O_3 dosimeters were buried in these samples and dose distributions were measured. The samples and their resulting dose distributions were also modelled with DosiVox / DosiSed. We present a comparison of the measured and modelled dose distributions.

The samples used for this investigation are mixtures of thorite or thorianite grains and fine quartz powder. The thorium-bearing minerals provide radiation hotspots for beta and alpha radiation while other parts of the simulants are inert. About 1.8 cm^3 were packed into separate cylindrical containers in the laboratory. Luxel® Al_2O_3:C dosimeters were buried in the simulants to measure beta radiation. Other containers included 250-355 µm Al_2O_3:C grains that measure alpha and beta radiation. The signal from the individual grains and Luxel was measured after 6 months of storage using a Risø TL/OSL-DA-20 reader and their dose distribution were obtained from their signals using grain-size-specific calibration curves.
Models for the simulants and dosimeters were set up in DosiVox and DosiSed. The dose rate distribution was obtained from the absorbed dose using the energy dose conversion factors of Guérin et. al. [2].

In this presentation, results from the model calculations will be compared to the laboratory measured dose distributions. We will discuss where simulations and measurements show good agreement and we will discuss possible reasons for discrepancies.

Keywords DosiVox; DosiSed; Dose rate variation; sediments; Al_2O_3:C

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O.4-4: Comparison of beta dose rates derived from Risø and LexCal calibration quartzes

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The calibration of radiation sources is crucial in any dosimetric method or technique. Numerous factors such as material properties, geometries, radiation energies etc. need to be taken into account. Because of radiation safety and ease of use with different measurement procedures, the source is usually incorporated into the device (e.g. luminescence reader); both beta sources (e.g. Sr-90/Y-90) and low energy X-ray sources are often employed in routine dosimetry measurements. The calibration of such sources is usually achieved via a transfer-calibration using material that was irradiated by a high energy photon (γ) source, preferentially in a secondary standard laboratory (SSL). The reproducibility of these transfer materials should be demonstrated in advance, using the chosen measurement technique and protocol.

In luminescence dating two such materials are widely used, both of which fulfil the requirements for transfer-calibration. These are Risø calibration quartz (RCQ) [1] and LexCal [2] with grain sizes 180-250 µm and 90-160 µm, respectively. Both provide excellent reproducibility when used for dose determination with a single-aliquot regeneration (SAR) protocol with blue luminescence stimulation. Here we compare the beta dose rates derived using these two materials.

Thermally reset portions of both RCQ and LexCal were irradiated with calibrated Cs-137 sources both at DTU Risø and at the Helmholtz Zentrum München, with the sources and glass irradiation cells used in the preparation of the original materials. In addition, thermally reset RCQ was irradiated at the Helmholtz Zentrum München in the Risø glass container. Radiation transport simulations were undertaken using MCNP [3] in Munich and Geant4 [4] at Risø for calculation of the absorbed doses. Using published SAR protocols, all the various irradiated quartz were then measured at Risø and at Freiberg Instruments, using a Risø DA-20 and a lexsyg smart, respectively.

The results of the SAR-OSL determinations as well as a comparison of the codes will be presented, and the resulting small difference in the specified absorbed doses discussed.

Keywords
coarse grain quartz; transfer calibration; RCQ; LexCal; absorbed dose simulation, beta-source dose-rate

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O.4-6: Advancing dosimetry for Dating Environmental Materials (ADDEM)

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Beta dose rate heterogeneity is a recognized source of uncertainty when applying luminescence dating to heterogeneous samples, such as coarse crystalline rocks and clast-rich sediments. Simulations have shown that a combination of a heterogeneous distribution of minerals and it radioactive elements can lead to complex dose distributions, overdispersion and potentially to bias in equivalent dose determinations for dating. However setting realistic conditions for such simulations remains difficult to the complexity of the samples, and there are at present only a few experimental validation cases for such results.

The project ADDEM is investigating means of linking Monte Carlo simulations of beta dose rate [1] and luminescence sensitivity distributions with direct observations using high sensitivity phosphor plates and laser scanning imaging systems in combination with phase mapping. To overcome some of the limitations of autoradiographic imaging of low level beta dose distributions work has been undertaken using printed sheets of alumina OSL-D phosphors prepared by Landauer [2] in combination with SUERC laser scanning systems. As a preliminary excitation spectra, emission band characterisation and time resolved measurements were undertaken, confirming the potential of recording low doses using asynchronous stimulation at 635nm coupled with blue band detection. Taking advantage of the slow recombination decays the scanning equipment has been configured for pulsed stimulation and asynchrounous detection to maximise signal to background ratios. Exploratory work was calibrated using a 90Sr source operated at a working distance of 7,5 cm to work in the mGy range, and this has now been supplemented by a 60Co facility capable of calibrating doses in the microGray range. A series powdered granulite/basalt mixtures of known mean activity and dose rate have also been used to calibrate the phosphor screens. To reduce the background dose rates during autoradiographic signal accumulation rock slices are being exposed in the Zeplin shield of the STFC Boulby Underground Laboratory, in an environment which is essentially free from cosmic muon background.

Simulations have also been conducted providing preliminary deconvolution parameters in order to either reconstruct the beta dose rate distribution received by the grains in the sample, or retrieve the radioactive element distributions in the minerals of the sample, providing the data required for representative simulations of beta dose rate.

This presentation will outline the spectroscopy and sensitivity verification of the autoradiography systems, which confirm the prospects for conducting spatially resolved beta dose rate distributions with single pixel detection limit of 200 microGray and spatial resolution of 100-200 microns. Future prospects are outlined.

Keywords beta dose rate; Alumina OSL-D; mapping; simulation; pulsed OSL.

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P.4-1: Field screening instruments for rock surface dating

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There is ever-increasing application of rock surface dating technique to measure burial ages of coarse-grained geological or archaeological deposits (pebbles and cobbles) and the exposure ages of bedrocks. Often these studies involve expensive field work in remote locations that cannot be readily revisited. In the absence of any prior knowledge of the luminescence/bleaching characteristics of the rock samples, it is often challenging to design an appropriate sampling strategy in the field. Indeed, it is not uncommon that the majority of sampled rocks do not show desirable characterises, e.g. the signal may be insensitive or the rock was not sufficiently bleached prior to its burial or we cannot easily guess the relative exposure history of different bedrock surfaces. Unfortunately, such information becomes available only by laboratory measurements based on cumbersome sample processing after the field work has been concluded. Any method of screening samples in the field for their suitability for rock surface dating would be huge saving on both time and expenses.

We have recently developed two different approaches based on imaging or scanning of luminescence signals for rapid *in-situ* measurement of luminescence-depth profiles. The first method is based on imaging of IRPL and/or IRSL of rock samples, and does not require an ionising radiation source for sensitivity correction; instead, normalisation is based on using signals of different bleachabilities [1, 2]. This method requires that a rock be cut perpendicular to the (prior) exposed surface, and it gives a rapid, high-resolution profile measurement for *in-situ* determination of the bleaching depths.

The second method is based on gradual insertion of an excitation-detection probe perpendicular to the exposed rock surface. This method simply requires drilling a hole of 14 mm diameter down to ~50 mm depth. Given the low sensitivity of IRSL, the scanning method only utilises the IRPL signal. The instrument consists of an excitation light source (830 nm), a photomultiplier tube with appropriate filter (955 nm detection) and a detection probe coupled to a liquid light guide. The detection probe has a horizontal slit (e.g. 1 mm) to restrict the measurement area during the scan from the top (bleached surface) to the bottom of the borehole. The sensitivity correction technique developed for the imaging system [2] can be also applied to the scanning system.

In order to demonstrate these novel methods we drill a core from a naturally bleached rock sample with a core-bit of 10 mm inner diameter and 14 mm outer diameter. The drilled hole is measured with the scanning system, while the core itself is measured with the imaging system after splitting it parallel to the light penetration direction (long axis). The results from the two different measurement systems will be inter-compared and discussed.

Keywords Field screening instrument, Rock surface dating, Infrared Photoluminescence (IRPL)

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P.4-3: X-ray and laser calibration of the spatially resolved luminescence instrument LuCIDD

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Conventional OSL methods have been applied to dating cobble surfaces but require the cobbles to be processed into and dated as sediments (e.g. [1]). An instrument named LuCIDD (Luminescence instrument with Confocal and Imaging unit for Dating and Dosimetry) has been developed for measuring OSL from cobble surface slices (~2.5 cm diameter). LuCIDD is based on a confocal microscope. It is equipped with four lasers that can be focused on the surface and at depth, a photomultiplier tube for signal measurement, an X-ray source for sample irradiation, and a heating plate for sample temperature control. In this presentation we describe the characterization and calibration of the X-ray source as well as the characterization of the laser stimulation.

The built-in Magnum 50kV, 200uA X-ray source has a silver target and can be equipped with various absorption filters. GAFchromic EBT-3 radiochromic film was used to determine the shape and width of the beam at different irradiation distances. The energy spectrum was observed with an Amptek CdTe X-ray detector using multiple filters. The source's irradiation penetration depth was experimentally verified using alternating layers of Luxel dosimetry sheets and 1 mm slices of cobbles. The dose rate was determined using the conventional luminescence methods for source calibration. The stimulation spot sizes of the infrared (873nm), green (532nm), and blue (473nm) stimulation lasers were found using a Thorlabs BC106-VIS Camera Beam Profiler. The penetration depth was evaluated using alternating layers of Luxel dosimetry sheets and 1mm slices of cobbles. We will describe the details of the laser spot characterization procedure and discuss implications for dating applications of rock surfaces.

Acknowledgements: This research has been funded by grants #0722552 and #1643868 from the National Science Foundation – Office of Polar Programs.

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P.4-4: A pragmatic approach to using X-ray irradiation in optically stimulated luminescence measurements on quartz using the single aliquot regenerative dose (SAR) method.

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X-ray irradiation sources have been available as optional upgrades to commercially available luminescence instruments for a number of years [e.g. 1,2]. These sources have a number of potential benefits, including: 1) high dose rates relative to standard beta sources; 2) dose rate variation over several orders of magnitude via software control; 3) spatially homogenous irradiation fields and 4) low radiological risk when not energised. However, X-ray sources have not been adopted widely for use in luminescence dosimetry because apparent dose rates are sample dependant [e.g. 3], and possibly also dose dependant [4]. The sample dependence of apparent X-ray dose rates may be reduced by filtering softer X-rays from the beam, though this approach can substantially reduce the dose rate advantage over beta sources. Nonetheless, the high dose rates available when using X-ray irradiation sources may make them advantageous in fields of research where the robustness of the geological inference may be more dependent on spatial (e.g. dune field mobility studies) or temporal (e.g. high-resolution loess studies) coverage rather than the precision of individual equivalent dose estimates.

In this study, the properties of a Varian VF-50J X-ray tube (50 kV, 1 mA, 50 W) "hardened" via 100 µm of Al filtration and attached to a Risø TL-DA-20 instrument are explored using a variety of sedimentary quartzes. Maximum apparent X-ray dose rates (50 kV, 1 mA) are ~10-15 times higher than those attained using a 1.48 GBq ^{90}Sr/^{90}Y beta source. A simple single-dose cross-calibration procedure [4] was tested using two suites of samples (one sand-sized and one fine silt) covering the last glacial-interglacial cycle. In both cases, there is good general agreement between beta and X-ray equivalent doses, though care is required in choosing the calibration dose. These results suggest that the routine use of X-ray irradiation in luminescence dating studies is feasible, and may be beneficial for studies where high spatial/temporal coverage is preferable to high precision.

Keywords X-ray; quartz, SAR; calibration.

References Leave one blank line (font size 11) between the keywords and the references. The reference list should be written out in full using Calibri font size 10:

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P.4-6: Measurements of uranium, thorium, and potassium as an inter-laboratory comparison: A New World experience

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Various luminescence labs in the New World luminescence dating community have launched a small inter-laboratory comparison for gamma spectrometry measurements of a single shared sample, specifically to measure the abundance (or respective specific activity) of uranium, radium, thorium and potassium in the sediment. This study is aimed at collecting results in a double-blind fashion, publishing the results, and using the information to better inform on best practices for the luminescence group. It will also help all luminescence labs identify reputable non-luminescence chemistry labs or dating labs that may be used for the wider benefit of the community. It is the kind of simple, yet vital, experiment that is often needed to identify areas of strengths and weaknesses so that we can all benefit from the knowledge we will acquire.

As we are all aware, the last wide-scale inter-lab comparison [1] ended on a perplexing note: the measurement of the equivalent dose had good reproducibility between labs, with an average relative standard error (RSE) between 2 and 3 %. Unexpectedly, the (simple) measurement of uranium, radium, thorium and potassium was far more dispersed, ranging from 3 to 13 % RSE. Perhaps this was a sign that we have neglected the bottom half of the age equation for too long! The only way to resolve this is to repeat the exercise, with the hope of identifying something that we have neglected.

We have recently retrieved two buckets of sand from a Colorado River terrace at a quarry in Grand Junction (Colorado) USA. The sand is a mixed source of exotic Colorado River sands and Mancos Shale, which underlies the area. One bucket was thoroughly homogenized, riffled, and split into 200 bottles at the U.S. Geological Survey Reference Sediment Laboratory for use as a gamma spectrometry calibration standard. A secondary purpose guided our site selection: in the future we want to execute an in-situ intercomparison, with portable gamma spectrometers. For the labs in North America, Grand Junction is of great interest because for the past 40 years the U.S. Department of Energy has maintained various horizontal pads and vertical wells for the purpose of calibration of portable gamma detectors. During the autumn of 2019, we united five laboratories at this site for a group calibration. Due to unforeseen reasons, we could not access the quarry during that weekend, sadly, but in the future, we plan to hold community calibrations there as well. After a hard day of calibration, attendees can retire to one of several nearby vineyards to discuss the science.

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P.4-7: Dose rate variability in Żabinko dune profile

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Accurate luminescence dating requires accurate determination of the dose rate. Recently, more intensive research has been conducted in Gliwice Luminescence Dating Laboratory [2] to improve the methodology of dose rate determination [3], [4]. This allowed us to detect and confirm profile with very large dose rate changes. This dune profile is located in Żabinko (Poland) and was previously studied by others [5]. Żabinko is one of key sites with fluvial-aeolian succession and it is situated in a complex dune in the Warta Pradolina, about 20 km to the south of Poznań.

Our investigation indicates that this aeolian profile is characterized by a very high variability of natural radionuclide concentration. This was not reported earlier. In contrast other investigated profiles [1] near Żabinko does not show such natural radionuclides variability.

This atypical variability may be due to the postdeposition fluvial processes which included sediments of aeolian origin. As part of the conducted research, we are able to check what part of this variability is due to the post-deposit processes themselves, and for which the natural diversity of the investigated material is responsible.

Keywords: dose rate; aeolian deposits; luminescence dating

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Acknowledgments

Presented results were obtained with the support of Polish National Science Centre, contract number 2018/30/E/ST10/00616.

P.4-8: An attempt to date contaminating feldspar within quartz

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Quartz from Himalaya is not only 'dull' but also 'dirty'. Here, dull quartz means low sensitivity (cts.Gy^{1}.mg^{-1}) and dirty quartz means the presence of infra-red stimulated luminescence (IRSL) which is not expected from 80 min HF etched quartz grains. This indicates the presence of feldspar not on the surface but inside the quartz grains as inclusions. By suppressing IRSL from feldspar using post IR OSL method, quartz may be used for dating. However, the dullness of quartz cost machine time because many aliquots need to be measured as the rejection rate would be high. In this context feldspar inclusions appear to be a blessing in disguise as IRSL signals from these inclusions are stronger than that of quartz OSL (pIR OSL). So, we made an attempt to date feldspar inclusions.

We used 11 feldspar contaminated quartz sample from Himalaya. The degree of contamination varies from 40 % to 90 % (percentage IR depletion ratio, pIRDR). All the samples have established chronology either by fine polymineral luminescence ages or radiocarbon ages. New Risoe TL/OSL Reader DA 20 with DASH unit has the flexibility to change the filters during luminescence measurements. It made possible to make IRSL measurements during the post IR OSL measurements. Therefore, we could estimate the IRSL and pIR OSL ages on the same aliquots.

Ages of the contaminating feldspar (IRSL; fading corrected) are overestimated by 18–30 % compared to the age quartz (pIR OSL). Dose rate for these samples is used based on the calculation for the grains size (90–150 μm) for quartz and feldspar. However, dose rate value for feldspar inclusions need modification as per the geometry of feldspar within quartz. Corrected dose rates can only be estimated once the size, amount and structure of feldspar inclusions are known. The presence and kind of feldspar inclusions in the quartz grains are being investigated using petrological microscope (thin section slides), Raman spectroscopy and ICP-MS. Detailed results will be presented in the conference.

Keywords: IRSL; pIR OSL; contaminated quartz; IR depletion ratio

P.4-9: Improving reproducibility in geochronology: application in gamma spectrometry.

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Reproducibility is one of the main challenges facing modern science. Since the early 2000s, it has been recognized that we are experiencing a "reproducibility crisis" [1, 2, 4]. Emerging from this crisis requires a profound change in our practices of publishing and diffusion of research tools and data. It is generally accepted that reproducible research production must involve a shift from proprietary software (true black boxes) to open-source software, whose source code can be inspected and modified. Moreover, the use of scripting languages (unlike graphical interfaces) facilitates the complete documentation of the steps and processes that lead to the published results.

This poster introduces an easy way to process high resolution, low background gamma-ray spectrometry data in the context of geochronology such as OSL dose rate determination. It enhances a previous work allowing field gamma spectrometry spectra processing [3]. The gamma project, written in the R language, offers a complete solution for the processing of gamma spectra, from their importation to the determination of K, U and Th contents. This package provides a transparent, interoperable and reproducible workflow by making all the code public (distributed under the GNU-GPL3 license).

Keywords gamma spectrometry, reproducibility, programming, R language, workflow

References Leave one blank line (font size 11) between the keywords and the references. The reference list should be written out in full using Calibri font size 10:

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P.4-13: OxGamma: a MATLAB based application for gamma spectrum analysis

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Gamma-ray spectrometry is a versatile technique to perform both qualitative and quantitative analyses of radioactivity. In trapped charge dating, portable gamma-ray spectrometers are commonly used to acquire spectra in the field. The latter can then be used to assess radioisotope concentrations and to determine dose rates at the exact location where samples have been collected for dating. However, accurate assessment of concentrations and dose rates demands proper energy and efficiency calibration of the instrument by comparison against one or several radioactive standard(s). The 'Oxford blocks' [1-2] which consist of four concrete cubes doped with known concentrations of potassium [K-block], thorium [Th-block] and uranium [U-block], as well as a background [Bk-block], were constructed for this purpose and have become widely adopted by researchers for calibrating their instruments.

For untrained personnel, including many archaeologists or environmental scientists simply wishing to collect good samples for luminescence or ESR dating, the processing of gamma-ray spectra for determining isotope concentrations can be a difficlut and laborious task which often involves multiple steps (e.g. downloading and conversion of data files, peak identification and selection, true full-peak area calculation, efficiency calculation, etc.). The processing of calibration spectra from the Oxford blocks is further complicated by the fact that the K-block contains only 72% concrete and the Th-block contains small amount of uranium. These factors must be accounted for in order to obtain true count rates and the latter factor necessitates the calculation of stripping factors, which determine the contribution of individual isotopes to their own windows. The stripping factors can then be used to calculate the concentrations of radioisotopes from the individual field spectra. The calibration and processing of data can be facilitated by expensive proprietary software provided by various instrument manufacturers or through the use of freely available software and more recently, dedicated functions written for the statistical programming language 'R'. However, despite being a valuable aid, the task of deriving dose rates from field measurements can still be a time-consuming exercise and often requires training and familiarity with dedicated software or programming. Here we present a simple and user-friendly MATLAB based application (OxGamma), available for both Windows OS and macOS, which will allow easy and speedy (less than a minute!) calibration and calculation of the concentrations of radioisotopes (K, U and Th). The application provides output using both a windows and a threshold approach and crucially, without requiring the user to have any previous experience in programming or excel wizardry. During the the presentation, we will demonstrate the practicality of the OxGamma application and we will discuss our results with those obtained using existing software/codes.

Keywords Gamma-ray Spectrometry; Dose Rate Calculation; Radioactivity Analyses; Oxford Blocks.

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Session 5:
Luminescence dating of rocks and glacial sediments

Oral Presentations

	Presenter	Title
1	Xianjiao Ou	Rapid assessment of beta dose variation inside cobbles, and implications for rock surface luminescence dating
2	Regina DeWitt	OSL dating of cobble surfaces from raised Antarctic beaches: Challenges and results
3	Furong Cui	Luminescence dating of buried cobbles from river terraces: a pilot study on using quartz source signal via pulsed stimulation
4	Geraint Jenkins	Luminescence dating of cobbles to determine the retreat of the last British-Irish ice sheet
5	Christina Neudorf	Investigating the luminescence dating potential of beach pebbles and cobbles associated with the last (~16 ka) pluvial lake highstand in the Great Basin, USA
6	Jakob Wallinga	What do feldspar single-grain dose distributions tell us?

Poster Presentations

	Presenter	Title
3	Henrik Olesen	Investigating the dependence on excitation wavelength of luminescence bleaching and sensitivity change in rocks
4	Stephan Fuhrmann	Evaluating the parameter values of the bleaching-with-depth-model for rock surface exposure dating – an empirical approach
5	Daria Semikolennykh	Dating a catastrophic flood in the Altai mountains using Rock Surface Luminescence
6	Tristan Bench	Trialling the Use of Controlled Exposure Experiments for Optical Surface Exposure Dating on Quartzite Quarry Surfaces in Washington State
7	Felix Martin Hofmann	Challenges in luminescence dating of the last glaciation maximum in the southern Black Forest, Germany
8	Daniela Mueller	Luminescence chronology of Middle Pleistocene sediments from the Lower Aare Valley region, northern Switzerland
10	Nikolas Krauß	Testing a novel Weichselian ice advance model for the SW Baltic Sea region by new quartz OSL ages from the Jasmund peninsula (Rügen Island)
11	Pranshu Bhardwaj	Optical Chronology and Climatic Implication using Equilibrium-Line Altitude of Late Quaternary Glaciations in Nubra Valley, Karakoram Himalaya, India
12	Christopher Lüthgens	Using single grains of feldspar for the dating of glaciofluvial sediments – key results from a case study in the Drau glacier area, Austria, for unravelling Alpine chronologies

O.5-1: Rapid assessment of beta dose variation inside cobbles, and implications for rock surface luminescence dating

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There are two significant advantages of rock luminescence dating for determining the burial age of cobbles. Firstly, the variation in luminescence with depth provides a clear assessment of how well the signal of the cobble was bleached prior to deposition [1,2]. Secondly, differences in equivalent dose along the luminescence-depth profile may indicate different exposure and burial events, thus this technique has the potential to reveal multiple phases of deposition and transport history [1-3]. However, previous approaches were based on the assumption that radionuclides are homogenously distributed within each cobble. Recent studies [4,5] show us that this assumption is not applicable to all cobbles, and thus the variation of beta dose inside cobbles should be assessed. However, mapping or modelling mineral or beta dose rate distributions in cobbles is labour intensive and requires specialist equipment (e.g. μXRF, SEM, QEM-EDS, LA-ICP-MS).

This study investigates the beta dose variation of cobbles using rapid methods based on beta counting and use of a portable XRF instrument. Several granite cobbles were collected from sites associated with deglaciation of the British Irish Ice Sheet. Beta counting of rock slices from different depths inside the cobbles shows variation in the beta dose rate, but the magnitude of this variation is different between cobbles. We also measure K contents for the same rock slices using a portable XRF instrument, and the patterns were consistent with beta counting, meaning that either method is capable of assessing the beta dose rate distribution through a cobble. Portable XRF is much faster than beta counting, though it chiefly provides K concentrations and obtaining U and Th values is more challenging.

Cobbles that have homogenous radionuclide distributions are recommended for rock luminescence dating. For cobbles that show inhomogeneity on the scale of analysis, caution should be paid when calculating the age and identifying different events by 'plateaus' in the luminescence-depth profiles. To correctly interpret such depth profiles, it may be necessary to measure and model the beta dose rate for every single rock slice for these cobbles to distinguish between multiple exposure events and the impact of dose rate inhomogeneity.

Keywords: rock luminescence dating; beta dose rate heterogeneity; homogeneity; XRF; beta counting

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O.5-2: OSL dating of cobble surfaces from raised Antarctic beaches: Challenges and results

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GPS data from the last 20 decades reveal that the Antarctic continent is rising faster due to an increased rate of ice loss and the resulting isostatic adjustment. To determine how these uplift rates compare to rates from the last ~5,000 years, ages and elevations of ancient beaches on the Antarctic Peninsula have been determined. In the austral summer of 2018 and 2019 nearly 100 cobble and sediment samples were collected on Joinville and Livingston Islands, and ages were obtained with OSL dating. The OSL ages of buried cobble-undersides reflect the last time the cobbles were turned over in the swash zone and thus the time elapsed since continental uplift raised the beach to an elevated level. In this presentation we will compare the OSL properties of sediment and cobble samples from the two locations. We will present measurement procedures to overcome challenges inherent to Antarctic material and we will discuss the resulting ages.

Sediment samples consisted mostly of small pebbles with only a small fraction of sand-sized grains, resulting in a dearth of suitable grain sizes for OSL dating. For cobble samples, the outer 1 mm of the surface was sliced off, gently crushed, and prepared like a sediment. Coarse grain mineral separates (63 – 500 μm) were dated for all samples. Quartz from neither location had any signal. Feldspars from Joinville Island were bright, while samples from Livingston Island were challenging due to low or no signals. Signal brightness appears to be correlated with nuclide concentrations. Low preheat temperatures (160 - 190°C) resulted in the best dose recovery. Due to a lack of material, mixed feldspars had to be dated for some samples, resulting in large overdispersions and challenges in dose rate calculation. We will compare ages from multiple samples taken from the same beach ridge and ages of beach ridges at different elevations.

This research has been funded through grant #1643868 from the National Science Foundation – Office of Polar Programs.

Keywords Antarctica; cobble dating; raised beaches; feldspars; dose rate

O.5-3: Luminescence dating of buried cobbles from river terraces: a pilot study on using quartz source signal via pulsed stimulation

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Optically stimulated luminescence (OSL) dating of rock surface has been applied to constrain the rolling history of rocks, burial age of cobbles, etc., and IR_{50} or $pIRIR_{225}$ signals mainly from the feldspars are always employed[1]. Although the OSL signals sourced from quartz is much easier to be bleached, rare case study is reported due to the difficulty of extracting pure quartz dominated OSL signals and their poor characteristics[2]. In this study, we tentatively employed the pulsed green light stimulated luminescence (PGLSL) measured following two-step IR stimulations (IR_{50} and IR_{225}) to determine the burial age of cobbles from terraces of Jingou River, which is located on the northern piedmont of Tianshan Mountain and with very limited sandy materials to be samples[3,4].

The comparison of stimulation curve, fast ratio between OSL signals of our cobble slice and calibration quartz (Calib Q) and pure K-rich feldspar (KF) shows that the pIRIR $PGLSL_{25}$ signal of cobble slice is akin to that of quartz. Further, the luminescence-depth profiles show that the bleaching front depth of the pIRIR $PGLSL_{25}$ signals is similar to that of the IR_{50} signals, which shows that the pIRIR $PGLSL_{25}$ signal is indeed quartz dominated. Subsequently, the pIRIR $PGLSL_{25}$ equivalent doses (D_e) of the cobbles are determined by using the slices in the plateau identified from the luminescence-depth profile. The resultant preliminary pIRIR $PGLSL_{25}$ burial ages of cobbles are in agreement with the depositional ages determined by conventional pIRIR dating of sands from the same strata. The results shed light on employing this signal for establishing detailed chronological sequence of fluvial terraces of Jingou River in future.

Key words pIRIR PGLSL; buried age-dating; Luminescence-depth profiles; D_e value; fluvial terrace

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O.5-4: Luminescence dating of cobbles to determine the retreat of the last British-Irish ice sheet

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In the last 15 years measurements of the optically stimulated luminescence (OSL) signal from single sand-sized grains of quartz have been used to date glaciofluvial sediments [e.g. 1, 2], but this approach requires complex statistical models to identify the population of grains that were bleached. Recent studies have shown that high-precision luminescence ages can be obtained from cobbles buried within glaciofluvial sediments [3,4]. Changes in luminescence intensity, with depth into cobble sub-surfaces, provide a potentially unambiguous record of the extent of bleaching at deposition and cobbles therefore potentially offer significant advantages for dating heterogeneously-bleached sediments. However, dating cobbles from glaciofluvial sediments is still relatively novel and many questions remain. The aim of this study is to test the method on sediments deposited during the retreat of the last British-Irish ice sheet.

Cobbles were obtained from glaciofluvial deposits from three different locations across the UK. Two sites are located on the north-west coast of Wales (Nefyn and Bryn-yr-Eryr) and the age of the sediments is constrained by single grain OSL and cosmogenic isotope ages from the region [2], and the third site (Bridgwalton) lacks age constraint but is the southernmost extent of the terrestrial-terminating Irish Sea glacier. The L_n/T_n ratios for both the $IRSL_{50}$ and post-IR $IRSL_{225}$ signals were measured for 61 different cobble surfaces from these sites. At Bridgwalton, bleaching was observed up to ~ 7 mm into a cobble sub-surface and the age from this cobble has provided new constraints on the maximum extent of the Irish Sea glacier [2]. In contrast, at Nefyn and Bryn-yr-Eryr, $IRSL_{50}$ L_n/T_n ratios only remained low for the upper ~ 2 mm of the cores making it hard to provide an unambiguous record of the extent of bleaching at deposition. However, $IRSL_{50}$ ages from the surface slices of a number of cobbles from Nefyn are consistent with each other and averaging these yields an age of 24.8 ± 2.5 ka that agrees with independent age control (21.2 – 23.4 ka) within uncertainties. For Bryn-yr-Eryr the ages from the surface slices are consistent with each other, but they yield an age that is much younger than expected, and reasons for this will be discussed.

Keywords cobbles; post-IR IRSL; glaciofluvial; grain-size; poorly-bleached

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O.5-5: Investigating the luminescence dating potential of beach pebbles and cobbles associated with the last (~16 ka) pluvial lake highstand in the Great Basin, USA

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In the Great Basin, Quaternary climatic oscillations driven by orbitally controlled northern hemisphere summer insolation impacted a vast system of over 80 pluvial lakes occupying tectonically controlled basins [1]. The sedimentary and geomorphic archives preserved in these lake basins record a complicated history of lake expansions and contractions extending back 100's of thousands of years. Ancient pluvial lake beach ridges in the Great Basin also serve to demarcate areas of human habitation next to invaluable water sources during the late Pleistocene and Holocene epochs [2]. The timing of the most recent pluvial lake highstand associated with the Sehoo lacustral, is well constrained to ~16 ka by hundreds of radiocarbon ages from inorganic carbonates, shells, ostracods, bone, collagen, wood, and charcoal [e.g., 3 and references therein]. In this study, we test luminescence dating methods for rocks on beach ridge pebbles and cobbles associated with the Sehoo highstand in the Coal Valley region of Nevada, USA, to develop dating methods for chronologically unconstrained pluvial beach deposits here and elsewhere in the Great Basin.

Past research in Coal Valley, has revealed challenges associated with traditional luminescence methods of dating pluvial lake shoreline features using silts and sands. Silts and sands sampled from beach ridges have yielded ages that severely underestimate the age of the landform based on radiocarbon ages and regional lake studies. This age discrepancy is caused by a difference in the mobility of finer grain size fractions relative to larger clasts in shoreline deposits. Finer grained silts and sands that make up the matrices of gravels are commonly winnowed away by waves and replaced with much younger wind-transported sediment that infiltrates the porous gravels thousands of years later. Accurate luminescence age estimates of beach ridges in these cases can only be obtained by sampling the larger, more stable constituents of these landforms (i.e., pebbles and cobbles). Thus, this research intends to test luminescence rock dating methods on pebble and cobbles from the Coal Valley region to determine the feasibility of obtaining more reliable ages from pluvial lake deposits. We anticipate that these new methods, developed on landforms associated with archaeological sites by elevation and proximity, may later be directly applied to archaeological features such as rock circles, cairns, walls, rock art, or artifacts. This new geochronology will not only constrain the timing of lake level fluctuations in the Great Basin, but also further our understanding of how the Great Basin's earliest inhabitants adapted to changing environmental conditions that effected their water supply.

Keywords Rock dating; Pluvial lakes; Great Basin; Beach ridges; Archaeology

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O.5-6: What do feldspar single-grain dose distributions tell us?

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Quartz OSL dating is usually the method of choice as the quartz OSL fast component bleaches rapidly and the signal is stable over the timescales of interest. For palaeodose estimation often small aliquots are measured to detect overdispersion in equivalent-dose (D_e) distribution caused by heterogeneous bleaching or post-depositional mixing. As the luminescence signal of each of the aliquots is dominated by a few grains, appropriate 'age' models can be selected to obtain the palaeodose from the dose distribution. However, in some cases true single-grain information is needed to gain insight in causes of overdispersion and identify which 'age' model is appropriate. As quartz single-grain dating is notoriously cumbersome for most environments, we explore the added value of single-grain feldspar measurements in such cases.

Feldspar post-IR IRSL (pIRIR) methods largely circumvent anomalous fading problems and paved the way to obtain valid equivalent doses from feldspar. Single-grain pIRIR dating of K-feldspar grains is relatively straightforward, as about half of the grains often have sufficient luminescence sensitivity to determine an equivalent dose. Hence, measurement of a single disc with 100 positions in a Risoe single-grain reader already provides a meaningful D_e distribution for most samples. Using a full SAR procedure, such a measurement takes between a few hours and a day for a young or old sample, respectively.

In this presentation we share our experiences with single-grain pIRIR dating to investigate D_e distributions. We compare results obtained using small-aliquot quartz with those obtained using single-grain pIRIR. For some samples the pIRIR results showed a clear bimodal distribution, while quartz results were scattered due to within-aliquot averaging. In addition, we discuss challenges with regard to dose-recovery and experiences with overdispersion of single-grain pIRIR D_e distributions.

Keywords feldspar single-grain; pIRIR; heterogeneous bleaching; post-depositional mixing

P.5-3: Investigating the dependence on excitation wavelength of luminescence bleaching and sensitivity change in rocks

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Optically and infrared stimulated luminescence (OSL and IRSL) dating are well-established techniques for determining absolute chronologies, and have been successfully applied to a wide range of sedimentary deposits. Recently, based on the measurement of luminescence-depth profile perpendicular to the rock surface, these techniques have been extended to estimate burial or exposure ages of rocks. In the high-resolution infrared photoluminescence (IRPL) and IRSL images of luminescence depth profiles, it has often been observed in our lab that the sensitivity corrected signal (L_n/T_n) deviates from the expected exponential form near the rock surface. In particular, it rises in the first few mm towards the surface. This problem is of considerable importance both for fitting of exposure models to the experimental data, as well as for the accuracy of derived equivalent dose from the surface slices. Although still under investigation, our data suggests that this apparent rise in L_n/T_n is due to a loss of luminescence sensitivity close to the surface.

In this work, we explore sensitivity changes in previously unexposed rock interiors due to bleaching. Feldspar rich granites were sampled from the Risø beach in Denmark. Several 10 mm cores were drilled from the saturated part and were subsequently cut into slices. First, the natural IRPL signal was acquired using the Risø TL-OSL reader. The same slices were then progressively bleached using different wavelengths comprising the solar spectrum, namely 320, 365, 410, 460, 528, 590, 617, 656, 740 or 850 nm. The IRPL signals (880 and 955nm) were monitored after each bleaching event thus providing a power-normalised bleaching-response curve for different wavelengths. After the IRPL signals reached a background, the samples were given a test dose to measure sensitivity change as a function of the bleaching wavelength. The same experiment was repeated for a sample that had been heated to empty the pre-existing signal and then given a gamma dose.

We will present and discuss the results from these investigations to conclude on dependence of IRPL bleaching and sensitivity change on the excitation wavelength.

Keywords: Rock surface dating; Infra-red photoluminescence (IRPL); sensitivity change

P.5-4: Evaluating the parameter values of the bleaching-with-depth-model for rock surface exposure dating – an empirical approach

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OSL Rock surface dating (RSD) is used increasingly in the geosciences and in archaeology, because it allows for a range of new dating applications (e.g. Jenkins et al., 2008; Gliganic et al., 2021). One RSD variant – rock surface exposure dating (RS*e*D) – is based on the principle that the light-sensitive OSL signal is bleached within the first few millimetres to centimetres of a light exposed rock surface as a function of (i) exposure time (t), (ii) the material specific optical attenuation of light flux (or rock transparency, μ), and (iii) the wavelength dependent decay rate of the luminescence signal at the rock surface($\overline{\sigma\varphi_0}$) (Sohbati, 2012). The surface bleaching rate $\overline{\sigma\varphi_0}$ is directly influenced by factors such as latitude, longitude, altitude, rock surface orientation and site-specific shadowing effects. For RS*e*D $\overline{\sigma\varphi_0}$ must first be obtained from a known age rock surface with no erosion, which the same lithology as the rock surface of unknown age (i.e. shows identical μ and σ) in order to derive an exposure time (t) (Lehmann et al., 2019). Another pre-requirement for such a cross-calibration to be valid is that the known age rock surface and the unknown age calibration surface both have identical φ_0, which in practice often implies that they are from the same site and are facing in the same direction. Because exposure time (t), μ and $\overline{\sigma\varphi_0}$ all directly influence the shape and depth of the bleaching front and because of the need for $\sigma\varphi_0$ cross-calibration in RS*e*D, careful evaluation of these parameters of paramount importance. Meyer et al. (2018) and Ou et al. (2018) investigated how changes in rock opacity (μ) affect light penetration into rock surfaces, however, until now little is known about the relative importance of the $\sigma\varphi_0$ parameter for the formation of bleaching profiles.

We carried out experiments where unbleached samples from two different lithologies (granite and quartz sandstone) were exposed to sunlight, facing roughly into the four cardinal directions north, east, south, and west as well as vertically upward, i.e. into the open sky. The amount of solar insolation reaching each sample was determined via a set of pyranometers, placed next to each rock sample. After four months of light exposure (June 11th to October 25th 2019), the bleaching profiles of all rock samples were measured and the respective bleaching depths were compared to the insolation measurements as well as rock colour characteristics (as a proxy for μ). The results of these investigations are presented.

Keywords : Rock surface dating; exposure dating; photon flux;

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P.5-5: Dating a catastrophic flood in the Altai mountains using Rock Surface Luminescence

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Evidence of catastrophic discharges of huge masses of water from glacial dammed lakes was discovered in the Altai mountains (southern Siberia) in the 1970s and 1980s by Soviet geologists; these discharges are seen as one of the five most powerful fluvial disasters in the history of the Earth [1]. Evidence includes long-wavelegth ripples of cobbles in the valleys of large rivers, spillways, vehicle-sized blocks of rocks transported over considerable distances, and incised deposits of thickness up to 200 m. These landforms are presumed to have resulted from catastrophic drainage of an ice-dammed lake during deglaciation [2].

Despite the long history of study in the region, there is still no consensus on the timing or magnitude of the outburst flood. The main problem is the lack of data on the age of the sediments and landforms. Conventional OSL dating is not suitable, because of the coarseness of the deposits and the improbability of bleaching during the event. However, in places gravel units contain beds of cobbles and boulders, providing the option of using rock surface OSL dating. Large clasts have a different transport history to the gravel sediment, and some may have had prolonged daylight exposure prior to final transport and deposition. Luminescence depth profiles into a rock surface also provide evidence of whether individual clasts were sufficiently bleached.

We sampled granite and quartzite clasts from several sections in the gravel terraces of the Katun and Chui rivers in the Altai mountains. Further clasts were collected from the giant ripples in the Kurai depression – the presumed bed of the formerly ice-dammed lake. More than 20 cobbles have been examined, and two age clusters were obtained, of 17-19 ka and 3-5 ka. We associate the first cluster with large-scale floods that occurred in the valley of the Chuya river as a result of deglaciation, the second is explained by local reworking events of a smaller scale.

This work was carried out with the financial support of the Russian Science Foundation project No. 19-17-00179.

Keywords rock surface dating; Altai Mountains; catastrophic flood; LGM; deglaciation

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P.5-6: Trialling the Use of Controlled Exposure Experiments for Optical Surface Exposure Dating on Quartzite Quarry Surfaces in Washington State

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Optically stimulated luminescence (OSL) depth profiling utilizes an OSL-at-depth signal to extrapolate an exposure age from a rock's surface. The depth profiling model proposed by Sohbati et al. [1] represents luminescence intensity at depth x (L) relative to an unbleached intensity (Lo) in the form: $L = L_0 e^{-\overline{\sigma\phi_0}\, te^{-\mu x}}$, which follows the double exponential shape of bleached depth profiles based on first order luminescence kinetics from a single trap, as well as the exponential optical attenuation (μ) of surface photon fluence rates relative to depth into the surface. Exposure ages (t) are obtained by fitting the forms of bleached profiles, which depend on parameter estimates of μ as well as the variable $\overline{\sigma\phi_0}$ that combines a single value of σ, the effective photoeviction cross-section for a trapped charge (cm^2), with ϕ_0, the incident solar photon flux ($cm^{-2}\ s^{-1}$). Age calculations are possible between $<10^2$-10^4 years [2].

Current procedures for obtaining variables $\overline{\sigma\phi_0}$ and μ for a rock surface require matching OSL depth profiles from compositionally and morphologically matched rock surfaces with known exposure ages. Derived variables from such proximal sites are used to calculate ages from the age-unknown rock surface. Problems arise in that similar rocks can produce inconsistent $\overline{\sigma\phi_0}$ and μ variables [2][3]. Also, the method can only be performed where well-dated proximal matches are available, severely limiting the scope of applications. Uncertainty in proximal sample exposure ages reduces precision further [4].

A modified technique will be presented to improve the accuracy and applicability of depth profiling methods. This new procedure aims to reliably determine $\overline{\sigma\phi_0}$ and μ directly from the rock surface of interest using ^{60}Co gamma irradiated surface samples subjected to controlled sunlight exposures. The technique will be tested this summer on quartzite rock surfaces of known annual and decadal ages at Lane Mountain Quarry in eastern Washington, USA. The derived ages from each quarry surface using this technique will be compared with surface ages produced using the proximal surface method. If serving an improvement over the proximal method, the controlled exposure technique can offer depth profiling applications at sites where either no proximal rock surfaces exist or proximal samples are deemed problematic. Future applications will be considered on glacial erratic quartzites in southwest Alberta.

Keywords: surface exposure dating; OSL; Quaternary geology; quartzite; Pacific Northwest

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P.5-7: Challenges in luminescence dating of the last glaciation maximum in the southern Black Forest, Germany

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During the last glaciation maximum, an ice cap and its more than 20 kilometres-long outlet glaciers covered the highest summit of the Black Forest, the Feldberg (1493 m above sea-level), and the surrounding region [1]. This event has hitherto not been dated by applying up-to-date geochronological techniques to glacial deposits or landforms. Due to the lack of significant topographic control, the climate probably mainly controlled the mass balance of the ice cap. Dating its last maximum extent may thus have important implications for the reconstruction of atmospheric circulations patterns during the Pleistocene. A last glaciation maximum out of phase with the Alps would strengthen the hypothesis that a meridional atmospheric circulation prevailed over Europe during the last glaciation maximum in the Alps (at ca. 25 ka).

We aim at filling this gap by re-investigating a well-preserved, multi-ridged terminal moraine complex several kilometres north-west of the Feldberg. Since the beginning of the twentieth century, this landform is undisputedly assigned to the last glaciation maximum. As units of sorted sediments occur in two sections on one ridge of the terminal moraine complex, luminescence dating was deemed a suitable technique to infer the age of the landform. We decided to apply luminescence dating to both quartz and feldspar, as these dosimeters have different drawbacks. Since quartz from crystalline source areas often shows no or only a relatively weak luminescence signal, we anticipated that this also applies to the sampled sediments from the crystalline part of the Black Forest.

Optically-stimulated luminescence (OSL) measurements revealed a bright signal in quartz. Developing a suitable measurement protocol for determining the palaeodoses proved to be difficult. A thermally unstable medium component turned out to be the major obstacle. OSL measurements revealed palaeodoses in the order of 400 Gy below the saturation level. This finding contrasts with results of previous studies on glacio-fluvial sediments in the northern Foreland of the European Alps, as quartz from this area has a considerably lower saturation level. Although the measured palaeodoses are overdispersed, we did not find any obvious signs for partial bleaching. This possibility will be evaluated via further OSL measurements, since the sampled sediments were not transported over large distances. Component analysis will also be performed.

Infrared-stimulated luminescence (IRSL) measurements on feldspar will be undertaken. It is expected that anomalous fading and partial bleaching will be two major future challenges. To overcome the first problem, post-infrared IRSL dating will be applied. As resetting of this signal is more difficult when compared to IRSL and OSL signals, problems associated with incomplete bleaching may arise in future work.

Keywords Luminescence dating; Glacier; Last Glacial Maximum; Moraine; Black Forest

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P.5-8: Luminescence chronology of Middle Pleistocene sediments from the Lower Aare Valley region, northern Switzerland

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The northern foreland of the Swiss Alps has seen multiple glacial advances during the Middle and Late Pleistocene. While the latter have been readily chronologically constrained, numerical dating of older advances have had its shortcomings. This is mainly due to a limited source of suitable dating techniques and a seemingly upper age limit of quartz OSL ages at about 200 ka. However, the reconstruction of the landscape evolution of northern Switzerland has become a crucial component, particularly for the long-term safety assessment of deep geological repositories for radioactive waste.

To constrain a conclusive chronology, coarse-grained quartz and feldspar extracts were obtained from pro- to periglacial deposits of an overdeepened valley setting (Lower Aare Valley) and different luminescence approaches were trialled. The luminescence properties of quartz and feldspar from the study area have been described in detail previously [1], as has been the application [2] of state-of-the-art standardised growth curve approach [3] and the L_nT_n-method [4]. Presented here is the complete data set comprising conventional quartz OSL ages, fading corrected IR_{50} and uncorrected pIR_{225} feldspar ages. Methodological aspects and implications for the glacial history of the Swiss Alps will be discussed.

Keywords Switzerland; Middle Pleistocene; OSL; pIR; IR_{50} fading correction.

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P.5-10: Testing a novel Weichselian ice advance model for the SW Baltic Sea region by new quartz OSL ages from the Jasmund peninsula (Rügen Island)

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A new model for Weichselian advances of the Scandinavian Ice Sheet (SIS) into the southwestern Baltic Sea region has been proposed by Lüthgens et al. [1]. These authors reinterpreted available age data and concluded that the main ice advances occurred during early and late MIS 3 and during MIS 2. One line of their reasoning is based on a chronological reinterpretation of the Jasmund Glacitectonic Complex (JGC) genesis on the island of Rügen. Gehrmann & Harding [2] presented a multi-stage evolutional model for the JGC in which the formation was caused by SIS advances during MIS 2. In contrast, in the new concept of Lüthgens et al. [1], an early MIS 3 ice advance formed the northern part of the JGC, whereas the formation of the southern part is related to a late MIS 3 ice advance. If true, the entire glacitectonic genesis of the JGC needs to be rethought and rewritten.

In order to review this model, we present a set of new quartz OSL ages from a key profile near Glowe. The cliff outcrop is located on the northwesternmost end of the northern JGC, which offers one of the most complete Pleistocene successions in this area. The profile consists of diamictic units interpreted as subglacial tills and intercalated (glaci-)fluvial to (glaci-)lacustrine sediments. The tills represent ice advances during the Saalian and Weichselian Glaciations, whereas the intercalated units were deposited under ice-free conditions, most likely exclusively during the Weichselian. Consequently, the dating of the sorted sediments below and above the tills by OSL allows an indirect age constrain of the ice advances. With the obtained new luminescence ages and the available age data set from the Rügen Island, we are able to evaluate the new ice dynamic model with special focus on the formation of the JGC as proposed by Lüthgens et al. [1].

Keywords OSL dating; Weichselian Glaciation; Scandinavian Ice Sheet; ice dynamic; glacitectonism

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P.5-11: Optical Chronology and Climatic Implication using Equilibrium-Line Altitude of Late Quaternary Glaciations in Nubra Valley, Karakoram Himalaya, India

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Compared to the monsoon dominated central Himalaya, where the high surface erosion, constrain the preservation of older glacial deposits, the Trans-Himalayan glaciers provides unique opportunity to understand the Quaternary climatic history. These glacial remnants help in establishing Equilibrium Line Altitude (ELA) which is a major indicator of climate change. The former ELA was calculated by determining the elevation of moraines using Total Station Survey. The modern ELA is obtained from Digital Elevation Model (DEM) using ArcGIS ELA Toolbox. The investigations of Nubra Valley in Karakoram indicate distinct events of glacier expansion with varying values of ELA. The lateral and latero-frontal moraine around Nubra-Shyok confluence (Tirith-II) dates back to 60 ka and is elevated at 3900 m. Following this, occurrence of multiple recessional moraines of decreasing elevation (3400 m) suggests pulsating thinning of the ice volume which persisted until 42 ka. This advancement is represented by Tirith-I (30 ka and 18 ka) situated at an elevation between 3500 and 3200m. The OSL ages are at variance with the exposure ages by others. The well-developed paired lateral moraines and assigned as Siachen Glacial Advance (SGA) dated to 6.8 and 7.2 ka, whereas the snout proximal recessional moraines are dated between 1.0 and 0.5 ka. The corresponding moraine elevation values are 3576, 3570, 3600 and 3598m respectively. These are referred to as former ELA values. The modern ELA values calculated from 2002 to 2016 lies between 4755 and 4888 m. The shift in ELA over years is attributed to either winter precipitation or summer temperature. This study, therefore, presents a reason for the shift by obtaining a trend line of the contributing factors for ELA.

Keywords: Optical chronology; ELA; Westerlies; North-western Himalaya; Siachin glacier.

P.5-12: Using single grains of feldspar for the dating of glaciofluvial sediments – key results from a case study in the Drau glacier area, Austria, for unravelling Alpine chronologies

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For more than a century, efforts in establishing and improving glacial stratigraphy in the Alps have predominantly been focused on the northern flank of the Alps and its foreland. On the other hand, recent progress in constraining the timing of the LGM (last glacial maximum) in the Alps was achieved on the southern flank. However, even for the short time span of the LGM, our understanding of e.g. climatic gradients from N to S and W to E across the Alps is limited due to sparse data especially in the inner alpine areas. Here, the area of the former Drau glacier system, located in the south-eastern sector of the Alps, comes into play. It is characterized by extensive sedimentary archives of the Last Glacial cycle, which can be traced from the LGM terminal moraines to areas close to modern glaciers, offering the opportunity to constrain glacial chronology and dynamics and close the gap in knowledge between the northern and the southern flank of the Alps. However, metamorphic and carbonatic source rocks dominate the catchment area, which limits the use of quartz as a dosimeter, mainly because of low sensitivity of the quartz in general, as well as the occurrence of medium and slow components in the quartz signal.

Recent studies from the European Alpine foreland [1] highlight the obstacles, but also the chances in deciphering the chronology of glaciofluvial sediments and thereby of glacial processes using feldspar as a luminescence dosimeter. In this study we built on previous work at the Vienna Laboratory for Luminescence dating (VLL), successfully dating glaciofluvial sediments from another research area, the Patagonian Andes, using single grains of potassium-rich feldspar [2,3]. We present and compare luminescence data and ages derived from post infrared infrared (pIRIR) luminescence SAR (single aliquot regenerative) dose protocols using stimulation temperatures of 50°C (IR50) and 225°C (pIRIR225). The obtained ages were integrated into a geomorphological and geochronological model for the development of the tongue basin of the Drau glacier and its forefield, for the first time constraining the timing of advance and retreat of the Drau Glacier from pre-LGM times to Termination I. The key findings from this study may provide the methodological tools for unravelling previously unexplored glacial chronologies from Alpine settings.

Keywords feldspar, single grain, IRSL, Alpine, glaciofluvial

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Session 6:
Luminescence and ESR dating of marine, fluvial and lacustrine sediments

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O.6-1: Holocene evolution of buried tidal sand body in North Jiangsu Plain of China based on luminescence dating

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Coastal tidal sand body is formed under the interaction of climate, sea-level change, tidal currents and sediment supply, which records the information of land-sea interaction. The buried tidal sand body on the coastal zone of northern Jiangsu Province is closely related to the coastal plain evolution. However, there is a lack of systematic chronological study of the sand body. This limits our understanding of the formation mechanism of the tidal sand body. In this study, optically stimulated luminescence (OSL) dating technique is used to develop a reliable dating methodology for coastal sandy deposits.

Two sediment cores (LDC and XYK) were drilled from the western (inshore) and eastern (offshore) part of the buried tidal sand body in North Jiangsu Plain to depths of 26 and 25.6 m, respectively. A total of 17 and 22 OSL samples were respectively obtained from cores LCD and XYK. Two different quartz grain-size fractions of 45–63 μm and 90–125 μm were extracted to determine the sediment ages using small aliquots (2 mm) and single grains, respectively. The results showed that the 90–125 μm quartz OSL ages were systematically older (~0.2-3.4 ka) than the corresponding 45–63 μm quartz OSL ages of most samples. If the higher values of sand-sized quartz OSL ages were caused by incompletely-bleached residuals, then the single grain technique would be very efficient at detecting incomplete bleaching, and accompanied by high overdispersion (OD) value. However, the above hypothesis is not supported by our data, and large age difference between two grain-size fractions are pretty much irrelevant to the OD value of sand-sized OSL ages ranging from 14% to 64%. Indeed, two separated peaks are identified for the 45–63 μm D_e probability distribution, and their relative younger ages were directly affected by the lower of the two peaks corresponding to a small number of aliquots (~10-15%). Based on grain-size analysis of these two cores, it was found that mean grain size of sediments is mainly concentrated in 80-150 μm. In combination with the sedimentary environment and facies analysis, we suggested that sedimentary environment changes, such as the transition of tidal channel and sand ridges, would facilitate fine sediment infiltration into coarser sediment on the interface between new and old sediments. The above process will lead to a low OSL age yielded by relatively finer silt-size grains. When the aliquots distributed on the left weak peak of D_e distribution were rejected, two group OSL ages obtained by silt- and sand-sized grains are consistent, ranging from 0.07 ka to 10 ka with many sedimentary hiatuses. Finally, Holocene evolution of buried tidal sand body in North Jiangsu Plain will be discussed in conjunction with relative sea-level changes. Collectively, our results highlight the importance of understanding how sedimentary process of tidal sand body affects the robust interpretation of OSL ages

Keywords Chronology; Holocene; Sediment infiltration; Depositional dynamic; North Jiangsu Plain

O.6-2: Controls on luminescence signals in lake sediment cores: a study from Lake Suigetsu, Japan

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Sediment cores retrieved from Lake Suigetsu, Japan, provide an unparalleled limnological record of the annual- to millennial-scale climatic and environmental changes of the late Quaternary in East Asia. Chronological control for the most recent ~50,000 years is robustly defined by >800 radiocarbon dates, manual and automated varve counting, and tephra tie-points. The cores themselves extend beyond this period, to in excess of 160,000 yr BP (98 metres of composite sediment accumulation) and are the subject of ongoing multiproxy analysis including pollen and stable isotopes.

The Suigetsu cores offer an exciting opportunity to produce a long-term assessment of luminescence dating from MIS6 to MIS1. This study appraises the luminescence characteristics of the Suigetsu cores during four key time periods, each selected for their unique environmental context and significance on either a local or global scale. The four periods are: 1) from 500 yr BP to the present day, which includes the artificial connection of the lake to the Sea of Japan in 1664 AD and subsequent seawater incursion (24 samples), 2) from 45,000 to 35,000 yr BP, a period of global change containing the Laschamp geomagnetic excursion (11 samples), 3) from 73,000 to 69,000 yr BP, including the transition from non-varved to varved sediment in the Suigetsu cores (12 samples), and 4) from 140,000 to 118,000 yr BP, encapsulating the transition from MIS6 to MIS5e, also known as Termination II (13 samples). The selection of these time periods also allowed for characterisation of variations in net luminescence signal and sensitivity across periods covered (1 and 2) and not covered (3 and 4) by the existing chronology.

Rapid IR- and blue light- stimulated luminescence profiles were made in Japan using a portable OSL (pOSL) system and small samples put through laboratory profiling procedures at SUERC to register luminescence sensitivities and estimated dose profiles from quartz and polymineral extracts. Together, this suite of measurements provides unique insight into the environmental changes occurring during each time period and an appraisal of the suitability of this material for dating across a range of key late Quaternary ages. The results of our analysis will be presented in this paper and contribute to our wider understanding of the application of luminescence techniques to lake sediment cores.

Keywords luminescence profiling; sediment core; Lake Suigetsu; Quaternary change; environmental change

O.6-3: Luminescence dating of Late Pleistocene deposits in Hangzhou Bay, China

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The environmental evolution of coastal zones since late Pleistocene, especially the study of transgression-regression cycles caused by sea-level changes, has become an increasingly important scientific significance for predicting the sustainable socio-economic development of coastal zones under future global warming. Hangzhou Bay is the largest funnel-shaped estuary in China. Sediments in Hangzhou Bay are mixed from multiple sources, which are influenced not only by the provenance of the Yangtze river, but also by the sediment from the Qiantang River and the sea. Thickness of sediments since the Late Pleistocene can reach more than 100 m distributed to the Ningbo-Shaoxing Plain in the south bank of Hangzhou Bay, where coastline changes are closely related to the development of the Yangtze River Delta. It is an ideal location for studying land-sea interaction. At present, there are few chronological studies on the stratigraphy of the southern wing of Hangzhou Bay since the Late Pleistocene, especially early stage of Late Pleistocene sediments. Accurate and abundant dating data are indispensable for the study of high-resolution stratigraphy. With the rapid development of optically stimulated luminescence (OSL) technique over the last two decades, both the accuracy and precision have been greatly improved, which provides a new opportunity for the determination of the late Quaternary stratigraphic chronology in the coastal zone.

In this study, core BZ (156 m depth) was collected on the southern bank of Hangzhou Bay. Sixteen OSL samples were obtained. Single-aliquot and single-grain optically stimulated luminescence (OSL) dating techniques are carried out to study the luminescence properties of different particle-size (4-11 μm, 45-63 μm, 90-125 μm, 150-180 μm and 150-224 μm) of quartz and feldspar. It should be pointed out that the quartz in the sediments of the Yangtze River Delta is dominated by the fast component according to our previous studies, but the quartz luminescent signals of the late Pleistocene sediments from southern Hangzhou Bay are dominated by non-fast components, which may indicate different sediment provenance. Component-related problems in OSL of quartz can affect the accuracy of the dating. Two paired De values are calculated for these component-related samples by a computerized deconvolution procedure and early background subtraction (EBS), to evaluate effectiveness of EBS method in the area. Our dating result shows that the Holocene deposits of core BZ1 began at a depth of ~60 m below the land surface, and the deposits belonging to Late Pleistocene are buried to depth of ~150 m. The core in the area recorded three major marine transgression since the late Pleistocene, which corresponded to MIS 5, MIS 3, and Holocene, respectively.

Keywords Qiantang River; Optically stimulated luminescence (OSL) dating; Fast component; Marine transgression; Sea-level change

O.6-4: Luminescence applications in marine sediment cores: challenges and perspectives

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Marine sediment cores are unique archives for past climate reconstructions since they can store information from the ocean and the continent. Over the past decades, marine sediment cores had a key role in paleoenvironmental reconstructions, leading to the development of several new proxies to attain different parameters to track changes in rainfall, vegetation and oceanic circulation. Beyond paleoenvironmental reconstructions, the oil and gas industry uses gravity marine sediment cores to evaluate geohazards in deep-sea infrastructure implementation for hydrocarbon exploration and production. In this context, luminescence methods figure as a promising tool for dating and provenance analysis of marine sediments. Besides the possibility of extending the time covered by radiocarbon dating, the luminescence sensitivity of quartz was successfully used as a proxy for past precipitation (Mendes et al., 2019). Here we present three examples of luminescence methods applications to marine sediment cores retrieved in the western equatorial Atlantic: (i) We obtained 11 OSL ages both with single aliquot regenerative dose (SAR) and standardized growth curves for core GeoB16224-1; (ii) Luminescence sensitivity of quartz for core GL1248; (iii) We tested different protocols to measure quartz OSL sensitivity for tracking the continental sediment supply (core GeoB16206-1), with measurements at room temperature and in bulk samples (without chemical treatment).

The results show good agreement between ^{14}C ages and the OSL ages obtained with the SAR protocol and the standardized growth curves for the same marine sediment core. The luminescence sensitivity data from the marine sediment core GL1248 spans the last 100 kyrs and can be compared with the other published sensitivity data for the same region. The comparison between different marine sediment cores, measured in two different readers, was possible by statistically normalizing the data. Finally, the OSL sensitivity measurements at room temperature in bulk sediment samples without chemical treatments can also be used to track continental precipitation in the same way as presented by Mendes et al. (2019). Despite the promising results obtained so far, there is still plenty room for improvements in using luminescence to study marine sediments.

Keywords OSL ages; quartz luminescence sensitivity; marine sediment core; past precipitation

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O.6-5: Quartz OSL dating of deep marine sediments from the continental slope offshore Israel

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Submarine sediments can move along the continental slope via submarine channels, turbidity flows, or landslides. Mass sediment movement can damage underwater infrastructure such as oil pipes or communication lines. These features have been studied extensively, yet it is very hard to date the movement of the sediment. Chronology is usually established with stratigraphic relationships, biostratigraphy, and radiometric dating of foraminifer shells. Dating deep-sea sediments with optically stimulated luminescence (OSL) methods is not common due to significant dose rate uncertainties and bleaching issues at the great water depth. In a case of a turbidity flow or a landslide, the OSL dating is even more complex as the sediment moves for long distances under water without any additional exposure to sunlight and only the final mixed sediment is dated.

Here we test the applicability of quartz luminescence dating for deep-sea sediments from various environments offshore Israel, from water depths of 100 to 1000 m: a submarine canyon, a landslide scar, and an open slope. Twenty-six samples from eight different sediment cores were dated with OSL on very-fine-sand quartz grains and small (2 mm) aliquots. Samples with high overdispersion were also dated using single grains. The OSL ages were compared to ^{14}C ages on benthic foraminifers.

Modern up to middle Pleistocene ages were obtained. The equivalent dose distribution of most samples implies adequate bleaching that must have taken place during transport and before deposition in deep water. The single grain data suggest sediment mixing rather than poor bleaching for the heterogeneous samples. The OSL and the ^{14}C ages are in agreement for the landslide and open slope samples, however for the submarine canyon sediments, there is no consistency between the two methods, probably due to more complex geomorphological processes involved in a canyon environment such as canyon wall collapse and turbidity flows. Our results suggest that the OSL method can be used for the open slope sediments. For submarine channels, the OSL dating can provide only a rough estimate of the sediment age.

Keywords Quartz OSL; Single grain; deep-sea sediments.

P.6-2: Illuminating the speed of sand – quantifying sediment transport using optically stimulated luminescence

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Sediment burial dating using optically stimulated luminescence (OSL) is a well-established tool in geochronology. Yet, an important prerequisite for its successful application is that the OSL signal is sufficiently reset prior to deposition. However, subaqueous bleaching conditions are vastly understudied, for example the effect of turbidity and sediment mixing on luminescence bleaching rates is only poorly constrained. The possibility that slow bleaching rates may dominate in certain transport conditions led to the concept that OSL could be used to derive sediment transport histories. The feasibility of this concept is still to be demonstrated and experimental setups to be tested. Our contribution to this scientific challenge involves subaquatic bleaching experiments, in which we suspend saturated coastal sand of Miocene age in a circular flume and illuminate for discrete time intervals with natural light. We further record the in-situ energy flux density received by the suspended grains in the UV-NIR frequency range by using a broadband spectrometer with a submersible probe.

Our analysis includes pre-profiling of each sample following a polymineral multiple signal protocol [1], in which we simultaneously measured the quartz dominated blue stimulated luminescence signal at 125°C (BSL-125) and the K-feldspar dominated post-infrared infrared stimulated luminescence signal at 155°C (pIRIR-155). Preliminary results from the flume experiments show that the bleaching rates are indeed slow, differ for both signals and that the feldspar pIRIR155 seem to bleach faster than the quartz BSL125. Besides the good prospects of acquiring a new tool for quantifying sediment transport, these results might have important implications regarding the preferred target mineral for OSL dating in fluvial settings.

Keywords sediment transport; bleaching rate; BSL-125; pIRIR-155, OSL

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P.6-4: OSL Dating for the upper reaches terraces of Han River

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Abstract: River terraces represent an important component of fluvial archives, which records the evolution history of river geomorphology. According to accurate dating of terrace strata, it is impossible to reveal regional tectonic movement and climate change. Located in the south of Qin Mountains and north of Daba Mountains, the upper reaches of Han River lies in the key transitional zone between the northern part of the tropical monsoon climate region and the southern part of the temperate zone. Thick loess deposited on the terrace, which is an important carrier to study the age of terrace formation and climate evolution. Previous studies on the age of terraces in the upper reaches of the Han River River have mainly focused on the first-order terraces. In this paper, the luminescence dating of the sand layers of loess and floodplain facies overlying T2 and T3 terraces in the Hanzhong Basin, the Ankang Basin and the Yunyang Basin in the upper reaches of Han River, has been carried out. The equivalent doses of quartz and feldspar were measured by conventional SAR, TT-OSL and pIRIR methods. The results show that the ages of the top of the floodplain sand layers of T2 terraces in Yunyang Basin, Ankang Basin and Hanzhong Basin are 226.66 ± 22.37 Ka, 215.14 ± 9.99 Ka and 206.17 ± 18.04 Ka, respectively, while the ages at the bottom of the loess layer are 166.47 ± 6.66 Ka, 198.09 ± 9.65 Ka and about 180 Ka respectively. These are determined that T2 terraces in the upper reaches of Han River began to appear about 230 ka ago, and formed about 190 Ka at the latest. The oldest age of T3 terrace loess is 486.74 ± 27.71 Ka. Based on the data of paleomagnetic and cosmic nuclide ages, T3 terrace formed about 1 Ma ago. All these terraces' formation is the result of tectonic movement and climate change.

Keywords: Upper reaches of Han River; River terraces; OSL dating; Loess

P.6-6: Optically-stimulated luminescence dating of Holocene sediment cores from a wave-dominated delta in central Vietnam

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Global warming causes the sea level to rise, which then directly can affect the sensitive coastal environments. The coastal zone, especially river delta, is important for human activities. The research on long-term coastal development is particularly important for understanding and predicting its future changes. Vietnam has a long coastline along the East Sea (South China Sea). Two Holocene large deltas, Mekong and Red River in the southern and northern ends of the coastline, respectively, have attracted detailed and comprehensive studies on the sedimentary evolution along with well-established chronology. However, there have been few studies in the central coast of Vietnam. To clarify the deltaic sedimentary evolution in Holocene, we obtained two sediment cores (VG-1 and VG-2) from the Thu Bon delta, a cuspate wave-dominated delta, in central Vietnam and applied optically-stimulated luminescence (OSL) dating of quartz and feldspar to 35 samples. The 35m long core, VG-1 was collected at 3.9 km inland from the present shoreline. About 30m long core, VG-2 was collected 2.7 km seaward from the core VG-1 site. These cores both show the sediment succession composed of the lower muddy part and upper sandy part. Coarse grains (CG) of quartz and K-feldspar and fine grains (FG) of quartz and polymineral were extracted from the upper and lower parts, respectively, for measurements of the quartz optically-stimulated luminescence (OSL), feldspar infrared-stimulated luminescence at 50°C (IR_{50}), and feldspar post-IR IRSL at 175°C ($pIRIR_{175}$) to determine the burial ages to compare with radiocarbon ages of shells. Sedimentary facies and radiocarbon ages indicate that the lower part of the VG-1 core is the transgressive estuarine deposits overlain by the upper part, which is interpreted as sandy beach-shoreface deposits prograded just after the sea level reached highstand around 6 ka. The lower part of the VG-2 core in contrast, along with the sandy upper part, comprises a shallowing-upward inner-shelf to beach-shoreface succession representing the coastal progradation in relation to the sea-level highstand. The luminescence characteristics of the quartz and feldspar are suitable for the OSL dating. Ages of quartz OSL, feldspar and polymineral IR_{50}, and radiocarbon are reasonably consistent with each other. $pIRIR_{175}$ ages are largely consistent with OSL and IR_{50} ages in CG samples but are overestimated by several thousands of years in FG samples. These results indicate that mud was not well-bleached before the deposition regardless of its depositional environment (estuary or inner shelf) while sand was well-bleached in the beach and shoreface. Thus, different grain sizes have experienced different degrees of OSL signal bleaching during the transport in the river. Our results also reiterate that comparing the OSL results from multiple grain size fractions and different minerals is an effective way to ensure the reliability of OSL dating.

Keywords OSL dating; pIRIR175; IRSL50; Sea-level change; Vietnam.

P.6-7: Holocene fluvial dynamics of the Kampar River, Sumatra, Indonesia

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Tropical rivers are highly dynamic, driven by strong seasonal variability in discharge caused by monsoon-influenced precipitation and equatorial convective rainfall. The Kampar River, Sumatra, floods almost every year. However, little is known about its fluvial dynamics. This study will develop a chrono-stratigraphical framework at the time-scale of the Holocene for the Kampar River with the aim of understanding its long-term fluvial dynamics and flooding frequency relative to changing climate and vegetation. Volumes of sediments are transported by the meandering river system of the Kampar River (Figure 1), forming a series of metres-thick fluvial terraces and numerous abandoned channels that document its past dynamics. Five luminescence samples were collected from a 9.6 m-high fluvial terrace section in the vicinity of the Rumbio village (orange dot in Figure 1c). We used optically stimulated luminescence (OSL) of both quartz and K-feldspar minerals analyzed using single-grain dating to evaluate their signal characteristics and bleaching history over the Holocene. Our preliminary results provide the first numerical constraint on the Holocene fluvial activity of the Kampar River.

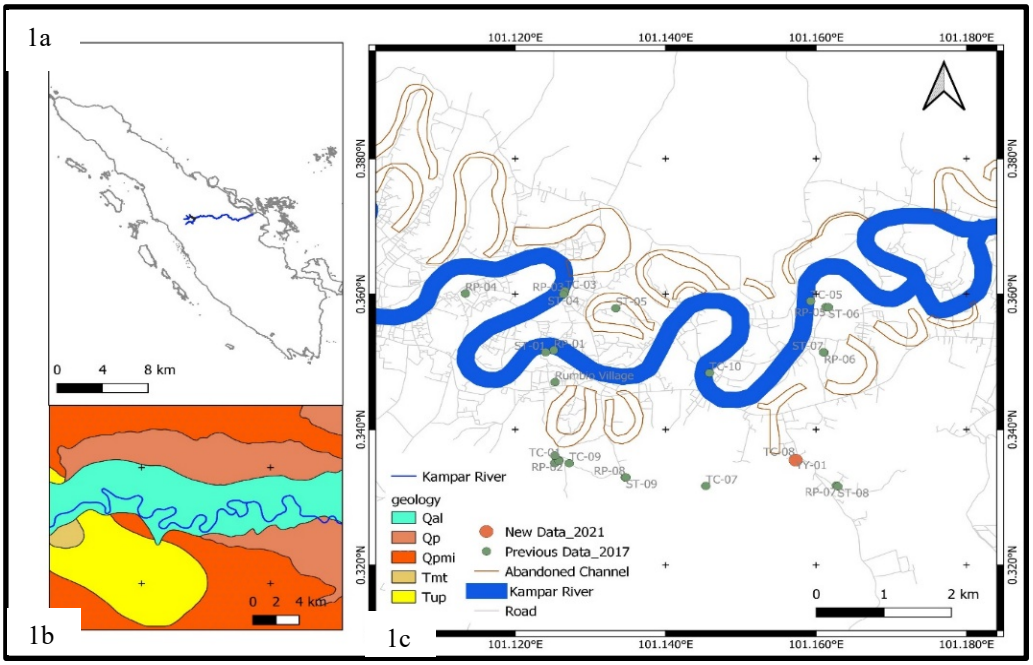

Figure 1. Research area in Kampar River, Riau Province – Indonesia

Keywords: Single-grain dating; fluvial sediment; terraces; tropical river; Holocene.

P.6-8: Upper Pleistocene chronology for fluvial deposits in the coast of the Ria of Coruña (Galicia, NW Spain) by quartz OSL.

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The Ria of Coruña, as all Galician rias (NW Spain), is an estuary formed by the flooding of a fluvial valley during transgressive episodes, such as the present Holocene interglacial. During glacial regressive episodes, the coastline was locally fallen more than 100 m (bpsl) [1], and this valley remained completely emerged. This is also evidenced by the coastal fluvial deposits preserved at heights ranging between +2 m and +60 m (apsl). The deposition age of such deposits was assessed by optically stimulated luminescence (OSL) in quartz ranging the ages between 51 ka to 128 ka. Small multigrain aliquots (100 grains) were used for dating, as quartz showed a low luminescence signal and sensitivity although fast signal decay, decreasing by 90% during the first second of stimulation. The estimated dose-rates (D_r) ranged between 1 and 2 Gy/ky. These D_r*s* are relatively low, as most of the deposits are located on schists, when compared to estimated D_r*s* frequent in the region (>3 Gy/ky), overlying granitoid rocks [2]. Due to the dim OSL-signal, both the Late Background (LBG) and Early-Background (EBG) signal integration methods were used to estimate equivalent doses (D_e). The use of EBG implies the acceptance of a smaller number of aliquots and, sometimes, a higher error of the D_e with respect to these obtained with LBG. The accepted aliquots show distributions with a high dispersion, although symmetrical and unimodal. Thus, the central age model (CAM) has been used to calculate the ages. No evidence of incomplete bleaching of the OSL-signal was observed, although the overdispersion (*OD*) of the central dose were high. Dose-recovery tests indicated that there was also no intrinsic cause for the high *OD*-values in quartz. It was possible to relate the *OD*-values to the beta micro-dosimetry in the studied sediments [3]. Such micro-dosimetry can be correlated with the amount of potassium in the samples. As a result, OSL ages are obtained for the first time for fluvial deposits in this area, and can be correlated with the OSL ages of other coastal fluvial deposits in Galicia and Northern Portugal [2,4,5], in the Upper-Pleistocene. These results have allowed us to establish a reliable model of evolution for this fluvial valley during the last glacial period.

Keywords Fluvial-coastal sediments; OSL dating; Upper Pleistocene; glacio-eustasy; NW of Spain.

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P.6-10: Chronology of megaflood sediments in the Jinsha River: implication for luminescence dating of hyperconcentrated flow deposits

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Partial bleaching is potential problem for OSL dating of fluvial sediments. Megaflood sediments are characteristic hyperconcentrated flow deposits. The grains in the sediments may have lowest chance to expose to sunlight during transportation. Thus, partial bleaching was very serious for OSL dating, which impeded the investigation of such disaster process. Megaflood sediments with a thickness of 1-2 m covering a few Bronze Age archaeological sites (2.47-2.85 cal ka BP) were discovered along the Jinsha River valley. The top of the megaflood sediments is about ~30 m above modern river level and mainly consisted of medium to coarse sand with weak horizontal bedding.

Different grain size minerals (4-11, 90-125, 180-250 μm quartz and feldspar) were separated for OSL dating, using SAR and signal grain protocols. Our dating results show that FG (4-11 μm) quartz was better bleached than the CG (90-125 μm) quartz, suggesting that majority of FG and CG fractions were transported as suspended and bed load, respectively. The CAM (central age model), MAM (minimum age model) ages of the small aliquot quartz and feldspar were much higher that the age underlying aeolian sediments, suggesting that partial bleaching was very serious for our megaflood sediments. The MAM ages of single grain quartz were close to the age of underlying aeolian sediments, and suggesting that a megaflood event occurred at ~1.2 ka in the Jinsha River.

Keywords Megaflood sediment, OSL dating, Different grain-size fractions, Partial bleaching, Jinsha River.

P.6-12: Novel applications of luminescence dating to examine the drivers of fluvial change in the Rio Chubut (Argentina, ~42°S).

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The eastern margin of the former Patagonian Ice Sheet was drained by large and dynamic river systems, which remain largely unstudied. Here, we present a new chronology for the deposition of large fluvial gravel deposits and a large-scale shift in channel planform from a braiding to meandering river system. We also report on the novel use of luminescence properties to examine sediment provenance of the braided plain and a sampling technique for collecting light-safe samples through augering. New geomorphological mapping of the glacially-fed Rio Chubut and post-infra-red infra-red stimulated luminescence (post-IR IRSL) dating of single grain K-feldspar reveals the preservation of large gravel terraces up to 50 m above the modern-day river channel, the oldest of which is dated to 85.4 ± 7.8 ka. Also, the new ages reveal a time-transgressive shift in river planform from a braided to a meandering regime which is preserved in terraces ~3 m above the modern channel. The abandonment of this braided activity is dated between 12.3 ± 1.0 ka and 9.4 ± 0.8 ka. Comparison of the luminescence properties infers that the braided sediments were not derived from local alluvial fan activity. Alternatively, the difference in post-IR IRSL signal-intensity and equivalent dose (De) grain yields suggests differences in source rock and/or length of transport pathways between the braided and alluvial fan samples, which indicates that the braided sediments were likely sourced from the igneous rocks found in the Andes mountains rather than the local sedimentary lithology that comprises the alluvial fans. The augering sampling technique was used where vertical sediment exposures were not accessible. Using a light-tight sleeve placed over the coring rods to shield the bore hole from light, samples were able to be brought to the surface and transferred into sample bags without being exposed to light. The use of the Finite mixture model on single grain measurements showed the success of this techniques as <2% of the population were identified as younger contaminating grains.

Keywords Fluvial Geomorphology; Planform change; Chronology; Luminescence properties; Sampling technique

P.6-14: IRSL dating of fluvial terrace deposits along the Ani River, northeastern Japan

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Fluvial terraces have attracted much attention in studies of fluvial geomorphology because they are records of fluvial responses to climate and sea-level changes and crustal uplift. Accurate chronology of fluvial terraces is necessary to understand fluvial responses to such allogenic controls. Previous studies have established chronology of terrace development in Japan mainly based on tephra layers in the loess deposits overlying on terraces. However, comparison of terrace development between fluvial systems and comparison with paleoclimate records are not straightforward because tephra layers on terraces only indicate minimum age of deposition and different tephra layers between regions. This study determines the depositional ages of fluvial terrace deposits along the Ani River, northeastern Japan, using post-IR IRSL dating and pulsed IRSL dating, and discusses the influence of climate changes.

A fluvial terrace was formed in the last glacial period in the study area, and the deposits are ca. 10 m thick. I obtained 8 samples from an outcrop (ca.10 m thick) and post-IR $IRSL_{50/150}$ measurements were made on K-rich feldspar grains. The g-values of IR_{50} and $pIRIR_{50/150}$ signals were 5.17±0.18 and 1.96±0.15, respectively. Fading-corrected IRSL ages of the lower 6 samples (43.1–47.3 m in elevation) and the upper 2 samples (48.6–50.8 m in elevation) are 80–70 ka and 55–50 ka, respectively. The ages of the upper 2 samples are consistent with To-Of tephra (ca. 36 ka) in the lower part of loess deposits. The fading-corrected $pIRIR_{50/150}$ ages are 10–30 ka older than fading-corrected IRSL ages and might overestimate the depositional age due to incomplete bleaching. Pulsed IRSL measurements are being made, and the ages and a comparison with IR_{50} ages will be made in the presentation.

The depositional succession suggests that the rapid deposition at 80–70 ka and 55–50 ka reflects basin-wide aggradation with frequent avulsion, rather than single channel fill. The hiatus at 70–50 ka corresponds to a decrease in precipitation and temperature reconstructed from pollen composition of lacustrine sediments in central Japan, which may reflect a weakening of East Asian summer monsoon. This suggests that the fluvial terrace development in Japan was controlled by climate changes in time scales of a few tens of thousands of years. Further investigation in other river systems in Japan is needed to understand fluvial responses to climate change in the last glacial periods.

Keywords IRSL dating; pulsed IRSL dating; fluvial terrace; the last glacial period; Japan

P.6-15: OSL chronostratigraphy of the Late Pleistocene fluvio-aeolian succession in central and south-eastern Poland

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Fluvio-aeolian succession has been recognized in Poland, based on sedimentological and absolute dating methods. Appropriate correlation and dating of the aforementioned deposits are one of the crucial problems. Previous studies postulate asynchronous of sedimentary processes (Zieliński et al., 2015). Recent studies reveal different model of aeolian phases in Poland, where main dune-forming phases were detected in the Allerød interstadial (Moska et al., 2021).

To testify potential chronological differences four key sites from central and south-eastern parts of Poland were chosen. All key sites are located in the extraglacial zone of Last Glacial Maximum. Two of them are located in central Poland (Zarzecze and Kuźnica Kaszewska sites) and two in south-central Poland (Ostrowy Tuszowskie and Kamionka sites). Obtained OSL chronology is based on 34 dating results. Preliminary results confirm asynchronicity of depositional processes, particularly in fluvial and fluvio-aeolian complexes.

Keywords: luminescence dating, aeolian dunes, Last Glacial Maximum

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Acknowledgments

Presented results were obtained with the support of Polish National Science Centre, contract number: 2018/30/E/ST10/00616.

P.6-16: Late Quaternary lake level changes of Nam Co and Dawa Co as revealed by OSL dating of paleo-shorelines

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The Tibetan plateau (TP) is the source region for several largest rivers in Asia and is highly sensitive to global climate change. Knowing the paleo-environment changes on the plateau is the basis to better understand regional climatic variations in the future, with special regards to Asian monsoon system and hydrological cycles on the TP. Thousands of lakes spread across the plateau and their evolutionary history reflects regional hydrological change and past climatic variability.

Paleo-shorelines provide direct geomorphic records for reconstructing past lake level/volume changes. Many large inland lakes in Tibet are surrounded by high-stand paleo-shoreline systems, suggesting a process of lake shrinkage. Nam Co is the 2nd largest lake in Tibet [1], but systematic OSL dating of its shorelines is still less well studied. In this work, OSL technique was applied to date a series of paleo-shorelines of Nam Co to reveal its lake fluctuation history in the late Quaternary. To further study the applicability for using paleo-shorelines to indicate past lake levels [2], another lake in central TP, Dawa Co, was also investigated.

Combining with several radiocarbon dates, our results suggest that: 1) For Nam Co, the highest shoreline (S1, +26 m above modern lake level) indicates the highest lake level occurred around ~25 ka, with a coverage of ~2555 km^2. An overflow point west of Nam Co has a close elevation to that of the S1, suggesting the limit for high lake levels. 2) In contrast to the swift variations of Indian monsoon precipitation and glacier melt water in the late Quaternary, water level of Nam Co remained relatively stable during the period of 25 ka to about 8 ka (from +26 m to +22 m), suggesting the lake was in a continuous outflowing stage and lake infill constantly exceeds evaporation until the early Holocene; 3) the lowest S5 (+11 m) has an age of 1.3-0.7 ka, suggesting a gradual shrinkage of Nam Co in the middle to late Holocene; 4) The highest lake level of Dawa Co and its neighbouring lake Zhari Namco has a consistent age and elevation, confirming that such a geomorphic-chronologic assembly should be a typical feature for lakes in central Tibet that were past-connected but are presently-split. Lake volume change of Nam Co and Dawa Co was also discussed in association with possible climatic/geographic controls.

Keywords Nam Co; Dawa Co; paleo-shorelines; lake level; paleo-climate

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P.6-19: Testing the applicability of standardised growth curves (SGCs) for OSL signals of quartz grains from Yangtze Delta, China

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The standardised growth curve (SGC) technique has the potential to save instrument time for equivalent dose (De) determination when applying single-aliquot regenerative-dose (SAR) optically stimulated luminescence (OSL) measurement. In this study, we test the applicability of various SGC procedures for OSL signals of quartz grains using single aliquots from aqueous deposits of Yangtze Delta in China, which had been reported for weak luminescent signal and suffering from partial bleaching. Multiple silt-sized and sand-sized fractions of quartz samples from eight cores were used to construct SGCs by different normalisation procedures, i.e., test dose normalisation and least-square normalisation (LS-normalisation), respectively. The highly variability of dose response curves (DRCs) exhibiting in these samples has been substantially reduced by all of the SGC methods, and hence, establishing common SGCs for samples in individual core and cores in the whole delta, irrespective of their distinctive grain-size fractions, luminescence sensitivity and OSL components. Our results show that De values estimated by SGCs are generally consistent with those measured by full SAR protocol for well-bleached samples, while the degree of diversity of De values derived from the SGC and SAR techniques is gradually increasing for partial bleaching samples. We argue that the validity of De values obtained by LS-normalisation SGC, before choosing age models, need to be taken precaution to prevent ostensible dose distribution.

Keywords Quartz grains; Standardised growth curves; Optically stimulated luminescence; Partial bleaching; Yangtze Delta

P.6-20: Luminescence dating of the Huliu River terraces in the Nihewan Basin, north China

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As one of the most important regions for early human occupation in East Asia, the Nihewan Basin in north China is well-known for an abundance of archaeological sites with ages spanning the last 2 Ma. By the time of writing, more than 200 archaeological sites have been discovered from the fluvial-lacustrine sediments of the Nihewan Paleolake or fluvial deposits of the Sanggan River terraces and the Huliu River terraces. However, many Paleolithic sites in the fluvial sediments from Huliu River terraces are with no age data (e.g., Xiaoshuiliang site). The lack of reliable ages for sites in the fluvial sediments affects our understanding for the development of the stone-tool technology in the Nihewan Basin. The aim of this paper is to study the formation ages and the evolution history of Huliu River terraces. Based on field investigations, three terraces were identified. Systematic sampling for optical dating was carried out on these terrace deposits. The fluvial terrace sequence of the Huliu River was dated based on single-grain post-infrared infrared stimulated luminescence (pIRIR) procedure on potassium (K-) feldspar [1]. Our results reveal that the formation ages of three Huliu River terraces are ~130 ka, ~8 ka and last 2 ka. On the basis of these pIRIR ages, a chronology frame can be built for the archaeological sites in the Huliu River terrace in the Nihewan Basin.

Keywords Huliu River terraces; Nihewan Basin; pIRIR; single grain

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P.6-23: OSL dating of the lacustrine deposited in broad-valley reaches of the Jinsha River: implications for dammed lake formation

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Many large rivers that originate from the inner Tibetan Plateau (TP) and which empty into the Eurasian continental marginal seas drain through the southeastern TP. Steep gorges incised by these swift-flowing rivers form the well-known Three Rivers Drainage Basin, involving the Jinsha River (the uppermost reach of the Yangtze River), the Lantsang–Mekong River, and the Nu–Salween River. The Jinsha River flows southeastward across terrain of distinctively high relief without fluvial terraces developing until it reaches Shigu Town, which different from the SETP morphology characterized by high mountains and deep-narrow valleys, broad-valley was developed in the First Bend (Shigu Town) reaches of the Jinsha River, uppermost Yangtze River.

Within 150 km along the Jinsha river from Qizong to Shigu (First Bend reaches), an about 3-m thick lacustrine layer accumulated in broad-valley, which is 20 m higher than water level. In present study, 16 lacustrine sediment samples were collected from 6 profiles for OSL dating. The analytical results show that the lacustrine sediment deposit from 9.05±0.55 ka to 14.18±1.50 ka. Field investigations demonstrate that the lacustrine layer overlap directly on bedrock, compared with other dating results of the fluvial terraces in this area, we propose that the lacustrine sediment in this area are formed by dammed lake, instead of fluvial terrace sediment.

Keywords: southeast Tibetan Plateau; broad valley; lacustrine; OSL dating; dammed lake

P.6-25: Luminescence chronology of the Sankosh River terraces in the Assam-Bhutan foothills of the Himalayas: Implications to climate and tectonics

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Fluvial terraces are the results of climate and/or tectonic perturbation and thus preserves the information about such changes in the past i.e. they are important geomorphic archives. River terraces in the Himalayas have been recently paid attention to understand the relationship between climate change, surface processes and tectonic movement. The Main Frontal Thrust (MFT) which marks the southern end of the Himalaya has been active in the recent past, thus fluvial terraces in the foothills preserves any signature of tectonics and at the same time fluctuations in the monsoonal rainfall as the climate changes also controls the formation of terraces. These terraces can be used to reconstruct past events.

The present study is an attempt to understand the formation of terraces along the Sankosh River in the Assam- Bhutan Himalayan foothills of Kokrajhar District of the North- East India. Sankosh River originates in northern Bhutan and joins the Brahmaputra River in Assam. Detailed field studies along with satellite mapping and optically stimulated luminescence dating (OSL) suggest three levels T1, T2 and T3 formed at 9.6- 16.8 Ka, 23.9-43 Ka and 64.2-82.5 respectively. The dates represent that the terraces were generally formed between interglacial phases and the presence of deformation represents different phases of deformation. The flood plain Seismites are indicative of such deformation events in the past.

Keywords Luminescence dating, Sankosh River terraces, Himalayan foothills

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P.6-28: Revisiting the late Quaternary mega-lake in Tengger Desert from western China using K-feldspar luminescence dating

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The late Quaternary palaeolake evolution across western China (e.g., Tibetan Plateau and surrounding desert areas) has been extensively studied, but the timing of late Pleistocene lake highstands has still been hotly debated when different dating techniques were applied. Based on the application of radiocarbon dating in lake shorelines and terrace remains in the 1980s and 1990s, many studies reported the highstand timing between 40 and 30 ka (equal to late marine isotope stage 3, i.e., MIS 3a), which was so called the notion of "MIS 3a mega-lake period". In contrast, in the light of recent optically stimulated luminescence (OSL) dating applications on quartz minerals from these lacustrine sediments, the mega-lake period was apparently dated back to much older stage (i.e., MIS 5), and these quartz OSL dates mostly are falling within ~90-70 ka, corresponding to the late MIS 5. The differences between radiocarbon and quartz OSL dating results of the high lake-level event are likely due to radiocarbon age underestimation on such old materials [1]. For dating the sediments of >30 ka the introduction of trace amounts of young carbon, either during sampling or in sample preparation, could cause some of these ^{14}C ages to be erroneous.

However, the obtained quartz OSL ages of mega-lake period could also be underestimated, because the OSL signal from quartz normally saturates at approximately 200-300 Gy (although this range also varies between samples), and with typical dose rates of 3 Gy/ka this gives an upper limit of ~100-70 ka. Even though the dose response curve is still growing for some samples, ages obtained with equivalent dose (D_e) values close to the limit of saturation should be regarded with additional caution. In contrast to quartz OSL signal, the feldspar infrared stimulated luminescence (IRSL) dose–response curve grows to much higher doses; this has the potential to extend the age range by a factor of 4–5 compared with quartz OSL. In the current study, we chose a late Pleistocene lake sequence, which has been dated to ~100-70 ka by quartz OSL approach, from Zhuyeze palaeolake in Tengger Desert. The developed feldspar post-IR IRSL (pIRIR) approach is applied to the dating of this sequence (six samples), which would allow us to test the reliability of quartz OSL dates for the mega-lake period. Furthermore, in order to test whether or not radioactive disequilibria in the uranium decay chain exists in the studied lake sediments, the specific activities of radionuclides are measured by high-resolution gamma spectrometry for dose rate calculation, for which the radionuclide concentrations of these samples were previously determined by the neutron activation analysis.

Keywords Mega-lake period; ^{14}C dating; quartz OSL dating; feldspar pIRIR dating; dose rate

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P.6-30: Holocene lake-level history of Taro Co in Tibetan Plateau based on OSL dating of shorelines

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Lake-level fluctuations are highly sensitive to climate change, which can be reconstructed directly by dating paleoshorelines. In this study, we reconstructed the Holocene lake-level history of Taro Co on the southwestern Tibetan Plateau, based on 17 optically stimulated luminescence ages of paleoshorelines. Results show that lake-levels were at the highstands of ~40 m above modern lake-level (a.l.l.) between 11.8 to 7.0 ka, while interrupted by two abrupt lake-level declines at 10.5 ka (14 m a.l.l.) and 8.8 ka (6 m a.l.l.). After that, lake-levels dramatically dropped to 3 m a.l.l. at 6.9 ka with two highstands at 4.4 ka (6 m a.l.l.) and 2.6-2.2 ka (9 m a.l.l.). The Holocene lake-level fluctuations simultaneous change with other lakes (e.g., Selin Co) in the southern and central Tibetan Plateau. Compared with other paleoclimate records, it showed that the Holocene lake-levels pattern coincides with the change of Indian Summer Monsoon intensity. On the other hand, the three rapid abrupt lake-level declines were correlated to Holocene ice-rafted debris events in the North Atlantic.

Keywords OSL; Lake-level history; Taro Co; Tibetan Plateau; Paleoshorelines

Session 7:
Advances and applications in archaeology and palaeontology

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O.7-1: Application of optically stimulated luminescence for dating ancient bricks from the gothic church of St. James in Toruń, Poland

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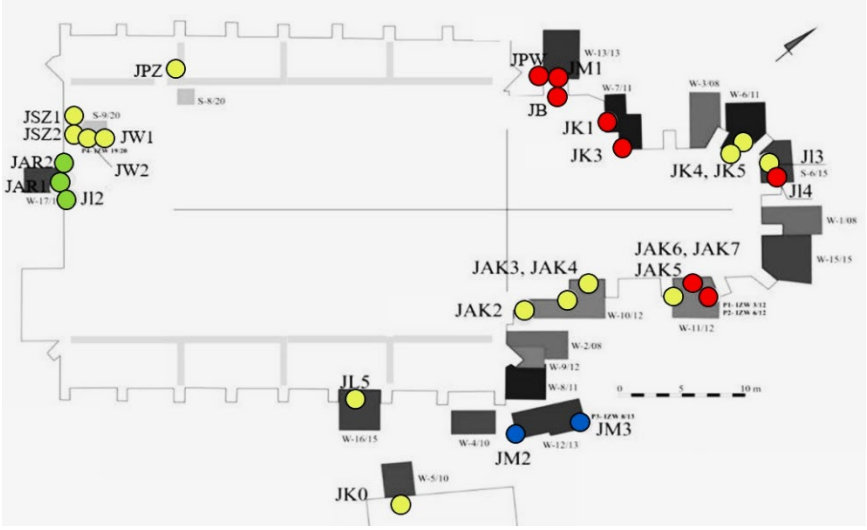
Saint James Church in Toruń is one of the most valuable gothic monuments in Poland. It is located on the present New Market Square in Toruń, where in 1264 the New Town of Toruń was established. According to the version of the history of the church currently accepted by most historians, its construction began in 1309 [1]. The church is built in a two-story basilica layout. The unique character of details, the richness of decorations and the coloured glazed bricks make it an example of the wealthiest religious architecture in the former Teutonic state. During the first excavations, deeper foundations of the church were discovered, which are not entirely consistent with the final location of the church buttresses. The buttresses visible above the ground are set at an angle to the chancel walls, whereas the deeper foundations under the buttresses are perpendicular to the church's walls. The most important purpose of dating a brick collected from this place was to check which of the hypotheses was correct: (1) the construction of the church began in 1309, right from the presbytery, which is uniform and is the oldest part of the church; the entire nave was built in the 14th century; the building was erected by at least two masters where the second one changed the course of buttresses [1], or (2) on the site of the actual church, there was another brick temple erected in the 13th century, and according to the inscription preserved inside the chancel, the reconstruction of the chancel after a fire and the further expansion of the church began in 1309 from the presbytery, [2]. During several years of archaeological work almost 30 samples, mainly from the foundations of the temple, were collected for luminescence dating and few additional samples from the brick surroundings for the annual dose estimation. OSL dating using 100-200 µm quartz grains was performed. The results, which will be presented in detail, prove that the second thesis concerning the history of church construction presented above is true.



Keywords OSL dating; medieval brick; quartz

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O.7-2: Luminescence dating of pre-historic ditched enclosures from calcite-rich contexts: a new approach to the dose rate estimative

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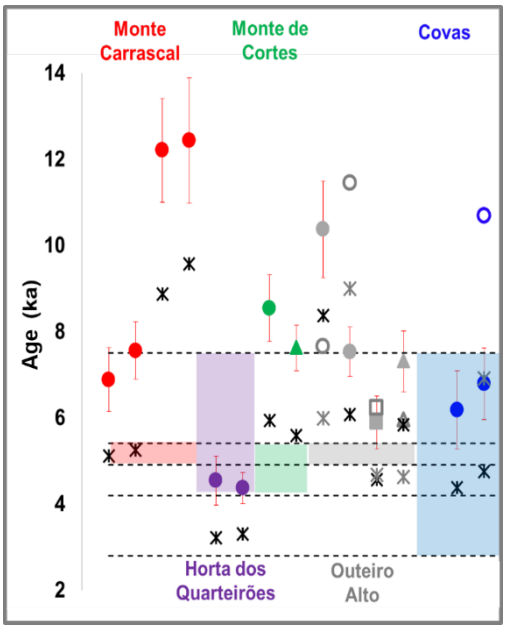

The concept of ditched enclosure comprises one of the most common and important architectures of recent Pre-history of Iberia [1]. These enclosed spaces, delimited by lines of excavated ditches, appear in different topographies, are usually associated with large quantities of circular ditches (and associated pits) and "life" times that can range from a few hundred to a thousand and a half years. Many of the them have particularities (sun orientation, topography, architecture, sequential fill with anthropogenic actions and selected materials, and a complex stratigraphy with events of opening, sealing and reopening) that allow them to be used for purposes related to high load practices, symbolic and ceremonial [2]. All of them are excavated in geological substrates associated to calcite-rich materials (calcretes). Regarding constrains of dating calcite-rich materials this work aims to explore this issue proposing a proxy for dose rate estimation: "Radionuclide weighted protocol" [3]. The protocol mitigates the "dilution effect" promoted by the high calcite proportion, considering a no calcite scenario and obtaining a maximum possible dose rate for the studied context. A clear improvement of the dose rate estimation was obtained, contributing to a more reliable chronological data for almost of the studied samples from five archaeological enclosures.

Keywords Ditched enclosures; Luminescence dating; Calcite-rich contexts; Dose rate; Radionuclide weighted protocol

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O.7-3: OSL single-grain and post-IR IRSL pottery dating for an archaeological key-site in the Western Mediterranean Sea – The Case of Iron Age Monte Iato, Sicily

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The archaeological "Master Archive" of Monte Iato in Western Sicily, was created by the archaeological long-term project “Between the Aphrodite Temple and the Late Archaic House I-III”, over the last 9 years. The project focused on the Early Iron Age and Classical Antiquity and investigated in detail the cultural and social changes in the western Mediterranean region during these times [1, 2]. Due to the limitations of in situ preservation of material that can be dated by ^{14}C dating or dendrochronology and because of the so-called ^{14}C Hallstatt plateau problem, the chronological resolution of critical time periods at Monte Iato is still poor (i.e., the time period between ca. 400 and 800 BC cannot be well resolved; [3, 4]). This study aims at (i) improving the chronological resolution and overcoming the ^{14}C Hallstatt plateau problem, and (ii) embedding the archaeological master-section at Monte Iato into a well-dated paleoenvironmental framework using state of the art optically stimulated luminescence (OSL) dating techniques and micromorphology. The ultimate goal is to deepen our understanding of human-environmental interactions during the Early Iron Age in Sicily.
Here we present preliminary data of OSL single-grain and post-IR-IRSL-based pottery dating. We examined an archaeological section of high cultural significance, covering the initial contact between native Sicilians and Greek colonists and subsequent cultural transformations (i.e., VII-V century BC). From this key section OSL and micromorphological samples as well as over 100 ceramic pieces were extracted. OSL dating is conducted on the single-grain level using 10^3 to 10^4 individual grains of quartz per sample from the archaeological layers IX, V and IV (listed in stratigraphic order), that suffer from the ^{14}C Hallstatt plateau problem. The single grain De distributions are characterized by low overdispersion values (19±2% on average) and preliminary OSL age estimates based on the central age model of 2.77±0.13 ka, 2.80±0.14 ka, 3.08±0.16 ka, have been obtained for the layers IX, V and IV, respectively. We calculate an average estimate of 2.88 with an error of ±0.15 ka in absolute or ±5.1% in relative terms, for the timing of initial cultural contact. These age estimates correspond to a time period of ca 300 years, i.e., from 980 to 680 BC and are thus already slightly more precise (by ca. 25%) than the radiocarbon-based chronology (i.e., 400 ^{14}C years of duration of the Hallstatt plateau).
More specific dose rate measurements are underway and will be combined with micromorphological investigations and quantitative mineral mapping (QEMSCAN) to further improve dating precision for the archaeological key layers. The ceramics (ca. 10^1 to 10^2 per layer) will be dated using a post-IR-IRSL290 protocol, and quartz single grain OSL and pIR-IRSL pottery ages will be pooled to further improve the dating precision on each archaeological horizon. This multi-pronged approach will also provide an additional control line on the stratigraphic integrity of individual cultural layers and excavation sectors.

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O.7-5: Neanderthals of the North: A pIRIR$_{290}$-chronostratigraphy of the Middle-Palaeolithic sites Lichtenberg I and II, Lower Saxony (GER)

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The open-air site of Lichtenberg in Northern Germany is one of the northernmost Neanderthal occupations on the European Plain and was originally dated to 57 ± 6 ka [1]. Its artefact assemblage is famous for its eponymous bifacial backed knives (Keilmesser). Due to the pre-existing chronology for Lichtenberg, this tool type was largely believed to be restricted to the early MIS 3 interstadial [2]. We revisited the site to reassess its chronostratigraphy by means of luminescence dating, sedimentology, palynology and micromorphology. An accompanying coring campaign, meant to provide landscape context, eventually led to the discovery of a second Middle-Palaeolithic site in the immediate vicinity. We rebranded the previously known site as 'Lichtenberg I (Li-I)' and the newly discovered one was named 'Lichtenberg II (Li-II)'. The stratigraphic layers of both sites are identical, except for two additional older units that are present in Li-II, the lowermost being the find layer, yielding an assemblage distinctly different to Li-I. The majority of sediments at our two sites are colluvial deposits derived from Saalian glaciofluvial sands that crop out about 100 m upslope. Out of the 11 layers we encountered, the uppermost 5 to 6 suggest cryogenic impact during and after their deposition, whereas the lower layers (including the find layers) lack those respective features.

For the 16 luminescence samples in total, we applied the pIRIR$_{290}$ protocol on potassium feldspar. We used very small aliquot sizes (0.5 mm) to account for possible incomplete bleaching due to short-distance redeposition on the slope. Equivalent doses were determined utilizing Abanico plots, which combine the strengths of radial plots and kernel density estimations. The non-cryogenic lower part of the sequence (incl. the find layers) yields very consistent ages. A set of three dates (70.8 ± 8.0 ka, 71.6 ± 7.0 ka and 71.5 ± 7.0) describes the find layer of Li-I. The previous date for this layer of 57 ± 6 ka is very close to some cryoturbation ages we obtained in our data set. The second find layer (Li-II) is dated to be between 89.5 ± 8.2 and 91.5 ± 9.1 ka. Pollen analysis supports the ages of these find layers by attributing Li-I to a cold phase around the MIS 5a/4 transition and Li-II to a temperate phase of the latest MIS 5c. However, the cryogenic layers produced less satisfactory results and where thus subjected to additional single-grain luminescence dating. The chronostratigraphic information together with the palaeoenvironmental data of the sites significantly improve our understanding of Middle-Palaeolithic behaviour, e.g. specific tool production and migration patterns.

Keywords pIRIR$_{290}$ dating, slope sediments, Middle Palaeolithic site, Northern Germany

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O.7-6: Investigating the effect of diagenesis on ESR dating of Middle Stone Age tooth samples from the open-air site of Lovedale, Free State, South Africa

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Among the materials that can be dated using electron spin resonance (ESR), teeth are the most prone to diagenetic alteration, including the uptake of trace elements such as uranium in dental tissues. Characterising the mineralogy and structural integrity of samples prior to dating may thus provide important information related to their state of preservation, especially in the case of teeth whose U content can significantly affect the dose rate.

In this study, we dated five ungulate teeth using combined ESR/U-series dating. They were collected at the Middle Stone Age site of Lovedale, located in the central interior of South Africa. Analyses using cathodoluminescence, laser-induced fluorescence, Fourier transform infrared and Raman spectroscopy were performed to assess the degree of diagenesis of the samples. Results reveal that carbonate hydroxyapatite underwent post-depositional alteration, based on their molecular structure and elemental composition. Although teeth all originate from the same layer, and were sampled in the same 1-m square and at a similar elevation, U-content in the enamel highly differs from one tooth to the other, with values ranging from 1.7 to to 30 ppm, which are correlated with equivalent doses (D_e) from 228 to 923 Gy. We also investigated the possible saturation of the ESR signal, by repeating measurements with microwave power values from 1 to 20 mW. The D_e obtained for each series of measurements are similar, suggesting that the value of the microwave power used for stimulation does not significantly affect the D_e for analysed samples.

Despite such diversity in U-content, the ages calculated assuming an early uptake (EU) of U all fall within the same range, from 63 ± 8 ka to 68 ± 15 ka. Considering that leaching was identified, precluding the use of the U-series (US) model, these ages may only represent a minimum estimate.

Characterisation studies prior to dating may give useful insights into the preservation of dateable materials such as fossil teeth, and will certainly help building reliable chronologies for the human evolution timeline.

Keywords: electron spin resonance; diagenesis; infrared spectroscopy; Raman spectroscopy; cathodoluminescence

P.7-1: ESR chronology of the fluvial sequence of Cueva del Silo (Sierra de Atapuerca, Spain)

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The Cueva del Silo is part of the lower karst level of the Cueva Mayor-Cueva del Silo karst system together with the Sima de los Huesos and Cueva Peluda (Sierra de Atapuerca, Burgos, Spain). It is a maze of sub-horizontal conduits with a ceiling at an elevation of 985 – 990 m.a.s.l. and characterised by a main passage formed by Sala del Caos-Galería Principal and a secondary network among which the Galería de las Arenas. This cave is remarkable for the presence of fluvial deposits consisting of gravels with clasts of metamorphic rocks in the Sala del Caos-Galería Principal, and sand and silt facies in the Galería de las Arenas that record the entry of the Arlanzón River water in the cave system.

This fluvial input from the Arlanzón River could be correlated to terrace T5 (+50 – 58 m) which has been dated by ESR to 600-700 ka or an older level on the basis of their altitudinal distribution. The chronological framework of these fluvial deposits inside the cave is very scarce. A TL age of 175.4 ± 28.6 ka was obtained by the now closed *Laboratorio de Datación y Radioquímica de la Universidad Autónoma de Madrid* (UAM Luminescence Lab) at the top of the fluvial sequence in the Galería Principal. However, a personal communication from D. Granger suggests a cosmogenic age of 990 ka in the Sala del Caos gravel level. At the same level of gravels, a paleomagnetic study revealed a normal polarity, presumably Brunhes.

So establishing a chronological framework for this fluvial sequence in Cueva del Silo is important in order to better understand the connection between the evolution of the karst system and the incision history of the Arlanzón River. With this objective in mind, six sediment samples were collected in two outcrops, Galería de las Arenas and Sala del Caos, in order to provide the first ESR chronology of this fluvial sequence. Our first results suggest an age of Lower Pleistocene for these deposits which seems consistent with the known geological data.

Keywords: ESR dating; fluvial sediments; bleached quartz; Pleistocene; Atapuerca sites complex;

P.7-2: Establishing an OSL chronology for Kostenki 17

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A key site for understanding the colonization of Eastern Eurasia by Anatomically Modern Humans (AMH) is the Kostenki-Borshchevo archaeological complex located on the west bank of the Don River (Russia). This site consists of 26 individual open-air Palaeolithic sites, one of which is Kostenki 17. Kostenki 17 has a well-defined stratigraphy, containing two distinct cultural layers (CL I and CL II) and between them sits a layer of tephra attributed to the Campanian Ignimbrite eruption which occurred 39.85 ± 0.14 ka [1]. Multiple efforts have been put into dating these cultural layers through radiocarbon dating, which has resulted in ^{14}C ages for CL II in the range of ~32-41 ka [2,3,4].

Here we present OSL ages obtained from 29 sediment samples collected at K17. We present results from both multi-grain and single-grain quartz OSL measurements and compare with results obtained from multi-grain pIRIR(50,225) measurements on K-rich feldspar. Preliminary results indicate that both quartz and feldspar are suitable for OSL age estimation.

Keywords AMH; Kostenki; chronology; luminescence; OSL

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P.7-3: Quartz OSL/TL-SAR dating and the OSL component characteristic of pottery, burnt clay, and sediment from Beicun archaeological site, China

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This study focuses on the analysis of the thermoluminescence (TL) and optically stimulated luminescence (OSL) dating signal characteristics of quartz in burned clay, pottery, and the sediment unearthed from Beicun site of Liangzhu culture in the Neolithic Age. It shows that the initial OSL signals (within 0.8 s) of most burnt clay and pottery sherds are not dominated by the fast component. Results of a heating simulation experiment of sediment quartz show that annealing at temperatures exceeding 600°C–800°C causes the proportion of the fast component in the initial signal (within 0.8 s) to decrease slightly. In addition, the proportion of the medium component in the later signal (0.8–5 s) is caused to increase significantly, resulting in a decrease in the Fast Ratio value. Therefore, high annealing temperature may be an important reason for the slow decay rate of OSL signals of these samples. The $D_e(t)$ plot shows that most of the samples have thermally stable OSL component signals, which have no significant effect on the final OSL ages. The OSL-SAR and TL-SAR protocols are used to determine the luminescence age of chunk burnt clay and pottery sherds. The results are consistent with the ^{14}C age of carbon chips extracted from burnt clay. The age of the Beicun site is finally determined to be approximately 5000–5300 BP_{2020}, belonging to the early period of the Liangzhu culture. This study also conducts an accuracy and precision analysis of the TL and OSL dating results. The results show that the natural TL signal sensitivity is not corrected appropriately, which leads to an underestimation or overestimation of the TL age, and its absolute error is generally greater than that of the OSL-SAR protocol. The high-precision age of the last archaeological heating event, such as sacrifice, burning, or domestic firing, can be obtained by determining the TL and OSL ages of a homogeneous chunk of burnt clay.

Keywords Luminescence dating; Burnt clay; Pottery; Liangzhu culture; Beicun site.

P.7-4: Luminescence Dating of Rock Structures in Northeastern United States

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Enigmatic rock structures are common features in the northeastern United States. Traditionally, archaeologists have attributed them to colonial farming practices, such as land clearing and storage facilities. Yet another view, held mainly by amateurs curious about their origin, posits they are prehistoric in age, presumably the work of aboriginal people. Outlandish claims have made this view less palatable to professional academics. Resolution of this dispute, of course, could be obtained by dating the structures, but their age is largely unknown. They generally are not associated with any organic remains or other kinds of artifacts that might lend themselves to traditional dating methods.

The University of Washington Luminescence Dating Laboratory has begun a project to apply luminescence methods to the rocks and underlying sediments in hopes of dating them. About 40 samples, ranging from New Hampshire to Pennsylvania, have been collected. For the rocks, mainly gneiss or pegmatite, collected from the structures under red light conditions, we are trying to date their unexposed surfaces to the last time they were exposed to sunlight. We are measuring luminescence as a function of depth to gain information on exposure history to confirm sufficient exposure to reset the surface signal at the time of interest. Beginning measurements have suggested some rocks were never exposed when they were emplaced in the structures.

We are also dating sediments collected from under the rocks using the assumption that turbation processes were sufficient to reset their luminescence signal prior to the rock being placed on them. This is also mainly using IRSL because quartz in most cases is not sensitive, at least to green or blue light. Single-grain dating in conjunction with the minimum age model is being employed to isolate the grains most likely to have been exposed.

Results will be reported in this poster. Preliminary indications are that some of the samples are prehistoric, but not by very much. If this pattern holds, archaeologists will have to re-evaluate their narrative of prehistoric developments.

Key words: Rock surface dating; sediment dating; IRSL; rock structures; northeastern United States

P.7-7: Interpretation of Neolithic rubble layers from Ba'ja and Basta sites using Luminescence Dating

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Many of the 7th millennium settlements in Jordan preserve widespread thick rubble and gravel layers in the occupation areas. Some scholars identify these as "Yarmoukian landslide" and they seem to occur mostly in the time interval 8.6- 8.0 ka [1]. They have been identified at, from north to south in Jordan, the Neolithic sites 'Ain Rahub, Wadi Shu'aib, Ain Ghazal, es-Sifiya, Ghwair, Ba'ja, Beihda, al-Baseet, Basta and 'Ain Jammam [2] [3] [4]. The layers are described as accumulations of depositional debris covering architectural structures, and consist mainly of angular or rounded stones, larger than fist-sized [5]. Cultural materials have also been found within the layers, such as artefacts, flint tools and plasters.

Interpretations have been put forward to explain these layers both from an anthropogenic and natural perspective. Previous studies have been based on associating these layers with damage and destruction of Neolithic sites, and in terms of climate change in the Levant and eastern Mediterranean. Factors related to the geomorphological setting of the site, such as flash floods and tectonic events, have been considered. The most widely accepted explanation relates these layers to the Rapid Climate Change (RCC) that took place during the Holocene and is associated with torrential episodic rainfall and flash floods in the region [1]. However, Gebbel [5] has argued that an acceptable interpretation is not necessarily "mono-causal". To improve our understanding of these widespread layers, an interdisciplinary approach should include an archaeological, chronological and stratigraphical description of the layers, and relate this to a climatic and seismic analysis of the region. In this work, we study the timing of the deposition of the rubble layer at two archaeological sites in Southern Jordan: Ba'ja and Basta, using luminescence dating. The outcomes are expected to show more indications and understanding of the cultural change during Neolithic times and the destruction of the Neolithic settlements. The new information will be used to identify, if existed, the correlation between different sites, not only by the composition resemblances, but also by the time of deposition.

Keywords Rubble layers; Neolithic; Jordan; OSL

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P.7-8: A combined OSL and ^{14}C dating study of charcoal production in the sandy environment of Zoersel forest (N Belgium)

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Zoersel forest is one of the few ancient woodland areas in northern Belgium. It is also one of the two sites in this region where well-preserved remains of past charcoal production have been found. These relics are increasingly studied to inform on former woodland composition and exploitation, which aids in outlining conservation and preservation strategies. The age of the features is commonly obtained through ^{14}C-dating of charcoal, which is abundant in the kiln remains. However, owing to natural and anthropogenic ^{14}C variations, this approach does not allow establishing the chronological order of burning activities during the last few centuries (i.e. from about 1650 CE onwards). In this study, we investigate the potential of quartz-based optically stimulated luminescence (OSL) dating of the sandy sediments that are associated with the kilns and which are expected to have been exposed to heat during their operation.

Using a set of 35 sediment samples collected from both charcoal-rich and underlying layers (i.e. kiln remains and substrate, respectively), we first document the OSL characteristics of sand-sized quartz in terms of signal composition, sensitivity, dose-response, and the diagnostic tests commonly used to assess the appropriateness of the single-aliquot regenerative-dose (SAR) protocol. Small (2 mm diameter) aliquots are then used to examine the distribution of equivalent dose (ED) in the samples. In general, the distributions are asymmetric, starting from a finite, non-zero value; OSL-minimum-ages derived from this population tend to be systematically higher compared to ^{14}C-ages obtained for the same kilns. Complementary analysis of single grains of quartz extracted from the charcoal-rich layer of one of the investigated relict kilns shows that, at least for this particular feature, most grains belong to a single dose population of which the average ED is consistent with that obtained using small aliquots.

Possible causes for the apparent discrepancy between OSL and ^{14}C-dating will be discussed, together with results from additional ongoing single-grain analyses. From the available small-aliquot and single-grain ED distributions, however, it is already clear that the sandy subsurface at Zoersel forest was prone to one or more heterogenous processes, making it a challenging environment for chronometric analyses.

Keywords: Charcoal production; OSL dating; Radiocarbon dating; Zoersel forest; Sand-sized quartz.

P.7-9: New ESR/U-series dates of the lowest AYCC levels of Qesem cave

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Qesem cave is a Middle Pleistocene site located close to Tel Aviv, Israel, assigned to the Acheuleo-Yabrudian Cultural Complex (AYCC) of the Lower Palaeolithic. The site provides rich assemblages of knapped flint, animal remains and some human teeth making it of particular interest. Its location in the Levantine corridor confers a major interest to the understanding of human dynamics during the Middle Pleistocene.

A series of 6 herbivorous teeth from the base of the 11 m archaeological sequence of AYCC Qesem Cave was analysed by combined ESR/U-series method. The teeth were measured according a regular protocol for which each tissue was analysed by inductively coupled plasma-quadrupole mass spectrometry (ICP-Q-MS) for U-series using a combination of a Thermo iCAP-RQ mass spectrometer coupled to a Cetac Aridus III desolvator system, and ESR analyses were implemented on enamel tissue. All these data were combined in order to yield modelled ages.

The goal was to find out whether there was a time gap between the carbonates layers dated to 420 ka [1] and archaeological layers of the AYCC found throughout the cave's sequence. The new results yield ages ranging between 220 and 430 ka confirming a great antiquity and a long duration of AYCC in the Levant corridor.

Key-words: ESR/U-series; Qesem Cave; Middle Pleistocene; AYCC

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P.7-10: Establishing a pIRIR procedure for D_e determination of composite mineral grains from volcanic terranes: A case study of sediments from Liang Bua, Indonesia

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Volcanic sediments are generally difficult to date using luminescence dating methods, but many important archaeological and palaeoanthropological sites are located in volcanic regions. Here we present an improved dating procedure for grains deposited at Liang Bua, the type locality of *Homo floresiensis* in Indonesia, using the post-infrared infrared stimulated luminescence (pIRIR) signal.

Individual grains with detectable pIRIR signals were characterised using a range of techniques, including quantitative evaluation of minerals using energy-dispersive spectroscopy (QEM-EDS). We found the grains to be composed of a range of minerals, including feldspars, quartz, clay minerals and heavy minerals, as well as volcanic glass, rendering the isolation of individual potassium-rich feldspar grains infeasible [1]. We investigate the luminescence behaviour of these composite mineral grains in detail, including their thermal stability, anomalous fading and dose-response characteristics. A standardised growth curve is developed to enable more time-efficient measurements, together with a 'micro-aliquot' approach in which each hole on a disc contains approximately 8–10 grains. Less than 1% of grains yield detectable pIRIR signals when measured individually, so the use of micro-aliquots provides, in effect, a means of estimating the equivalent dose (D_e) at single-grain resolution. Our results show that the pIRIR signal measured at 275°C is suitable for estimating D_e values of these composite grains, without the need for residual dose or fading corrections [2].

Keywords Optical dating; standardised growth curve; composite mineralogies; internal dose rates; potassium concentrations

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P.7-11: Agricultural terraced landscapes in the Mediterranean: novel discourses around the issue of chronological gaps

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Agricultural terraces, which demonstrate a sustainable way of transforming the hilly slopes into arable land, are ubiquitous features of Mediterranean landscapes, but their history is often poorly understood. Lack of dateable artifacts, occurrence of residual material in terrace soils and the potential for post-depositional disturbance mean dating terrace sediments is challenging. This further limits broader research on histories of landscapes and knowledge of how terraces reflect the long-term investment choices made by rural communities.

To this end, as part of a UK Arts and Humanities Research Council funded project called TerraSAgE (Terraces as Sustainable Agricultural Environments), we explore agricultural landscapes across the Mediterranean, from Turkey to Spain. Here, we report findings from our pilot investigations conducted in Greece and Spain where we identified key sites and applied the combined technique of luminescence field profiling and optically stimulated luminescence (OSL) dating [1] to produce a chronological sequence for sedimentary stratigraphies associated with different agricultural terraces. Samples were collected densely for luminescence measurements using a portable OSL reader, and pOSL data were then used to inform on depositional sequences and position samples strategically for OSL dating.

Preliminary results reveal that the phases of terrace construction and use date from the Middle Bronze ages (*c.* 1920 BC) to the later Middle ages (*c*. AD 1100–1600) and until the post-medieval period (*c.* 1900 AD). Though these phases suggest continuing intensive engagement with the landscapes, there remain significant chronological gaps, and broad chronological synchroneity is observed only at regional scales. The differences could be stimulated by a multitude of factors, either in isolation or combination, including differences in terrace morphology and function, rainfall patterns, population expanse and socio-economic factors. The preliminary findings demonstrate that terraces are multifaceted and whilst we can securely date when these were constructed (and abandoned), broader questions related to their sustainability that if terraces in the Mediterranean enabled greater resilience to economic or ecological instability require more investigations (both spatially and temporally).

Keywords Mediterranean; agricultural terraces; landscape archaeology; OSL dating.

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P.7-12: Systematic high-sampling resolution OSL dating of a well-preserved river dune in the Lys valley (Sint-Martens-Latem, NW Belgium)

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During the Late Glacial recolonization of NW Europe, hunter-gatherers preferably settled in sheltered environments and along river valleys and lake edges. However, in the Scheldt basin of NW Belgium (which includes tributaries such as the Lys river) remains of these Late Glacial settlers are scarce. Due to the lack of an in-depth assessment of Final Palaeolithic sites in the Scheldt basin, it is not clear at present whether this scarcity is related to specific taphonomic factors and/or corresponds to a prehistoric reality. Moreover, the few known sites in the floodplains of the Scheldt and its tributaries all seem to date to the Younger Dryas (final stage of the Late Glacial), which recently led to the hypothesis of a possible population shift from the inland lakes towards the rivers at the abrupt transition from the warm Allerød to the extreme cold Younger Dryas. We seek to investigate this hypothesis through intensive geoarchaeological research of aeolian river dunes in this area, as they represent dry elevations bordering a wet landscape, making them attractive spots for occupation.

This study reports on quartz-based optically stimulated luminescence (OSL) dating of an exceptionally well-preserved dune, as one of those potential contexts of sealed Final Palaeolithic sites.

The dune, locally called “Molenberg” (Lys valley, municipality of Sint-Martens-Latem, NW Belgium), is more than 10 m high (top is 24.82 m a.s.l.). Samples for OSL dating were collected systematically at 50 cm vertical intervals by hand coring at two localities, allowing for a complete sequence from top to base and resulting in a total of 31 samples. These were processed in the usual manner for OSL dating using sand-sized (125-180 μm) quartz and the single-aliquot regenerative-dose (SAR) protocol. All samples exhibit satisfactory luminescence characteristics (in terms of purity, signal intensity and composition, and SAR procedural tests). The optical ages range from 11.6 ± 1.1 ka at the top, to 14.9 ± 1.4 ka at the base of the dune, placing its formation in the Late Glacial. In general, the dataset is internally consistent although, further down the sequence, the observed variability appears somewhat larger than expected from measurement uncertainties (2 sigma) only. We consider additional sources of (partial) random uncertainty (such as water content) and use Bayesian chronological age-depth modeling to improve the chronological precision and connect the sedimentation ages with the different climatic and environmental changes during the Late Glacial. Our case study not only illustrates the importance of OSL dating for prospecting potential contexts for hunter-gatherer finds dating to the Final Palaeolithic; it also contributes to a chronological framework for the changing aeolian landscape in the Lys valley during the Late Glacial, which is somewhat contentious untill now. Finally, we show that results from a high-sampling resolution strategy contribute to debates on expected and observed variability, and hence the time-resolution that can reasonably be achieved for the sandy archives under consideration here.

Keywords OSL dating; aeolian dunes; Lys valley (NW Belgium); Late Glacial; human occupation

P.7-13: Rock surface burial dating of the Nazca Lines, Peru: First results

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The Nazca Lines at the south coast of Peru are among the most enigmatic geoglyphs in the world and a UNESCO world heritage site. Drawn on the desert by the Paracas and Nazca cultures in between 800 BC and AD 700 [1,2], they comprise large (up to a few kilometers) geometric structures such as lines, trapezoids and spirals, as well as figurative depictions like spiders, birds, and whales among others. They were created by removing the dark, patinated stone layer from the desert pavement, exposing the lighter silt layer beneath and accumulating heaps of stones on their edges. Whereas it is believed that they were used in the context of the enactment of fertility and water rituals, there are still many questions unanswered about their chronology and manufacture. For instance, the temporal relationship between geometric and figurative depictions is still unclear, and some geoglyphs were superimposed onto previous ones, but it is unknown why and when this happened.

To address these questions, and within a larger project assessing the impact of climate change on the preservation of the Nazca Lines [3], we took 57 rock samples for luminescence burial dating from three geometric figures (spirals, superimposed trapezoids) and one zoomorphic design (foot of a bird) in the area between Nazca and Palpa. Samples of preferentially felsic composition and devoid of patina were chosen such that they were most likely re-located by the Paracas and Nazca people during geoglyph construction. Drill cores were obtained from the lower (shielded) surfaces of these stones and cut into ca. 0.7 mm thick rock slices to measure luminescence-depth profiles. A plateau of normalized natural IRSL signals (measured at multiple elevated temperatures, MET) within the first few millimeters below surface served as indicators of an archeological dose corresponding to the burial of rock surfaces during construction. A MET SAR protocol was then applied to determine equivalent doses (D_e) for these plateau slices. Additionally, we collected three IRSL samples from the silt layer beneath the desert pavement to assess the temporal scales involved in the formation of this geoarchive.

Initial results indicate that some of the rock samples record the geoglyph construction event through a D_e plateau close to the rock surface. The young age of this event favors the use of the $IRSL_{50}$ signal over higher temperature signals, which yield more scattered results. The set of compiled luminescence-depth profiles further suggests that granite is the most suitable lithology for rock surface burial dating in this area. Post-IR IRSL dating of the sediment samples beneath the desert pavement produces MIS 4-3 ages, indicating that this geomorphic form has endured several major climatic fluctuations.

Keywords
Burial dating; Multiple-elevated-temperature post-IR-IRSL; Desert pavement; Archaeology

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P.7-14: Luminescence dating of historical mortars: the sensitivity question

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The possibility to date historical mortars is one of the key issues in building archaeology as it allows dating directly the construction of the building. Although all historical periods are concerned, this application is particularly in demand in early medieval contexts. In the period between the 4th and the 12th century in Europe, we note considerable lack of archaeological records and written sources that would enable reliable dating of ancient monuments. While 20 years ago it was not clear if luminescence dating can be efficiently used for this application, nowadays it becomes an established research dating approach.

When dating the mortar with optically stimulated luminescence (OSL), the resetting event corresponds to the anthropic activity related to the process of mortar making. Within the last two decades, the methodology for dating quartz extracted from historical mortars through single-grain OSL noted a considerable progress [1]. Many samples originating from various sites were successfully dated and hereby contributed to the better historical knowledge of early medieval architecture. However, there are also some cases in which very low or no measurable signals from quartz are detected. The majority of them seems to be concentrated in particular geographical areas which are consequently considered as unsuitable for OSL mortar dating.

Feldspar is usually considered as an alternative to OSL dating of quartz. Nevertheless, if we consider a very low age of mortar as a construction material and very short exposure of mineral grains to light during the dynamic process of mortar making, the slower bleaching rate and anomalous fading of the signal characteristic for feldspars might represent obstacles for this application. Recent research on feldspar luminescence dating has shown that promising dating results can be obtained also for young sediments affected by heterogeneous bleaching [2]. In order to find the solution to luminescence dating of mortars whose quartz does not respond to SG-OSL stimulation, for the first time we have tried to date feldspars extracted from historical mortars. The paper aims to present these very first attempts and to evaluate the potential of using feldspars as an alternative to quartz for luminescence dating of mortars.

Keywords
Mortar dating; quartz; feldspar; OSL; archaeology

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[3] Acknowledgment: This research makes part of the research project "ArchiDate: Mortar, Sand and Construction: Religious Architecture in Early Middle Ages and new ways for Dating" which is funded within the "Seal of Excellence @UniPD" programme (URBA_MSCASOE18_01). Acknowledgments belong to the supervisor Prof. A. Chavarria and to the collaborators M.-A. Causarano and P. Vedovetto. This research also received a financial support from the LaScArBx [Bordeaux Archaeological Sciences Labex] administrated by the French ANR [Agence Nationale de la Recherche] with the reference ANR-10-LABX-52.

P.7-15: New numerical age constraints for unit TD1 from Atapuerca Gran Dolina, Spain, based on a combination of ESR and luminescence dating methods

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Atapuerca Gran Dolina site (N Spain) is a 25-m-thick cave sedimentary infill comprising 12 lithostratigraphic units. While the uppermost part of the sequence has been widely studied over the last few decades due to its rich archaeological, paleontological and paleoanthropological remains, units TD1-2 at the bottom of the sequence have received much less attention. However, the recent opening of a 10-m-deep trench within TD1 has revealed a thick unit of cave interior deposits, including laminated silts and clays, providing new scope to examine the palaeoenvironmental significance of the basal sequence.

In order to constrain the chronology of these deposits, a detailed magnetostratigaphic study of TD1 was initially carried out [1]. Results showed a dominantly reversed polarity, suggesting a Matuyama age (>0.78 Ma) for TD1, with three short intervals of normal polarity recorded at depths of ~190-280 (N1) and ~510-550 (N2) and ~630-650 m (N3) beneath the top of the section. In particular, the uppermost N1 interval has been tentatively correlated to the Jaramillo Subchron (0.99-1.07 Ma). To confirm this initial chronological attribution, several sediment samples were collected through the sequence for Electron Spin Resonance (ESR) and luminescence dating purposes, following the multi-technique dating approach successfully applied elsewhere in Iberia and the Mediterranean Basin [e.g., 2, 3]. Quartz ESR dating was performed using the Multiple Centre (MC) approach with the standard Multiple Aliquot Additive Dose (MAAD) method [2]. Luminescence analyses focused on single-grain thermally transferred optically stimulated luminescence (TT-OSL) dating of quartz. Sample collection, preparation and dating analyses were performed at two different laboratories (ESR = CENIEH; Luminescence = University of Adelaide) following independent procedures. Comparison of these dating results enables improved evaluation of potential methodological biases, while the resulting chronologies help (i) refine the chronostratigraphic framework of these Early Pleistocene cave interior deposits, and (ii) enable correlations with other cave sedimentary infills of the Atapuerca complex.

Keywords ESR; single-grain TT-OSL; Magnetostratigraphy; Early Pleistocene; Atapuerca Gran Dolina.

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P.7-16: ESR/U-series chronology of Neandertalian occupation layers at Galería de las Estatuas (Sierra de Atapuerca, Spain)

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The Galería de las Estatuas is a Mousterian site within the Sierra de Atapuerca cave system (Burgos, Spain), located within the karstic system of Cueva Mayor-Cueva del Silo. This site is characterised by an important Upper Pleistocene stratigraphic sequence in which a large number of lithic artefacts exhibiting clear Mousterian affinities and a rich assemblage of faunal remains have been found. Neanderthal occupation has been confirmed by the discovery of a phalanx of a foot and the recovery of Neanderthal mitochondrial DNA extracted from the sediments.

Two test pits, GE-I and GE-II, have been excavated from 2008 which have been divided in 5 and 2 lithostratigraphical units, respectively. A minimum age of 45 ka cal BP for this site was obtained by radiocarbon dating in GE-II while older dates were provided using single-grain optically stimulated luminescence (80 – 112 ka in GE-II and 70 – 79 ka in GE-I). The detrital sequence is sealed by a flowstone dated to 13.7 ka cal BP using U-series dating.

In order to better constrain the age of this site, nine herbivorous teeth were collected along the whole sedimentary sequence to be dated by the ESR/U-series dating method though only seven have provided modelled ages. Six of them were collected from levels 2 to 5 of the GE-I test pit while the last tooth was taken at level 2 of the GE-II test pit. Our results, ranging between 80-110 ka, are in agreement with those obtained by single grain TT-OSL and suggest that the sedimentological levels containing Mousterian lithic artefacts and faunal and human remains began to be deposited during the second part of the MIS5. These results fill a temporal gap in the chronology of the Atapuerca sites for which no contemporary MIS5 date was obtained until recently.

Keywords: ESR/U-series dating; Neanderthal; Late Pleistocene; Atapuerca sites complex; Iberian Peninsula

P.7-17: ESR/U-series dating Eemian human occupations of Northern France

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Palaeolithic sites associated with the Eemian Interglacial (MIS 5e) are very rare in Northern France and their preservation is restricted to very specific geological contexts, in association with carbonated tufa (Caours) or peat deposits (Waziers). In order to check the reliability of ESR/U-series method to date teeth recovered from archaeological levels in such specific geological environments, teeth were sampled on these two Middle Palaeolithic sites and systematic *in situ* dosimetry was performed using portable gamma spectrometer. The ESR/U-series ages obtained on the Caours site are very homogeneous allowing the calculation of a mean age equal to 125 ± 11 ka, in agreement with the geological age and other available geochronological data (U-series on carbonate, TL on burnt flints, OSL on sediments), despite an relatively heterogeneous dosimetric environment (gamma dose rate ranging between ca 200 to 450 µGy/a). At Waziers, reducing environment linked to the peat leads to very specific U-series data of the analysed teeth (U content lower than 0.1 ppm in all the dental tissues, evidence of leaching in some tissues), but the mean ESR/U-series age, 129 ± 4 ka, is also in agreement with the available geological and palaeoenvironmental data. These two studies confirm then reliability of ESR/U-series method to date with good accuracy the archaeological levels linked to such short climate event.

Keywords - Eemian; ESR/U-series; teeth; Caours; Waziers.

P.7-18: Optical dating of prehistoric and historic anthropogenic features at Ninove Doorn Noord (East Flanders, Belgium)

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Archaeological excavations prior to the construction of the new Business Park "Doorn Noord" (Ninove, East Flanders, Belgium) revealed a complex of traces of human activity and occupation, spanning several millennia. The oldest traces are burial mounds and pits dating from the Final Neolithic / Metal Ages, followed by various remains of a Roman settlement; the youngest traces are the remains of three camps, dating from the seventeenth and eighteenth centuries. While a broad chronological framework for the site could be established on the basis of archaeological evidence, ^{14}C and archaeomagnetic dating, and historical sources, this remains either circumstantial and/or lacks precision.

In this case study, we report on the potential of quartz-based optically stimulated luminescence (OSL) dating of unheated and heated sediments that are associated with the archaeological traces. Given the availability of independent age information, we consider it a test of both accuracy and precision. At the same time, our study seeks to contribute to the development of methodologies that may aid in an improved understanding and care of the regional heritage.

Samples were collected from the infills of both a circular ditch surrounding a relict burial mound and a loam extraction pit, and from the heated sedimentary remains of fireplaces. We first document the OSL characteristics of sand-sized (63-250 μm) quartz and evaluate the performance of a single-aliquot regenerative-dose (SAR) protocol for equivalent dose (ED) determination through laboratory procedural tests in the usual manner (e.g. dose recovery). We then examine the distribution of ED in all samples using small 2 mm diameter aliquots. In most samples, the majority of the results appears to belong to a single dose population of which the average is then used to obtain the optical age. The resulting OSL dates are confronted with the available independent age, demonstrating that no inaccurate conclusions were drawn from the ED distributions. In terms of both accuracy and precision, the results are most promising for the heated sediments associated with post-Medieval encampments. For 6 samples from 3 features optical ages of around 1750 ± 30 CE were obtained, where independent information dates them to 1745 CE. As all features are comparable, and sources of systematic uncertainty are (largely) shared, this implies the possibility of distinguishing them with a time-resolution that is governed by measurement uncertainties only; for the investigated samples that is on timescales of 5 - 10 years.

Keywords OSL dating; heritage; accuracy; precision.

P.7-19: Chronology of the Xibaimaying site in the Nihewan Basin, North China, inferred from optical dating on fine quartz

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The Nihewan Basin in north China is famous for its archaeological sequence, from which plenty of Paleolithic sites have been found and excavated, while many of them have not been dated. Here we present the dating results of one site, called the Xibaimaying site, which is located in a gully in the basin and is considered as the latest small-tool site in the region. The site (Locality I) was dated to ~15 or ~18 ka using uranium-series technique on bovid teeth [1] and 46 ± 3 ka using optically stimulated luminescence(OSL) method on coarse quartz grains (only one sample taken from the cultural layer) [2]. Since this site is of great significance for understanding the relationship between small-tool and microblade industries in northern China, more archaeological material is acquired. Therefore, recently, new area at Locality I and other two localities (II and III) near Locality I in the gully were excavated. In order to obtain a reliable chronology for the site, 38 samples collected from the new excavated profiles were OSL dated using a single-aliquot regenerative-dose (SAR) protocol on fine-grained (4–11 μm) quartz. Fine-grained quartz from these samples demonstrated excellent luminescence properties for the SAR method, which are greatly different from coarse-grained quartz. The OSL signals from the fine-grained quartz was not saturated at a dose up to 413 Gy. Average water contents for these samples during their burial period were evaluated based on the water contents of the continuous samples from a nearby borehole. All OSL ages obtained for these samples were modelled using Bayesian statistics with stratigraphic constraints. Finally, we concluded that the cultural layer bearing small-tool assemblages was deposited from 79.7 ± 3.2 ka to 35.3 ± 0.9 ka, corresponding to the early-MIS 5 to late-MIS 3, rather than the late-MIS 2 as suggested previously by uranium-series dating [1].

Keywords: quartz OSL dating; Bayesian statistics; stratigraphic framework; Xibaimaying site

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P.7-20: Luminescence Dating of Archaeometallurgical Slag from Buriram Province, Northeastern Thailand: The Possibility and Reliability of Dating

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In this study, the possibility of dating directly the archaeometallurgical slags is assessed. According to a number of enormous slag heaps distributed, the Ban Kruat district Buriram province, Thailand, is interpreted as one of the most prominent archaeometallurgical sites in the Mainland Southeast Asia. Therefore, five slag samples were collected from the topmost of two heaps. The X-ray diffraction measurement of each slag reveals the existing of quartz mineral useful conceptually to the luminescence dating. Based on Optically Stimulated Luminescence (OSL) measurement, there are two of five samples show weak luminescence signal which is not suitable for OSL dating. This may according to the lack of quartz mineral by value. However, the rest three quartz-rich slag samples express clearly the OSL signal. Therefore, 40 – 96 aliquots of Single Aliquot Regenerative (SAR) measurement were employed.

With the combination of the activated dose rate obtained from environmental radioactive elements, i.e., U, Th, K, two timespans of iron-smelting activity were defined, i.e., 140 years approximately and 470 – 710 years. Comparing with the radiocarbon dates of the adjacent slag heap in Buriram (560 ± 280 years BP), the 140-year slag heap dated in this study is younger representing the latest datable iron-smelting industry in the Angkor highland, i.e., Thailand. Meanwhile, due to the radiocarbon dates (140 ± 20 years BP) of heap in the Angkor lowland, i.e., Cambodia, the date in this study is quite conform. Therefore, it can be concluded that the OSL dating is effective for date directly the slag-bearing quartz.

Keywords luminescence dating; iron slag; Ban Kruat Archaeological Site; Buriram Province; Northeastern Thailand

P.7-21: ESR Dating Ungulate Teeth at Mirosava Cave, Eastern Serbia: Reconstructing Paleoenvironments During Early MIS 3

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Near Ćuprija in eastern Serbia, Mirosava is a small cave (6 m x 3 m) formed in the Jurassic limestones within the mountainous hinterland of Velika Morava. In 2017, test excavations demonstrated that the back part of the cave preserves Pleistocene sediment with abundant faunal remains, including temperate species, such as *Bison priscus*, *Equus ferus*, *Equus hydruntinus*, *Megaloceros giganteus*, *Cervus elaphus*, *Dama dama*, *Capreolus capreolus*, indeterminate Rhinocerotidae, *Ursus spelaeus*, *Crocuta spelaea*, several smaller carnivores, several small mammals, rodents, herpetofauna, and fish. A sandy silty matrix-supported gravel layer with 20-30 vol% *éboulis* (rooffall blocks), hosted these fauna. From Layer 3, a late Pleistocene layers in Mirosava, three teeth, an *Equus ferus* milk molar, ET55, a *Bos* or *Bison* premolar, ET53, and a *Canis lupus* canine, ET54, were collected along with 10 associated sediment samples for ESR dating. The two herbivore cheek teeth both derived from the strongly red horizon within Layer 3, while the canid canine had come from a deeper horizon within Layer 3. Samples were prepared using normal protocols for standard and isochron ESR enamel dating with contaminant containment procedures for a Class 10,000 clean lab. After powdering to ≤ 100 mesh, 10 associated sediment samples were analyzed with NAA for U, Th, and K, while all dental tissues were analyzed only for U. Unfortunately, the canid did not produce enough enamel for an accumulated dose determination. The enamel U concentrations averaged 0.30 ± 0.02 ppm, while U in the dentine ranged from 14.23 to 17.42 ± 0.02 ppm. With volumetrically and time-averaged sedimentary dose rates averaging 780 ± 66 μGy/y and cosmic dose rates at 56 ± 6 μGy/y, ET55 dated at 48.0 ± 3.1 ka, while ET53 dated to 48.2 ± 2.0 ka. Their mean age, 48.1 ± 1.7 ka, correlates with early MIS (Marine Isotope Stage) 3, and most likely, with the Moorschoofd–Glinde Interstadial, aka Dansgaard–Oeschger (DO) Stage 14. Since Serbia has few sites containing deposits that date to early MIS 3, the new dates for Mirosava Cave allow better paleoenvironmental comparisons with other MIS 3 sites in the Balkans, such as Pešturina, Divje Babe I, Šalitrena Pećina, Hadži Prodanova Pećina, and Bacho Kiro Cave.

Keywords: Electron spin resonance **(**ESR) dating; mammalian teeth; Mirosava Cave, Serbia; Late Pleistocene fauna; Marine Isotope Stage (MIS) 3 paleoenvironmental analyses.

P.7-24: Luminescence dating of the Shangshangang paleolithic site, Zhejiang Province, China

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A few of Paleolithic archaeological sites in Eastern China have been reported, especially for well-dated sites. Here, we present the luminescence dating of the Shanghangang (SSG) site in the Changxing County, Northern Zhejiang Province, east China. The site is located on fluvial terrace, and the deposits of the site are 8.8 m thick, and composed of Red Clay. A total of 28 samples from the west excavation section were collected for luminescence dating. Before dating, grain-size distribution and chemical components were analysed, in order to understand the sedimentary properties of the samples and their origin, which will help to explain their luminescence behaviours. The results show that these terrace deposits are of aeolian origin, and they were chemically weathered, and the degree of chemical weathering increase with increasing depth. The weathering may cause the migration of some elements, which makes it difficulty to accurately estimate the average dose rate during the burial period for these samples. The chemical weathering also removes almost all of feldspar minerals, especially for middle and lower samples, demonstrated by their intensities of IRSL signals. The quartz grains from these samples show well luminescence properties for the single-aliquot regeneration-dose (SAR) method. The quartz OSL-SAR ages obtained for the upper nine samples (0.3 –2.7 m in depth) range from15 ka to about 152 ka, and they are in stratigraphical order. Base on these nine OSL ages, an average sedimentary rate is calculated to be about 1.75 cm/kyr. We then deduced that these ages are reliable. On the other hand, a standardized growth curve can be constructed for these samples. For the samples from the depths >2.7 m, their OSL ages are not stratigraphically consistent, we deduced that these samples cannot be accurately OSL dated, although some of their growth curves appear not to be saturation. In this case, the thermally transferred optically stimulated luminescence (TT-OSL) procedure were first tested for the nine samples <2.7 m. The preliminary results show that the quartz OSL-SAR ages are consistent with the TT-OSL-SAR ages for some samples.

Keywords Paleolithic site in East China; Red Clay; quartz OSL-SAR dating; quartz TT-OSL-SAR dating; Standard growth curve

P.7-25: Examining sediment infill dynamics at Naracoorte Cave megafauna sites using multiple luminescence dating signals

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The Naracoorte Cave Complex (NCC) represents Australia's richest Pleistocene megafaunal fossil locality, preserving extensive palaeontological and palaeoenvironmental sediment records that collectively span the last 550 ka. The majority of NCC allochthonous clastic deposits and associated faunal remains have accumulated via narrow, cylindrical solution pipe openings that acted as vertical pitfall traps. Relatively little is known about the temporal dynamics of NCC solution pipe formation, or whether preferential periods of solution pipe development have exerted accumulation biases on fossil-bearing infill deposits. Establishing reliable chronologies on the abundant late and middle Pleistocene solution pipe deposits lying close to, or beyond, the upper age range of OSL dating is particularly important for reconstructing longer term sediment infill histories at NCC, as well as for developing baseline estimates of palaeoecological change prior to human arrival.

This study aims to provide a multi-site examination of NCC sediment infill dynamics, and to assess the suitability of using different luminescence dating signals for reliably dating late and middle Pleistocene NCC deposits. A combination of single-grain OSL, single-grain TT-OSL and multiple-grain post-IR IRSL is applied to deposits associated with solution pipe openings at Alexandra, Smoke Tortoise, Specimen, Whalebone and Victoria Fossil Caves. Modern analogue samples collected from above and beneath active solution pipe entrances confirm adequate OSL, TT-OSL and pIR-IRSL signal resetting down to insignificant residual levels. Independent dating comparisons (quartz ESR, U-series speleothem dating) and examination of replicate quartz and K-feldspar equivalent dose (D_e) datasets are used to assess: (i) single-grain OSL dating suitability back to at least 200 ka for some NCC deposits with low environmental dose rates; (ii) potential complexities that may influence reliable D_e determination at different scales of analysis; (iii) the consistency of OSL, TT-OSL and pIR-IRSL ages over the last 300 ka, and the potential for applying extended-range luminescence techniques to older NCC deposits.

Single-grain OSL dating of a 1m core extracted from a sediment cone in Smoke Tortoise Cave reveals a complex formation history involving protracted accumulation between 300 and 200 ka, and at least one reactivation phases reflecting blocking and unblocking of the solution pipe. To examine general temporal trends of solution pipe formation and associated sediment accumulation across a broader range of NCC sites, we examine the frequency distribution of all published ages for NCC clastic deposits spanning the last 550 ka. Our preliminary analysis potentially suggests preferential clastic accumulation during warmer interglacial and interstadial climate cycles, implying discontinuous opportunities for allochthonous sediment and fossil accumulation inside the caves.

Keywords Naracoorte Caves; Australian megafauna, single-grain OSL; single-grain TT-OSL; post-IR IRSL.

P.7-26: Luminescence dating by k-feldspars of fluvial sediments of the urban complex of Maranga, Lima (Peru)

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The history of the Rimac Valley, where the capital city of Lima (Peru) is located, is one of the most important ones in South America, as over the course of ~2000 years several civilisations (Lima and Yschma cultures) settled before the arrival of the Incas. In the present-day city of Lima, the urban complex of Maranga is one of the best preserved pre-Inca examples, although there are doubts about its exact chronology which is based on a few radiocarbon ages only. There are several unanswered questions about this complex, such as why a part of the Rimac valley remained inhabited, how the occupation and adaptation of the southern river bank took place, and when the first man-made irrigation canals were built. Radiocarbon dating has shown that occupation occurred between the 6th and 8th centuries AD [1] on previously uninhabited land, as inferred from natural fluvial sediments without any evidence of human occupation. In this work, eight natural fluvial sediments, and altered sediments containing ceramics prior and contemporary to the occupation of the Maranga complex, were collected and dated by quartz- and feldspar-based luminescence dating to understand the effect that natural and human factors had on the evolution of the Maranga complex. Since the OSL signal of quartz in the Peruvian coastal area is problematic [2,3,4], both the IRSL and pIRIRSL signal of k-feldspars were used to obtain this chronology [5]. Our results provide for the first time a chronology that allows a better understanding of the natural fluvial and anthropogenic processes that affected this area of the Rimac Valley. The results also allowed a better understanding of the discrepancies between the radiocarbon, OSL and (PiR) IRSL ages, which will be useful to improve future luminescence dating approaches in the Peruvian coast.

Keywords Rimac Valley, human occupation, fluvial sediments, pIRIRSL dating.

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P.7-27: ESR and OSL dating of fossil deposits from the Naracoorte Cave Complex, South Australia

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Comparisons of palaeodosimetric dating methods that can be applied to shared sedimentary samples offer optimal assessments of dating reliability over Late to Middle Pleistocene timescales; enabling stratigraphically constrained evaluations of dose rate or palaeodose complications that may otherwise be difficult to unravel in certain depositional settings. In spite of these advantages, studies using paired electron spin resonance (ESR) and optically stimulated luminescence (OSL) dating of optically bleached quartz gains remain relatively uncommon. This study aims to assess the suitability of a combined ESR and OSL dating approach for resolving the chronologies of Late-Middle Pleistocene deposits within the Naracoorte Cave Complex (NCC) of South Australia. This karst system is known for its rich megafaunal assemblages and sediment infill sequences spanning the last 550 ka, and is considered a key fossil locality for understanding the drivers of Australia-wide Late Pleistocene megafaunal extinction. Establishing reliable chronologies on the NCC fossil-bearing deposits using trapped charge dating techniques is critical since most NCC sites lie close to, or well-beyond, the radiocarbon dating range.

In this study we apply ESR and OSL methods in tandem to a series of samples collected from three different NCC sites: Whalebone, Specimen and Alexandra caves. ESR quartz dating focuses on the multi-centre (MC) approach, which involves comparative evaluations of Al and Ti centre signals to provide insights into sample bleaching adequacy. The paired luminescence dating study focuses on single-grain OSL analysis, and includes examination of multi-grain averaging effects and dose saturation limits.

The comparative ESR-OSL dating results exhibit broad agreement for deposits spanning 50-150 ka, with either the Ti or Al centre ages overlapping with paired OSL ages at 2σ in nearly all cases. MC ESR dose evaluations indicate incomplete resetting of the Al centre signal for a small number of samples. Two-thirds of samples exhibit Ti-Li ages that are significantly older than corresponding Al centre ages, which is unexpected from a bleaching kinetics perspective and may indicate a broader reliability issue for Ti-Li D_e evaluation with these particular samples. Our findings: (i) support the applicability of both palaeodosimetric dating methods in this depositional setting; (ii) highlight the merits of applying combined ESR-OSL analyses in tandem, and; (iii) provide one of the first reliable evaluations of quartz ESR MC dating for samples with natural dose ranges as low as only a few tens of Gy.

Keywords: Quartz ESR dating; Multi-centre approach, single-grain OSL dating; Naracoorte caves

P.7-28: Detection of heating in archaeological sediments from Blombos Cave, South Africa.

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A number of single-grain dating studies of archaeological sediments have documented samples where the luminescence properties differ from those of the surrounding sediments, attributing the phenomenon to heating in antiquity. For example, quartz from Denisova Cave, Siberia, is very weakly luminescent, leading to a ~2% acceptance rate for measured grains from most samples [1]. Conversely, a single sample yielded a 28% acceptance rate, which was attributed to sensitisation by heating resulting from early Holocene hearth use in the overlying levels. The same study also suggested that heating of overlying sediments accounted for the presence of a low-dose population in the equivalent dose distribution of quartz, but not feldspar, for a bioturbated sample. The authors [1] suggest that the incorporation of younger heated material into older sediment by burrowing was evident in the quartz but not the feldspar data since the former mineral sensitises whereas the latter desensitises when exposed to intense heat. However, although firing has been used to explain otherwise anomalous differences between the luminescence properties of adjacent samples/grains, relatively few studies have measured the effect of firing upon individual mineral grains.

In this study we present luminescence data from samples obtained during an experimental archaeology field season conducted near Blombos Cave, South Africa, by researchers from the SapienCE Centre of Excellence. Fires were constructed and burned upon a modern sand substrate obtained from coastal dunes near Blombos Cave [2]. Temperature was continuously recorded at the sand/fire interface, and at 5 and 10 cm depth, yielding samples with a well-documented firing history. Burn times ranged from 1 to 10 days. The natural single-grain sensitivity distributions and abbreviated thermal activation characteristics (observation before and after a single controlled episode of heating, following [3]) were measured for quartz extracted from thirteen samples with known firing histories. The effects of firing can be detected in both datasets. The implications of our observations for identifying ancient heating in data obtained during routine equivalent dose measurements will be discussed.

Keywords Luminescence sensitivity; Thermal activation characteristic; Hearths; Single-grain; Archaeology.

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P.7-29: New extended-range luminescence chronologies for the Middle Pleistocene units at the Sima del Elefante archaeological site (Sierra de Atapuerca, Spain)

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The Sima del Elefante karstic infill site is located within the Sierra de Atapuerca system (Burgos, northern Spain), and forms part of a series of important Early and Middle Pleistocene archaeological complexes that have been dated previously with luminescence techniques (Gran Dolina, Galería Complex, Sima de los Huesos, Galería de las Estatuas). The sedimentary sequence at Sima del Elefante spans >25 metres and dates from the Early Pleistocene to the late Middle Pleistocene. A human mandible, associated faunal fossils and Oldowan stone tools recovered from the lower red units (TE7-TE12), and dated to ~1.2 Ma via cosmogenic nuclides, represent some of the earliest evidence for human occupation of Europe. A palaeomagnetic reversal located in the upper-middle section (TE16-TE17), interpreted as the Matuyama-Brunhes boundary, provides chronological constraint for the overlying sequence. Towards the top of the sequence, two isolated U-series ages of 200-300 ka have been obtained for the upper red units (TE18-TE19), which contain Acheulean lithic assemblages with associated large and small mammal fauna. However, the existing chronological constraint for these Middle Pleistocene units remains limited. Importantly, these uppermost units mark the closure of one of the main palaeoentrances to the Atapuerca karst system, and thus establishing their accumulation history is important for understanding past human occupation patterns and carnivore use of the caves.

The aims of this study are to: (i) provide the first detailed chronological assessments of the Sima del Elefante upper units using extended-range luminescence dating, and; (ii) determine the timing of ultimate infilling at Elefante and constrain the Middle Pleistocene cave closure event. In total, five dating samples were collected; one from unit TE18 and three from unit TE19 at the Elefante exposure, and an additional sample from Galeria Baja (located inside the Atapuerca karst system) from a level corresponding to upper TE19 and representing the closure of the palaeoentrance.

We present extended-range luminescence chronologies for the Sima del Elefante sequence obtained using both quartz TT-OSL and K-feldspar pIR-IRSL signals. The paired luminescence ages for the upper occupation levels are in agreement with each other, and are consistent with previously obtained U-series and biochronology age estimates for TE18-TE19. We discuss issues of technique suitability and examine temporal correlations with archaeo-palaeontological units preserved at neighbouring Atapuerca sites, drawing on comparisons with previously published luminescence dating results for Gran Dolina, Galería Complex and Sima de los Huesos.

Keywords Atapuerca; Sima del Elefante; single-grain TT-OSL; post-IR IRSL; Middle Pleistocene.

P.7-31: Luminescence Chronology of Fossiliferous Fluvial Sediments in the Middle Atbara River, Sudan

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Fluvial sediments of the Middle Atbara River Valley, eastern Sudan, contain abundant vertebrate fossils and stone tools. Previous work described six sedimentary units; BBS1-3 and KGS1-3 from the bottom to the top [1]. U-Th dating on bivalve shells suggested an age of ~130 and ~90 ka for KGS2 and KGS3, respectively, and mammalian biochronology suggested an age of ~0.8 Ma for the underlying BBS [1]. We conducted fieldwork between 2018 and 2020 in the Middle Atbara, and discovered numerous new sites, recovering a large number of new collection of fossils and stone artefacts. Twenty-seven luminescence samples were collected to establish a chronology of the fluvial sediment sequence.

The quartz OSL dating was applied for samples from the uppermost sedimentary unit (KGS3), but the signal reached to saturation below this unit. To select a suitable feldspar signal to date older samples beyond the limit of quartz OSL, a comparison of the quartz OSL, feldspar post-IR IRSL at 225 and 290°C, and pulsed IRSL signal at 50 °C [2] was conducted for a sample from KGS3. The result showed that only the fading corrected pulsed IRSL yielded a consistent age as the quartz OSL, and the post-IR IRSL signals (both at 225 and 290°C) overestimated the quartz age, presumably due to incomplete bleaching. We therefore selected the pulsed IRSL signal to date the older deposits. Anomalous fading rates of the pulsed IRSL signal were measured and the ages were corrected following Kars et al. [3]. The luminescence ages indicate that the entire BBS - KGS sequence spans ~200 20 ka, significantly revising previous conclusions. Our new chronology will help clarify the timing of the extinction of megafaunas in the Pleistocene and the context of late Acheulean stone tool technology in this under-explored region.

Keywords Pulsed IRSL; Fluvial sediments, Atbara River, Vertebrate fossils, Stone tools

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P.7-32: A needle in a haystack: using targeted drilling with low-resolution dating to identify archaeological sites for excavation

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Conducting an archaeological excavation is risky, requiring extensive planning and expense with respect to time, finances and expertise, while there is little to no guarantee that a significant scientific discovery will be made. A field project will, by necessity, involve many specialists and can be difficult to coordinate or justify, particularly when a new project is initiated at a previously unexcavated site. The aim of this study is to explore the feasibility of running a targeted drilling campaign with low resolution dating coverage to identify the archaeological potential, as well as the optimal spatial location to set up a new excavation at a field site.

Steenbokfontein is located on the west coast of South Africa, in close proximity to Elands Bay Cave and Diepkloof Rockshelter, and is several hundred meters to several kilometres from the sea, even during the high sea stand of MIS 5e. The proximity of the shelter to the coast, as well as to two other important later Pleistocene west coast occupations, suggest it may be an important site for hominin occupation through the later Pleistocene and Holocene. There are two sandstone caves at the site: Steenbokfontein Cave excavated by Antonieta Jerardino in the 1990s and Simons Cave, the focus of this study.

Two field seasons were undertaken at Simons Cave. During the first season a small team together with a group of local students undertook an electrical resistivity study and two cores (~3m depth) were collected from within the cave using a percussion corer and sampled for OSL and radiocarbon dating. The second field season saw a preliminary systematic excavation, with a larger scientific field team involved. All excavated finds were documented with either piece plotted or non-piece plotted data and further samples were collected for OSL dating, radiocarbon dating and micromorphology.

Preliminary inspection during the first field season documented a ~3 m deep stratigraphic sequence, consisting of beds and fine laminations of anthropogenic and geogenic sedimentary input. Preservation of several archaeological layers was good, documenting the presence of hearths, terrestrial and marine fauna and lithic remains, while preservation in other layers was less impressive. Geochronological data from the cores was varied. Single grain quartz OSL ages from the cores are stratigraphically consistent, ranging from 5.0±1.1 ka to 133±35 ka. These ages show a temporal overlap of the occupations at Simons Cave with MIS5-3 layers at Diepkloof; ages of ~55 ka and ~43 ka coincide with the later Howiesons Poort complex. In contrast, radiocarbon ages collected from the cores all returned a similar age of ~4,000 yrBP. Encouragingly, preliminary OSL ages from the excavation span a similar time frame (5.2±0.4 to 69.5±6.2 ka), and preliminary radiocarbon results for charcoal collected from the excavation, associated in potential with a later Middle Stone Age lithic industry, returned an age of 30,360±110 yrBP.

Keywords single grain; OSL dating; radiocarbon dating; percussion coring; archaeological excavation

P.7-33: Quaternary sediment mixing and chronological reversal in the main Narmada river channel in Sehore district, Madhya Pradesh, India

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The Central Narmada Basin has received major attention on Quaternary geoarchaeology since the region was resurfaced relatively recently (1997). Prior to that, numerous archaeological and palaeontological discoveries were made over several decades by various researchers. Extensive geoarchaeological surveys were carried out by the first author to understand the spatial distribution, sedimentary context and antiquity of microliths (miniaturized and advanced stone tools generally associated with later prehistoric and younger periods) in Sehore and Hoshangabad districts of Madhya Pradesh.

To understand the geochronology of the Quaternary sediments, to establish the geochronology of the stratigraphic sequence and to interpret their geoarchaeological implications in the floodplain zone, OSL samples were collected from thick stratigraphic sections at Sardarnagar on the northern flank of the Narmada River. Multiple samples were collected from two localities i.e. Sardarnagar-I (5 samples L1 to L5 from a 5 m section comprising of fine silty-sandy to coarser gravelly sediments with calcrete nodules) and Sardarnagar-II (3 samples from 3 independent sections of 2 m thickness comprising of coarse silty-sand).The Sardarnagar-I and II sections were devoid of any *in situ* archaeological implements except for one Palaeolithic hand-axe that was found in fresh condition at the bottom most layer close to the water level. The dating results demonstrated a significant sediment mixing and a chronological reversal in the Sardarnagar-I stratigraphy.

Dates acquired from both the locations are of different range as the results from Sardarnagar- I show a strong disparity in the dates (L-1: 26 ka; L-2: 12.7 ka; L-3:14 ka; L-4:36.6 ka and L-5: 17.6 ka)whereas the dates from Sardarnagar-II do not show any inconsistency in chronological order(S-1: 2 ka; S-2: 8.1 ka; S-3: 9.7 ka).Comparison of both fine polymineral IRSL (fading corrected) ages and coarse-grain quartz OSL ages, can help us to infer that this site has been affected by floods in the past. This experimental observation can be verified by the field observation as well. Possibility of low-energy degradation and multiple flood seasons being primary factors for disturbing the original sediment deposit in the section cannot be negated. Here we present results which signify the high probability of disturbed Quaternary sediments largelydevoid of archaeological deposits in the river sections affected by multiple floods.

Keywords: Fine grain IRSL; Quartz OSL; sediment mixing, chronological reversal, central Narmada Basin.

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P.7-34: Introducing the EARTHWORK project: feldspar single-grain pIRIR luminescence dating of earthworks in the Netherlands

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While most of the world's landscapes are heavily influenced by human activities since the beginning of the Holocene, the Netherlands is considered to have one of the extreme examples of human-induced landscapes. Earthworks erected by (pre-)historic humans are omnipresent and are key elements in the landscape formation. Understanding the roles and effects of such monuments within their natural surroundings is important to understand human-environment interactions in the Netherlands. In this respect, it is key to set up a firm chronology based on absolute dating of the earthworks. Contrary to the relatively firm chronology that has been developed for palaeogeographic reconstructions (e.g. driftsand, avulsions), little is known about the absolute age of the vast majority of earthworks.

The NWO-funded EARTHWORK project aims to set up a foundation for the chronology of earthworks using the feldspar single-grain post infrared – infrared stimulated luminescence (pIRIR) dating method. Attention has been drawn to luminescence dating as a method to date earthworks, due to the lack of other reliable dating materials (e.g. archaeological remains, organic material for radiocarbon dating). When applying luminescence dating at earthwork sites, partial bleaching, as well as post-depositional mixing, can substantially affect the dating results. Hence, single-grain dating approaches are needed to overcome these challenges. Most of the research utilizing single-grain methods used quartz, but it has been demonstrated to be difficult to do so in the Netherlands, due to the low OSL sensitivity of quartz [1]. Hence, we explore the suitability and applicability of feldspar single-grain pIRIR methods for dating earthworks. Although we focus on the Netherlands in our project, these methods may be universally applicable.

While the project roughly divides the Netherlands into two regions, the lower Netherlands and the higher Netherlands, the emphasis of this presentation will be on the higher Netherlands. The higher Netherlands is mostly covered by sandy soils and past inhabitants have created earthworks such as Celtic fields and plaggic soils to support agriculture on these nutrient-poor soils. We will present preliminary dating results for one of these plaggic soils, situated in the eastern Netherlands, and discuss the challenges and future tasks of dating the earthworks in the sandy regions of the Netherlands. The earthworks in the lower Netherlands, which include dwelling mounds and dikes, will also be introduced within their own challenges in applying luminescence dating.

Keywords earthworks; feldspar single-grain; pIRIR; the Netherlands

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P.7-35: The Palaeolithic occupations of the Central Aegean (Stelida, Naxos island, Greece) highlighted by single-grain IRSL dating

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Stélida, located in Naxos, Greece, is a prehistoric site studied since 2013 by Tristan Carter and Dimitris Athanasoulis as part of the SNAP project (Stélida Naxos Archaeological Project). This site has been exploited as a siliceous raw material source. Many artifacts from the Middle and Lower Paleolithic have been found both on the surface and in stratigraphy. This discovery challenges a long-standing dominant model that the Cycladic islands were not occupied until the Mesolithic. However, these discoveries need to be associated with numeric dating of the site in order to establish a clear chronological framework. Due to the *a priori* chronological significance and the absence of organic materials, the luminescence dating method was considered the most relevant.

The site is on a hill by the sea, on which there are colluvium. So, the site has a complex taphonomy, with potential mixing of grains of different ages. Following the lack of luminescence sensitivity of quartz, different IRSL measurements on K-feldspars were conducted. An initial study of a dozen of collected samples from the stratigraphic levels of three trenches (DG-A/001, DG-A/021 and SH/024) located on different parts of the hill and in which lithic material was found, gives interesting first results. Indeed, IR_{50} and $pIRIR_{290}$ multi-grain and $pIRIR_{290}$ single-grain measurements have been used and compared, giving more information about the taphonomy of the site and the potential presence of poorly bleached grains. These results, which are *terminus ante quem*, were then processed by different statistical models (Central Age Model, Average Dose Model, Finite Mixture). The results indicate that grains were well bleached and that multi-grain and single-grain ages correlate well. These discoveries demonstrate that the site has been occupied for the first time at least 200,000 years ago, indicating a probable new path of human dispersion towards Europe in the Middle Pleistocene [1].

Keywords Luminescence dating; single-grain IRSL; Palaeolithic; Central Aegan; human dispersion

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P.7-36: Single-grain OSL and extended-range luminescence dating of late to middle Pleistocene faunal assemblages from tropical eastern Australia

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Fundamental gaps remain in our knowledge of faunal responses to late and middle Pleistocene climate change across Australia owing to geographic imbalances in fossil discoveries and limited temporal coverage of existing chronological records. These limitations are particularly evident for tropical Australia and New Guinea (Sahul), where reliably dated fossil sites and palaeoenvironmental records are both significantly underrepresented. As a consequence, regional models of Pleistocene ecological turnovers for tropical Sahul, including late Pleistocene megafauna extinction, have relied on interpolation across vast landmasses that are essentially devoid of data. The fossiliferous cave deposits at Mt Etna and Capricorn Caves, central eastern Queensland, are among the few stratified, Pleistocene rainforest vertebrate fossil records known in Australia. U-series dating of speleothems bracketing the extensive fossiliferous layers at Mt Etna provides minimum and maximum ages spanning 205 – 484 ka, and constrains a major turnover from rainforest to xeric-adapted fauna sometime after 280 ka [1]. The sediment-filled chambers of the neighbouring Capricorn Caves system contain diverse fossil assemblages potentially extending into the late Pleistocene, but are currently lacking any systematic dating evaluations.

In this study we use complementary quartz and feldspar luminescence dating approaches to establish the first direct ages for fossil-bearing clastic infill at Mt Etna, and expand the chronological coverage of the region's fauna record to include two previously undated sites at Capricorn Caves (Zig Zag and Harp Cave). Single-grain quartz OSL dating is applied to the late Pleistocene deposits at Capricorn Caves, while a combination of single-grain thermally transferred optically stimulated luminescence (TT-OSL) dating of quartz and multiple-grain post-infrared infrared stimulated luminescence (pIR-IRSL) of K-feldspars is applied to the middle Pleistocene Mt Etna clastic infill sequences. Comparisons with independent age control (capping speleothem U-series ages) at Mt Etna is used to examine the suitability of different extended-range luminescence dating signals, and refine our equivalent dose (D_e) determination procedures.

The findings of this study are used to (i) provide insights into the broader applicability of extended-range luminescence dating techniques for refining the late and middle Pleistocene faunal history of tropical Sahul; (ii) refine the timing of the major faunal turnover recorded at Mt Etna during Marine Isotope Stage 8, and; (iii) enable improved correlations of sedimentary infills and fossil assemblages across the karst systems of central eastern Queensland.

Keywords
Megafauna extinction; Mt Etna, Capricorn Caves, Single-grain OSL; Pleistocene

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P.7-37: First luminescence chronology of the initial Upper Palaeolithic of Eastern Kazakhstan (Ushbulak site)

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In modern archaeology, one of the main assumptions is that, in Europe and western Asia, Middle Palaeolithic cultures are associated firstly with Neanderthals, and secondly with the emergence and spread of industries of the Late/Upper Palaeolithic, associated with the dispersion of anatomically modern humans across Eurasia. Starting from about 50 ka in various regions of Eurasia, changes are recorded in key elements of material culture; these include the emergence of new techniques for splitting stone, specific types of tools, the widespread use of bone material and the creation of non-utilitarian items. Establishing the causes, nature, distribution pathways and timing of this phenomenon occupies one of the central challenges in global archaeology. In Central Asia, an important region on the likely dispersion route, complexes associated with the early stages of the Upper Palaeolithic were recently discovered [1]. In 2016, during exploration work, the Russian-Kazakhstani expedition discovered the Ushbulak site, which is now established as a key location for studying the late stages of the Stone Age in the region.

We present here the first results of a detailed geochronological study of the Ushbulak multilayer site, now the reference for the Upper Palaeolithic of Kazakhstan. The site contains seven main cultural layers. Organic remains are scarce, and to determine the timing of the formation of the proluvial slope deposits of the site, OSL and IRSL dating has been applied. Unfortunately most samples of quartz are not sensitive, presumably because the sediment is mainly derived from nearby granite basement rock. In the upper part of the section, however, there is clear evidence of an increase in the supply of aeolian sediment, for which a comparison of the three dating protocols (OSL, $pIRIR_{290}$, IR_{50}) indicates sufficient resetting of all signals, so that the IRSL ages reflect the time of deposit formation. Three cultural and chronological stages have been identified, corresponding to different periods of the Upper Paleolithic: the initial Upper Paleolithic (layers 7.2–5.2) - recorded in the interval of 47–37 ka; the developed Upper Paleolithic (5.1–4) - 22–19 ka; and the final Upper Paleolithic (3.3–2.1) - 17–15 ka. This study has, for the first time, determined the timing of the main stages of the human occupation at Ushbulak site, starting from the initial settlement about 45–47 ka.

Keywords: Upper Palaeolithic; Central Asia; IRSL**.**

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Session 8:
Evaluating luminescence and ESR methods in archaeological and geological contexts

Oral Presentations

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2	Kira Westaway	Testing the accuracy of pIR-IRSL procedures using independent age estimates
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	Presenter	Title
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18	Yorinao Shitaoka	Quartz OSL dating to find formative ages of Higher terraces burring valleys in the central Lesser Nepal Himalayas
19	William McCreary	Challenges in updating the luminescence chronology of the Chaîne des Puys volcanic province, France
20	Yiwei Chen	OSL dating of young dunes in upper reach of the Yarlung Tsangpo River, southwest Tibetan Plateau
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22	Toru Tamura	Luminescence characteristics of coastal sediments in East Antarctica

O.8-1: Chronological framework for late Pleistocene and Holocene lœss sequences: Extending the LPH-IRSL protocol to Eastern Beringia archaeological sites

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The Low Preheat Infrared Stimulated Luminescence (LPH-IRSL) protocol was developed [1] in order to circumvent methodological challenges related to luminescence dating of central Alaskan wind-blown sediments. High thermal transfer and poor thermal stability prevented the use of traditional and high-temperature IRSL (post-IR IRSL) protocols for adequate age determination of these sediments, while the LPH-IRSL provided consistent and reproducible results corroborated by independent age controls.

The LPH-IRSL protocol was used to date 73 late-glacial lœss samples collected in 10 stratigraphic profiles, dispersed in 8 archaeological sites, mostly located in Central Alaska (USA), as well as in the nearby southwestern Yukon (Canada). This extensive dating program allowed the construction of a robust chronological framework documenting lœss accumulation processes and early human occupation of the area from the late Pleistocene and throughout the Holocene.

Direct dating of climate-sensitive lœss sediments by luminescence allowed the establishment of a robust link between the geoarchaeological chronology and the paleoenvironmental conditions prevailing in the past. By the observation of lœss intrinsic characteristics, a strong relation has been established between sedimentation rates and lœss composition, witnessing a significant climate shift at the onset of the Bølling-Allerød period. It is suggested that this change could have been beneficial for the establishment of human groups in this area, which is beginning at the same time in the central region of Alaska.

Keywords LPH-IRSL; Archaeology; Lœss; Central Alaska; Initial peopling

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O.8-2: Testing the accuracy of pIR-IRSL procedures using independent age estimates

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Feldspar pIR-IRSL dating techniques have been extensively applied to the Asian region to establish the burial age of sediments from cave and river terrace environments. These techniques are the most appropriate for luminescence dating technique in these sedimentary environments due to 1) heavy fading rates of sediments influenced by volcanic activity with g values in excess of 15 %, 2) high dose rates >3-4 Gy/ka, 3) saturated quartz, and 4) certain locations with minimal UV quartz OSL signal. In all applications the pIR-IRSL techniques have been used in conjunction with a multi technique approach providing an excellent opportunity to test the accuracy of this techniques both single aliquot and single grain against independent age estimates. These techniques have been applied to 58 samples from Java, Laos, Sumatra, Vietnam and Southern China and will be compared against independent age estimates derived from U-series dating of carbonate, U-series dating of teeth, US-ESR dating of teeth, and Ar-Ar dating of pumice. In most cases the independent age estimates are constraining a slightly different event, for example the burial of the sediments vs the death of the organism, or the precipitation of the flowstone, which occurred prior to and after the burial event, respectively. However, the independent age estimate still provides a baseline within which the performance of the pIR-IRSL techniques can be evaluated. In this talk I will review this data and assess the implications for dating the sedimentary environments in Asia.

O.8-5: Challenges of single grain quartz OSL dating sediment samples from a low dose-rate environment near Victoria Falls in Zambia

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Recent excavations near Victoria Falls, Zambia have uncovered an extensive record of Stone Age artefacts spanning the Early to Later Stone Age of south-central Africa. The sedimentary context is a ~34m thick sequence of red sands in Mosi oa Tunya National Park, which forms a distinct scarp on the landscape above the northern bank of the Zambezi River. A suite of samples was collected from the sands to attempt to constrain the age of the sediments and develop a chronology for the Stone Age sequence. This study discusses the results of single grain quartz optically-stimulated luminescence (OSL) analyses on these samples and the challenges of identifying the best methods for calculating ages from the highly dispersed dose distributions.

The sediments are quartz-rich and have very low dose-rates (~0.6 Gy/ka) with most of the samples having negligible potassium content. Equivalent dose measurements were made on 1200 grains of quartz for each sample and the resulting distributions have high overdispersion and positive skew. Previous studies have suggested that samples with lower dose rates are more susceptible to beta dose rate heterogeneity [1,2] as significant beta emitters may be localised in rare heavy mineral hotspots [3,4], and we consider the extent to which micro-dosimetry may impact the single grain equivalent dose distributions of these samples.

All the samples have a significant proportion of saturated grains (~10-30%). This is partly due to quartz OSL signals from these samples saturating at lower than typical doses (D_0 values of 20-40 Gy are common in these samples) but it is also a result of the highly scattered equivalent dose distributions as some of the saturated grains have higher D_0 values (>50 Gy). In this paper we investigate the effect of excluding grains with low D_0 values [5] as well as different methods of incorporating the dose information stored in saturated grains for inclusion in equivalent dose calculation, such as constructing synthetic dose response curves by summing OSL signals from individual grains [6], and present our ages for the samples.

Keywords Quartz; Single-grain; Micro-dosimetry; Saturation; Synthetic DRC

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O.8-6: Evaluation of the residual dose/age in quartz ESR dating: a study from archaeological sites near Victoria Falls, Zambia

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ESR dating of quartz has the potential to extend the age range beyond the limit of conventional luminescence dating techniques due to a larger saturation dose, but the ESR signals require a long time to reset under optical stimulation. Only a few studies have reported residual doses using modern analogue material so far [1-3], with doses ranging from ~100 to 700 Gy for the Al centre and from ~50 to 500 Gy for the Ti centre in aeolian sediments. For this reason, the importance of investigating modern analogue material in dating sediments with ESR has been highlighted [2].
As a part of a geoarchaeological project, this study aims to investigate the Early to Middle Stone Age transition (Mode 2/Mode 3) by using a combined approach of ESR and OSL dating of sedimentary quartz. The samples originate from the sand-scarp section of artefact-rich sediments in Mosi-oa-Tunya National Park, Zambia. We used the quartz OSL ages from the youngest samples of each sedimentary profile [4] to calculate ESR residual ages, which were subtracted from the apparent ESR ages of samples within the sequence to date the sediments beyond the limit of luminescence dating.
At the NP-site, within the sand-scarp, the uppermost four samples of the sequence were dated using quartz single-grain OSL [4]. Using these ages we calculated the corresponding ESR residual ages for the Ti centre and for the Al centre to a chronology of the technological changes from the Early Stone Age to the Middle Stone Age. We identified that this transition occurred between 340 ka and 120 ka (using the Ti centre). The same approach was carried out for the samples of another nearby site.

Keywords Quartz; ESR dating; Residual dose/age; Zambia; Stone tools

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P.8-1: Palaeoclimatic signals in loess-palaeosol sequences from Armenia accessed by fine grain luminescence dating

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In this study, we present three loess-palaeosol sections which are located in northern Armenia in the Sevkar loess area. These loess deposits cover the slopes of the Lesser Caucasus, which declines into the Kura depression to the north. Methods such as grain size analyses and magnetic susceptibility, as well as field observations show alternating loess and palaeosol units, representing different climatic phases of the mid to late Quaternary. Prominent tephra layers are also present, most likely originating from volcanoes in the Armenian Highlands. Dating of the loess layers was carried out mainly through luminescence dating of the polymineral fine grain fraction. These include two different post-IR-IRSL protocols on the majority of the samples and additional quartz fine grain dating for one section. An Ar-Ar age of one of the tephras in the MIS 6 loess serves as independent age control. The chronology shows a typical pattern of dry glacials and moist interglacials and interstadials, allowing soil formation. A comparison with two pollen records from Lake Van (Turkey) [1] and Lake Urmia (Iran) [2] is also presented.

Keywords loess; quartz fine grain dating; post-IR-IRSL dating; tephra; Armenia

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P.8-2: High detailed luminescence dating of the Irig loess-palaeosol sequence over the last 180 ka

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The southern Carpathian Basin comprises some of the most extensive and complete LPS in Europe (Buggle et al., 2008), providing the opportunity to better understand past European atmospheric mineral dust dynamics (e.g. Újvári et. al., 2010). Absolute luminescence dating has been performed on several loess sections in the southern Carpathian Basin and revealed a generally coherent stratigraphy in this region, although with the strong influence of the local geomorphological conditions (e.g. Fuchs et al., 2008). The only way too disentangle local effects is to apply detailed independent dating in order to reconstruct past dust accumulation rates from loess sequences, as well as target sites that are well away from likely transient local influences such as large rivers. In order to address these problems, we performed the first detailed multi-method luminescence dating at the Irig site, Vojvodina region, Serbia, where local conditions are negligibly influenced by changes in river dynamics. Irig is located on the south slope of the Fruska Gora Mountain, where it is ca. 40 km distant from the Danube River in the east and ca. 60 ka from Sava River in the south. Here we present the first detailed luminescence chronology of the Irig LPS based on 29 samples with a vertical spacing of 15-40 cm spanning the last two glacial cycles. We first investigated the properties of the 4-11 µm quartz OSL and polymineral $pIRIR_{290}$ signals, after which we used the calculated luminescence ages to construct a fully independent age model. Our results show that the 4-11 µm quartz is a reliable dosimeter only up to ~59 ka (179 Gy) after which the OSL signal underestimates the expected ages. The $pIRIR_{290}$ signal displayed a generally good behaviour and yielded stratigraphically consistent D_e values. The $pIRIR_{290}$ ages show very good agreement (within uncertainty) with the expected stratigraphic ages and the proposed marine isotope transition model except for the S2-L2 boundary where age underestimation of ~35 ka was observed. The constructed luminescence chronology suggests that the Irig LPS accumulated during the last ~180 ka. The reconstructed paleoenvironmental records show climate changes with a pattern of dry-cold glacial and humid-warm interglacial environment. This study also demonstrates that the dust accumulation rates at the Irig LPS were highly variable over the last two glacial-interglacial cycles

Keywords high-resolution luminescence dating, quartz OSL, polymineral $pIRIR_{290,}$ Carpathian Basin

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P.8-7: Identifying age limits of the Altay Late Quaternary megafloods from luminescence dating of loess

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Some of the largest catastrophic outbursts of periglacial lakes known in geological history of the Earth have been reconstructed in Altay Mountains. Traces of these events are expressed in the form of large terraces, predominantly composed of gravel material with numerous horizons of large boulders and blocks. Determining the age of these large-scale events is difficult due to the lack of organic material and specific genesis of these sediments. The experience of luminescent dating showed the absence of zeroing of the material during the formation of these deposits [1]. The results of cosmogenic dating showed the post-LGM age both for the breakthrough water source and for different regions of the distribution of catafluvial terraces in the Chuya and Katun river valleys. However, the age of catastrophic breakthroughs remains controversial. On the basis of a few IRSL dating results, an opinion is expressed about the age of the events as MIS 5, based, among other things, on geological evidence [2].

To resolve this issue, we studied the age of the catafluvial terraces of the Chuya and Katun valleys. In the area of the confluence of these catastrophic flooding events, on the surface of the high terrace, a thick stratum of loess-like loams was revealed, overlying the catafluvial sediments. In the prepared three pits, the revealed thickness of the loess was 2-3 m. A total of 24 samples for luminescence dating were obtained, for which the OSL, IR_{50}, and $pIRIR_{290}$ signals were measured to control the degree of signal zeroing and the reliability of dating results. The measurements showed a high convergence of age for quartz and feldspars, the $pIRIR_{290}$/OSL ratios is 1.04 (n = 24), which indicates a that quartz grains were probably well bleached. The age of the loess in all three pits was determined from 500 years at the top to 23 ka at the base of the loess strata. From the top of the catafluvial deposits, expressed in a sand interlayer, two ages of ~85-90 ka were obtained from feldspar $pIRIR_{290}$. The obtained results provide evidence in favor of the post LGM age of the geomorphological surface of the catafluvial terraces of Altai Mountains.

Keywords: Catastrophic floods, Altay Mountains, Proglacial lakes.

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P.8-8: Infrared stimulated luminescence dating of coarse-grained K-feldspar and fine-grained polymineral from Chinese Loess Plateau: A comparison

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Coarse-grained (CG) K-feldspar and fine-grained (FG) polymineral infrared stimulated luminescence (IRSL) signal has a more extended dating range than that of quartz optically stimulated luminescence (OSL) signal. Especially, the two-step and multiple elevated temperature post-IR IRSL (pIRIR) signals are promising to provide reliable luminescence ages for various sedimentary archives [1,2]. However, it is noticed that luminescence dating using CG K-feldspar and FG polymineral fractions may yield different luminescence characteristics [3]. The reason for the discrepancy is unclear whether it is resulted from different transportation process or different mineralogy.

The loess-palaeosol sequences on the Chinese Loess Plateau contain homogenous and quasi-consistent wind-blown dusts with independent age control for the entire Quaternary. Meanwhile, the materials were generally well-bleached. Therefore, these loess-palaeosol sequences provide an ideal material to test the reliability of IRSL dating using CG K-feldspar and FG polymineral fractions.

In this study, CG K-feldspar and FG polymineral fractions were extracted from 11 loess-palaeosol samples collected from Luochuan loess profile. Two single aliquot regenerative dose (SAR) protocols, $pIRIR_{50,225}$ and $pIRIR_{200,290}$, were applied for luminescence dating and comparison. The natural dose response curve (DRC) was constructed using the natural luminescence intensities from all samples and the corresponding reference ages. Rate of anomalous fading was determined in the laboratory. The simulated DRCs for the four luminescence signals were constructed using the fading correction model [4]. The natural and simulated-natural DRCs were compared to investigate the effect on the luminescence characteristics by stimulation temperature and grain-size. The dating results will be presented in comparison with the reference chronology to assess the reliability of luminescence dating using CG-K-feldspar and FG polymineral fractions.

Keywords IRSL; CG K-feldspar; FG polymineral; Natural dose response curve; Chinese Loess

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P.8-9: Quartz luminescence sensitivity from the critical-zone in the western Piedmont of North Carolina, south-eastern USA

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Soil, colluvial sediment, saprolite, and weathered bedrock are ubiquitous in the Piedmont of the south-eastern United States. Their distinction within a non-glaciated, forested, passive margin plays a key role in understanding Quaternary landscape evolution. Ultisols, or red clay-dominated soils, can have similar appearances and characteristics when formed in fine-grained surficial deposits like colluvium as well as in weathered saprolite. Distinguishing allochthonous and autochthonous sediment in these well-developed soils can be challenging without geochemical or geophysical analyses, and more refined granular details are needed to determine sediment source and mixing within mature-looking soil profiles. Our goal is to determine if luminescence sensitivity may be used to distinguish transported (i.e. sediment) vs non-transported (i.e. in-situ weathered bedrock) material in soil profiles. Here, we turn to OSL sensitivity and linear-modulated OSL (LM-OSL) in quartz grains from crystalline-bedrock-derived saprolite and from immediately overlying soil horizons that contain no remnant bedrock structure. This comparison formulates a relative gauge on the sourcing of material found in soil horizons from underlying weathered bedrock versus from aeolian, alluvial, and/or colluvial deposition.

Our study investigates soil and saprolite samples from both shallow and deeply weathered soil profiles from 1-meter soil pits and 10+ m deep regolith cores in the Redlair Observatory near Charlotte, North Carolina, USA. We measure single-grain LM-OSL over 10 seconds (0-100% green laser power) and divide the integral of the signal into three components, with 0-2 seconds (0-20% power) comprising the 'fast' component. Saprolite is not expected to have undergone sedimentary transport or pedoturbation processes. We find that it contains a small but measurable amount of luminescence following a beta dose and is dominated by non- 'fast' components. This occurs in both the deep saprolite (5-24 m) at hillslope summits as well as shallow saprolite (1 m) exposed in tributary hillslopes along the incised South Fork River. Single-grain LM-OSL measurements of overlying soil horizons (mainly B) show widely variable luminescence sensitivity, with generally more signal from the 'fast' component compared to saprolite. This variability may be dependent on soil forming factors such as slope, aspect, wet-dry cycling, and bioturbation, that differentially aid sensitization of soil grains. Upper soil horizons that have limited sensitivity and lack 'fast'-dominated signals are either derived from in-situ materials, are less mixed, and/or recently eroded from saprolite. Similarly-classified soil horizons with more luminescence-sensitive quartz grains may suggest increased weathering/mixing, and/or greater input from allochthonous aeolian, alluvial, or colluvial sources.

Keywords single-grain LM-OSL; quartz sensitivity; soil; saprolite; weathering.

P.8-10: Valles Caldera, New Mexico, USA: Dating and defining the rate of formation of soils and wildfire activity using luminescence

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About 1.25 million years ago a volcanic eruption in New Mexico's Jemez Mountains created the Valles Caldera, one of seven super volcanoes found in the world. The Valles Caldera Preservation Act of 2000 created the Valles Caldera National Preserve. The Valles Caldera is particularly susceptible to erosion induced by wildfires because of its steep slopes. Gullies that feed the bottom grassland locations are reactivated after a fire season when protective vegetation is burned off and the slopes of the caldera are subjected to increased erosion. In July 2011, the Las Conchas Fire, started by an electrical power line on nearby private land, burned 120 km^2 of the Valles Caldera National Preserve causing enormous erosion in a short amount of time.

A 3 m exposure was found in a gully, after the 2011 fire, which revealed alternating light and dark bands of material (15 – 25 cm in width). The abrupt and unusual nature of the contact between different colored material strongly suggests deposition events related to either fire cycles or heavy precipitation events on a fire-ravaged landscape. Two competing theories for the formation of the layers are that they reflect the fire history of the caldera by directly transporting and depositing charcoal or burned sediment or that these layers are part of an organic soil formation in a local wet spot (or marsh) that is periodically buried by alluvium or debris flows after fires. Fifteen OSL samples of the dark bands and three OSL samples of the light bands were measured for quartz OSL. When dated with OSL, material near the bottom is about 7,000 years old and material near the top is about 2,500 years old but there is no apparent pattern to the formation of dark bands.

The quartz was unexpected since the majority of the local sediments are sourced from tuff, although there are a few local exposures of sandstone near the top of the Preserve rim. Luminescence characteristics show that it is blown in and incorporated into the sediment. Particle size analyses reveals that both the light and dark sediment is 80% sand, 5% clay and 15% silt, with some variations, but no large swings, which is puzzling if the darker bands are organic soil, since one would expect a finer grain size. Elemental concentrations reveal no substantial difference in major or minor elements between light or dark layers. There are also no large pieces of charcoal, as revealed through loss on ignition and microscopic work. A young mollisol was sampled further upstream, along with a modern marsh deposit, and reveals that the darker layers are almost certainly mollisols. This presentation will focus on why these mollisols are unusual and what they indicate about past climatic events in Valles Caldera.

P.8-11: High sampling density OSL dating of aeolian samples from the south margin of the Tengger Desert using the global standardised growth curve (gSGC) method

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Chronostratigraphic records in the drylands of north China provide important archives to reveal the dynamic connections between climate changes and behaviour of aeolian systems. However, the interpretation of aeolian chronostratigraphy is not straightforward and may be associated with significant uncertainty due to a number of external and localised forces. Taking into account this complexity of aeolian systems, excluding preservation and sampling bias from paleoclimatic signals requires that the interpretation of chronostratigraphic records be based on as many dates from as many sites as possible [1]. In optically stimulated luminescence (OSL) dating, however, the determination of equivalent dose (D_e) using the single-aliquot regenerative dose (SAR) protocol is time-consuming for samples with burial doses larger than 100 Gy.

Rapid D_e determination for a large number of aliquots can be achieved by establishing a common dose response curve (DRC) [2–3] for the samples under analysis. In this study, the global standardised growth curve (gSGC) method [3] is applied to multiple-grain aliquots of coarse quartz from multiple sites covering a wide region of the south margin of the Tengger Desert in north China. The large between-aliquot variability in the shape of DRCs is significantly reduced using the least-squares normalisation procedure. The saturation dose (D_0) for the established gSGCs of 90–150 µm and 63–90 µm fractions are 189 Gy and 272 Gy, respectively, and the difference between gSGCs of the two grain-size fractions increases gradually from 100 Gy onwards. The D_e values determined using the gSGC method are consistent with those obtained using individual SAR DRCs up to at least 200 Gy and 500 Gy, for the 90–150 µm and 63–90 µm fractions, respectively. We demonstrate that the gSGC protocol can be used as an efficient procedure for a precise determination of D_e values for aeolian samples. This in turn provides a better constraint for the interpretation of aeolian chronostratigraphic records of late Quaternary from the south margin of the Tengger Desert. Importantly, independent gSGCs must be established for quartz grains of different sizes to obtain reliable D_e estimates.

Keywords: Quartz; OSL dating; Global standardised growth curve; Dose response curve; Tengger Desert

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P.8-15: Testing the application of infrared stimulated luminescence dating on feldspars from calcium sulphate-rich wedges in the Atacama Desert

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Polygonal patterned grounds are common surface expressions of subsurface dynamics in periglacial and Martian environments. In periglacial environments these structures are typically associated with vertically laminated wedges in the subsurface being the product of cryogenic processes. These landscape features similarly occur in arid to hyperarid environments, such as in the Atacama Desert, where haloturbation and salt heave mechanisms are thought to control the formation of wedges and polygons. X-ray diffraction and x-ray fluorescence analyses of the wedges from the central Atacama Desert revealed various calcium-sulphate phases as potential drivers for the wedge-growth activity. The formation of these wedges is connected to varying water activity, resulting in hydration- and dehydration-induced phase transitions of calcium-sulphate phases. In combination with crystallisation pressures of (re-) precipitating salts from infiltrated solutions, these salt dynamics cause significant volumetric changes in the soils.

Due to the water scarcity in the Atacama Desert, geochronological data on calcium-sulphate wedge evolution is crucial to understand the formation processes of these unique structures and their use as palaeoclimate indicators. We apply post-infrared infrared stimulated luminescence (post-IR IRSL) dating to establish a chronological framework for calcium-sulphate wedge formation in the Atacama Desert. Pre-tests show that the clastic sediments extracted from the calcium-sulphate wedges provide suitable dosimetric properties for luminescence dating and furthermore show that the majority of grains yield luminescence signals well below the onset of post-IR IRSL signal saturation. Here we present the first post-IR IRSL dating results of coarse-grain feldspars extracted from calcium-sulphate wedges located at the Andean foreslope. Our post-IR IRSL ages indicate multiple phases of wedge formation during the Pleistocene, and a continuation of salt dynamics into the Late Pleistocene.

Keywords Post-IR IRSL; subsurface wedges; calcium sulphate; polygons; Atacama Desert

P.8-16: The first OSL dating of Black Soil in northeast China

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As one of the most fertile soil types in the world, black soil (Chernozems and Phaeozems in World Reference Base for Soil Resource, Mollisols in Soil Taxonomy, Isohumosols in Chinese Soil Taxonomy) is suffering from heavy erosion and degradation due to intensive agricultural uses. To achieve its sustainability, we need to know not only how it loses, but also how it forms.

Dating the soils with certain soil materials provides valuable information on the ages and rates of soil formation. Based on the radiocarbon (^{14}C) dating of soils, black soils are generally developed since early Holocene over the world. However, the ^{14}C age of soils represents the duration of the accumulation of soil organic carbon, rather than the residence time for soil parent materials. The latter is more representative of the true age for soil beings. Till now, there is barely any report on the forming ages of the parent materials for black soils. This is partly due to the lack of suitable dating techniques. Considering that black soils are mostly derived from loess, the optical stimulated luminescence (OSL) dating method provides a solution for understanding the forming ages of parent material for black soils.

In this study, we apply both ^{14}C ages and OSL techniques to several soil horizons from a typical black soil from northeast China. ^{14}C ages indicated that soil organic carbon start to accumulate since ~8000 a BP, which agrees well with previous radiocarbon dating results from China and other regions. On the other hand, OSL ages suggested that soil parent material (assumably loess) deposited since the late galcial period and lasted during the Holocene. Moreover, the ^{14}C ages showed a liner relationship with soil depth while OSL ages showed a non-linear relationship with soil depths. This is the first time for the application of OSL dating on black soils in China, which provides valuable information on the ages, rates and environments for the formation of black soils. The pedogenic implications of the discrepancies between ^{14}C ages and OSL ages will be further explored.

Keywords: black soil; soil ages; soil formation; OSL dating; ^{14}C dating

P.8-18: Quartz OSL dating to find formative ages of Higher terraces burring valleys in the central Lesser Nepal Himalayas

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On the Lesser Himalayan side at 500–700 m above sea level in the foothills of rivers that form lateral valleys in the Greater Himalayas of central Nepal, a high terrace surface has developed along the river valley at 120–210 m above the present river bed, which has east–west width of 500–1000 m and a channel direction of several kilometers, leaving a clear flat surface. These high terrace surfaces are reddened near the continuous ground surface. They closely resemble high terrace surfaces formed before MIS 5e in the Japanese landform classification.

We conducted geomorphological and geological surveys in three river basins in the Lesser Himalaya of central Nepal: Trisuli, Budhi Gandaki, and Marsyangdi. Also, we conducted OSL dating of the upper part of the high terrace surfaces described above.

Five samples were collected from sandy silt relevant to the high terrace surfaces in three rivers for OSL dating. Quartz of ca. 75–150 µm diameter was separated at all samples. Quartz OSL measurements were taken using an OSL/TL reader (NRL-99-OSTL2-KU; Neoark Corp.) [1] equipped with 20 blue LEDs (465±15 nm). Irradiation was conducted using a small X-ray tube (dose rate 0.16 Gy/s) built into the OSL reader. Dose–response curves for Paleodose estimation were constructed using the single aliquot regenerative-dose (SAR) procedure. Annual doses were measured using a high-resolution gamma-ray spectrometer. All OSL ages were ca. 19–28 ka. Results show that formative ages of these high terrace surfaces were in MIS 2.

Keywords: formative ages; higher terraces; Lesser Nepal Himalayas; OSL dating; quartz

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P.8-19: Challenges in updating the luminescence chronology of the Chaîne des Puys volcanic province, France

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The Chaîne des Puys volcanic province in the French Massif Central is a prime example of a young volcanic province, recently (2018) inscribed as a UNESCO World Heritage site. Considering its central location in France, a potential future eruption could have serious impacts on a large population. Despite its importance, fewer than half of the Chaîne des Puys volcanoes have been dated so far. Furthermore, many of the dates available are from the 1983 thesis of Guérin [1], who used thermoluminescence dating of plagioclase. Since then, luminescence dating has seen several major methodological refinements.

The primary objective of this research project is to establish a revised and more reliable chronology of the Chaîne des Puys. We plan to achieve this by testing the chemical, mineralogical, and luminescence properties of Chaîne des Puys volcanic and xenolithic feldspars. From the results of this analysis we hope to draw connections between a sample's mineralogy and luminescence behaviour to create a protocol for determining the optimum luminescence method for dating.

In a preliminary study [2] we used the multi-elevated temperature post-IR IRSL protocol (MET-pIRIR) [3] to measure the feldspar fraction of two xenoliths contained in lava from Puy de Lemptégy. These xenoliths originated from the Variscian granitoid basement below the Chaîne des Puys. However, they experienced different levels of alteration during their ascent in the magma, with one being fully altered into a buchite, while the other only experienced limited alteration. The luminescence decay curves of the xenoliths took an abnormal shape, with an initial increase in the first 15 s of measurement followed by a transition to decay. A large intensity difference was also observed between the two xenoliths, with the buchite being brighter. Fading tests presented a final contrast between the two xenoliths, with the buchite showing almost no fading while the other had high fading rates. Furthermore, the applied fading correction did not bring the xenoliths into the same range. While relatively simple methodological changes are likely to resolve the issue of abnormal decay curve shapes, the cause of the contrasts in luminescence behaviour between the two xenoliths remains poorly understood. We hypothesize that the differing thermal histories of the xenoliths, as indicated by their degrees of alteration, is a potential factor in this behaviour. These observations indicate the need for further analysis of the xenoliths' thermal histories, their mineralogy, and their luminescence behaviour.

Keywords volcanic geochronology; volcanic feldspars; xenoliths; MET-pIRIR; Chaîne des Puys

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P.8-20: OSL dating of young dunes in upper reach of the Yarlung Tsangpo River, southwest Tibetan Plateau

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Tibetan plateau (TP) has a profound influence on atmospheric circulations due to its size and elevation. Recognizing the natural variability of climate in the TP is crucial for protecting its ecosystem, which is among the most extensively affected ecosystem due to global climate change. Regional desertification caused mainly by the degradation of permafrost in recent decades has attracted increasing attentions since permafrost is the key factor of soil water retention for grassland vegetation in the TP e.g. [1]. Aeolian sediments in the TP mainly develops along river valleys of the Yarlung Tsangpo, the largest river on the plateau.

Situated near the source region of the Chema Yongdrung Glacier in southwest TP, Maquan River is one of the largest wetland and forms the upper reach of Yarlung Tsangpo. Dozens of sand dunes can be found at the east of Maquan River, yet the timing and intensity of regional aeolian activities is less well defined. In this study, OSL technique was applied to date 11 sandy samples taken from two sediment sections on top of two dunes near the Zhongba and Payang area, using the SAR protocol of coarse-grained quartz (90-125 um). Our results suggest that :1) Samples have relative young ages of about centennial scale, suggesting a recent active dune-building process in this region; 2) The directions of windward slopes for these crescent-shaped dunes suggest that its source region is mainly from the west. Grain size analysis shows that these aeolian deposits are mainly coarse grains (~200 um), implying a short distance transportation from Maquan River wetland in the west. 3) Regional climate records show a constant rising trend in temperature and a relative stable precipitation in the past half century, as well as a stable river runoff but a larger scale in variations. The most probable triggering of this aeolian activity should be the degradation of permafrost caused by rising temperatures, because permafrost layers is the main factor to maintain water around plant roots by blocking further infiltration of soil water, which also helps to accumulate soil organic matter. Other possible factors were also discussed.

Keywords Aeolian activity; OSL dating; Yarlung Tsangpo River; Tibetan Plateau; permafrost

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P.8-21: Using infrared stimulated luminescence dating for establishing a chronology of morphologic activity in a dry valley in the Andean Precordillera, N Chile

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While palaeoenvironmental records of the Atacama Desert and Andean Altiplano region document wet conditions related to the Central Andean Pluvial Events in the late Pleistocene/early Holocene, information from the Andean Precordillera at 20° S is scarce, and uncertainties remain also for climatic fluctuations in the Holocene. Therefore, this study aims to shed light on the palaeoenvironmental conditions in this area by reconstructing the historical record of morphologic activity in a dry valley east of Pica town in the Andean Precordillera. In absence of quartz adequate for dating, a post-infrared infrared stimulated luminescence protocol ($pIRIR_{225}$) was used for palaeodune samples (>10 kyrs) while a low-temperature pIRIR protocol ($pIRIR_{180}$) was used to date late Holocene sediments. This dating approach was evaluated on recent deposits such as of the February 2019 flood event to assess, whether dose distribution (skewness) and dose scatter (over-dispersion) may be used to discriminate completely and incompletely bleached sediments in the stratigraphy. Since all samples (except of the palaeodunes) have only weak luminescence signals that, in addition, may not be completely reset during sediment transport, small multigrain aliquots were used for equivalent dose (D_e) measurements to differentiate well-bleached from poorly bleached subsamples. Due to large laboratory residuals of the pIRIR signals relative to the palaeodoses, the IR_{50} signals measured within the $pIRIR_{180}$ and $pIRIR_{225}$ protocol were used for palaeodose calculation.
Positively skewed D_e distributions of fluvial deposits are slightly different from moderately skewed D_e distributions of aeolian sediments, thus indicating differences in bleaching conditions during sediment transport. Fluvial modern analogues indicate remnant ages of ~175 yrs for fluvial transport at the study location. Since subtracting this inheritance from other feldspar results would overcorrect the stratigraphy and yield negative ages, fluvial deposits in the stratigraphic record are concluded to be better bleached than the modern analogues. Likewise, sediment mixing plays a major role for as there is no obvious pattern for over-dispersion in fluvial and aeolian samples.
Overall, obtained ages date aeolian activity and deposition within the valley back to the last ~60,000 to ~100,000 yrs while fluvial activity occurred during the last ~2,300, ~1,400, ~500, ~300 yrs, and within the last decades. The latter phases are synchronous to climatic perturbations such as the Medieval Climate Anomaly and Roman Warm Period and therefore support previous findings on their evidence in the southern hemisphere. Placing the Pica Valley in the regional (palaeo-) environmental context suggests its potential to serve as a link of palaeoenvironmental records from the Andean regions with archives from the Central Depression.

Keywords: Palaeoenvironment; Andean Precordillera; Infrared stimulated luminescence dating; Flooding activity; (Hyper-)Aridity

P.8-22: Luminescence characteristics of coastal sediments in East Antarctica

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The Late Pleistocene sea-level history in Antarctica is key for understanding and predicting glacial responses to changing climates, which significantly contribute to the global sea level. Coastal to shallow-marine sediments in the Soya coast, East Antarctica, have been characterized by radiocarbon ages at Holocene and Marine Oxygen Isotope Stage (MIS) 3 and identified in a range from the present sea level to +20 m in elevation. The inferred relative sea-level trend is considerably different from predictions by the glacio-hydro isostatic adjustment (GIA) modelling and misses the Last Interglacial highstand. Radiocarbon dating is however not an ideal method to date sediments close to or older than 40–50 ka, the upper limit of its application. We explored the applicability of luminescence dating to coastal sediments newly sampled at Langhovde and West Ongul in the Soya coast, East Antarctica. Samples were collected from shallow-marine facies identified in trenches dug by < 1 m deep and at several meters above the present sea level. Quartz coarse and fine grains, K-feldspar coarse grains, and polymineral fine grains were extracted from the samples. Quartz coarse and fine grains both show very low OSL sensitivity and no fast component and thus are not considered further. Dose-recovery tests on post-IR IRSL signals of K-feldspar and polymineral grains show variable results and indicate acceptable conditions of measurements for grain size and equivalent dose range. Preliminary measurements reveal that the Langhovde section is clearly divided into the upper and lower units, corresponding to the Holocene, and Last Interglacial period or older, respectively while the West Ongul section appears entirely older than the Last Interglacial period. Therefore, further application of post-IR IRSL dating to coastal sediments, including the sections that were radiocarbon dated, potentially refines the understanding of the Late Pleistocene relative sea-level history in East Antarctica.

Keywords Antarctica; post-IR IRSL dating; dim quartz; Late Pleistocene; sea-level change.

P.8-25: Feldspar luminescence characteristics from a large amazonian river: ages, SGC and sensitivity

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The Purus River is a main tributary of the Amazon River, it is one of the largest river in the basin in length and discharge and the deposits of both its margins are presumably related to major sedimentological events in the amazonian lowlands. Here we present feldspar depositional ages of samples from outcrops of the mid course of the Purus River, as well as a Standard Growth Curve and results of luminescence sensitivity of these samples.

Since initial experiments revealed that the quartz signal is saturated for most of the sampled deposits, we applied a $pIRIR_{290}$ protocol [1, 2, 3, 4] to produce ages that reached up to 557 ± 36 ka. But, as mentioned in previous works [4], we also registered a residual dose signal that we could not eliminate with bleaching procedures. Two feldspar samples presented saturated signals, and the oldest ages extend to a range that was not reached by any other western amazonian quaternary sample in the literature. The laboratorial time demanded with the dating procedure inspired the production of a Standardised Growth Curve (SGC). The plot of the normalised feldspar luminescence signal versus the regeneration dose of the samples presented monotonic growth curves for each sample. A SGC is usually standardised using the size of the test dose (5), but by using one of the regenerative dose signal we were able to reduce the dispersion from the inter-aliquot variation (6). The ratio of the equivalent doses from the dating sequences by the SGC dose estimates falls close to unity (mean: 1, number of aliquots: 54). Finally, we applied an experimental method to estimate sensitivity from the results of the dating sequences, this procedure was conducted for quartz and feldspar samples. While variations in the quartz data are related to location along the river course and stratigraphic position of the sample, the feldspar values presented stability regardless of location and depth of the sample, with mean values of 25% to 35% of a measure based on the first 2 seconds of signal contribution in relation to the whole signal.

Keywords Amazon; Feldspar; $pIRIR_{290}$; SGC; Sensitivity

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P.8-29: ESR dating of Early to Middle Pleistocene coastal dunes, South Africa: a comparison with the luminescence chronology

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Over the last three decades, ESR dating of optically bleached quartz grains has proven to provide reliable numerical age results for Early to Middle Pleistocene deposits and consistent with the existing independent age control [1]. However, some methodological issues remain poorly understood, particularly about the composition, nature and behaviour of the ESR signals measured in quartz grains. To contribute filling this gap of knowledge, we selected five quartz samples (Early Pleistocene to present day) from South African aeolian dunes, previously and independently dated by OSL [2]. The consistency and robustness of the existing Luminescence chronology obtained earlier make these samples excellent candidates for an ESR dating study in order to get a better understanding of the ESR signals measured in quartz and of their behaviour during sediment transport (optical bleaching) and deposition (radiation sensitivity). The quartz samples were dated following the Multiple Centre (MC) approach [3] and using the standard Multiple Aliquot Additive Dose (MAAD) method [4].

The signals measured and evaluated in all samples are from Al, Ti-Li, Ti-H and a mixture of Ti centres. While the D_E values derived from each centre show the standard 'bleaching' pattern that is consistent with the principles of the MC approach, they nevertheless lead to a systematic overestimation of the expected D_E values. Using the previous Luminescence results as independent dose/age control, several aspects of the ESR dose reconstructions can be investigated, such as (i) the influence of fitting functions, (ii) data weighting, and (iii) even spectrum noise, to determine the origin of this overestimation. Our result confirm that the Ti-H signal definitely shows the best potential for the evaluation of small D_E values (<100 Gy). Beyond the methodological outcome, this ESR dating study also provides new and finite numerical age constraints for a series of Early to Middle Pleistocene dune deposits in the Southern Cape.

Keywords Electron Spin Resonance (ESR) Dating; Quartz grains; Multiple centre approach; Dunes; South Africa

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P.8-31: Radiocarbon and luminescence dating of the Wulanmulun site in Ordos, China

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The Wulanmulun Paleolithic site on Ordos, China, was found in 2010, and excavated from 2011 to 2014. More than 13000 stone artefacts and more than 15000 mammal fossils were recovered. It is considered as another new important discovery of prehistoric culture in Ordos region after the Salawusu (also called Sjara-osso-gol) and Shuidonggou sites discovered in Ordos by a French in 1922. The site is located in a buried paleovalley on the north bank of the Wulanmulun river in Ordos, the filled materials are composed of, from bottom to top, fluvial-lacustrine sediments and aeolian sands. In this study, three charcoal samples from the excavation sections with a thickness of ~15 m were collected for radiocarbon dating, and 25 sediment samples were taken for optically stimulated luminescence (OSL) dating. Additionally, two bedrock (sandstone) samples were also collected to check the upper limit of the quartz OSL dating. The quartz SAR-OSL ages obtained for these sedimentary samples range from 4.6±0.7 ka for the top sample to 56.6±3.2 ka for the bottom sample, and the 25 OSL ages obtained are stratigraphically consistent. The ten samples from the cultural layer yield the ages of 50 to 65 ka. It is interesting that the two bedrock samples were OSL dated to 92.3±7.4 and 90.0±7.0 ka. Obviously, the bedrock OSL ages were greatly underestimated. On the other hand, the bedrock ages can be considered as the upper age limit of the OSL dating method on the sediments from this site, although the dose of dose-response curves for our samples are not saturated at the dose corresponding to the age of ~90 ka. For the three charcoal samples, two samples failed to produce enough carbon for radiocarbon dating, and another sample was radiocarbon dated to >47400 BP, which is close to the laboratory background. To some extent, the radiocarbon dating results support the reliability of the OSL ages for the sediment samples.

Keywords Paleolithic site; Ordos; optical dating; quartz OSL-SAR; Charcoal radiocarbon dating.

P.8-32: Luminescence and ESR dating of the multi-level karst system of Alkerdi-Zelaieta (Navarre, western Pyrenees) and implications for the provenance study.

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The finding of Upper Paleolithic engravings in 2016 triggered a multidisciplinary investigation of the Alkerdi karst system (Urdazubi, Western Pyrenees). The study of the speleogenetic processes led to the identification of at least 6 paragenetic cave levels. Two sediment samples were collected from levels 4 and 1 for numerical dating purpose, using both Optically Stimulated Luminescence (OSL) and Electron Spin Resonance (ESR) to unravel the timing of the changes in the karst dynamics.

First, OSL measurements were carried out using small quartz multi-grain Single Aliquot Regenerative-dose (SAR) protocol. Initial Equivalent Dose (D_e) results show evidence of saturated OSL signal for the sample of the higher level (with ~60% of saturated aliquots). Hence, both SG TT-OSL and ESR methods were subsequently employed, as the corresponding signals are known to have higher saturation level than OSL ones. ESR analyses were based on the Multiple Centre (MC) approach using the standard multi-grain multi-aliquot additive (MAA) dose method).

Besides, geomorphological evidence suggest that the origin of the sedimentary infill in each level could have been from the outside, or from the older (higher) levels, occurring sediment transfer from superior levels to lower levels. To test this hypotheses, we analysed the D_e distribution for each sample, based on the assumption that D_e overdispersion (OD) values could possibly reflect different origins. Results yield OD values up to 70%, suggesting that quartz grains must have been exposed to sunlight in different moments in the past. One sample from the modern flood-plain before entering the cave system was included for comparison of OD values.

Therefore, in the present work, the reliability and consistency of the resulting numerical OSL and ESR age estimates are assessed and further discussed in the light of the geomorphological context available for the area and compared with additional independent U-series ages on speleothemes. These new data enable to establish the first chronostratigraphic framework of the karst system. Besides, we evaluate the potential of using D_e values distribution as a proxy to differentiate grains of different origin within a given sedimentary deposit.

Keywords: Luminescence Dating; ESR dating; quartz grains; multilevel cave; sediment provenance.

Session 9:
Exploring age models and extending the age range

Oral Presentations

	Presenter	Title
1	Guillaume Guérin	Age-depth modelling and the effect of including – or not – shared errors across sets of OSL samples
2	Sebastian Kreutzer	Chronological reference datasets: reasoning, creation and application
3	Hélène Tissoux	Dating pre-Quaternary sediments using ESR: some attempts
4	Pedro Cunha	Pleistocene sea-level highstands and coastal uplift in westernmost Iberia: characterization and dating of the Peniche marine terrace staircase
5	Chuanyi Wei	Plio-early Pleistocene ESR chronology of Ganyanchi Gravel Layer, Haiyuan fault, China: implications for transformation from compressive fault to sinistral strike slip fault

Poster Presentations

	Presenter	Title
1	Agnes Novothny	Luminescence dating of loess-paleosol sequences containing the Bag Tephra from the Northern-Carpathian Basin – Can the Bag Tephra be used as a marker horizon?
2	Tiffanie Fourcade	Improving the chronology of marine cores: IRSL dating and Bayesian modelling of a core from the Bay of Biscay (NE Atlantic)
4	Mark Bateman	Getting the right age?
5	Madhav Murari	The performance of the existing statistical models on the palaeodose distribution: Observations from laboratory controlled samples
6	Alastair Cunningham	Seeking chronological precision for a Holocene loess sequence
8	Sarah Boyd	Utilising optically stimulated luminescence and radiocarbon dating to investigate depositional scenarios and relative sea level change at Ruddons Point, Fife, Scotland
9	Zuzanna Kabacińska	Revisiting quartz natural and laboratory electron spin resonance (ESR) dose response curves from Chinese loess
10	Margarida Porto Gouveia	Problems encountered in ESR dating on quartz extracted from Pliocene and Early Pleistocene sedimentary formations in Central Portugal
11	Yawei Li	Evaluation and application of multiple centers ESR dating method on Plio-Quaternary fluvial sediment: A case study from core ZL in Jianghan Basin, middle Yangtze River Basin, China
13	Libin Wang	Research on ESR chronology of lacustrine sediments from Taoyuan paleo-lake, middle reaches of Jinsha River
14	Jingran Zhang	The luminescence chronology of the Yellow River terraces in Gonghe Basin and its tectonic and palaeoclimate implications since Mid-Pleistocene

O.9-1: Age-depth modelling and the effect of including – or not – shared errors across sets of OSL samples.

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The coastal site of Beg-er-Vil (Brittany, France) has yielded remains of a dwelling site from the Mesolithic period, dating back to ca. 8,000 years ago. These archaeological remains were covered by a marine sand dune. Among the research questions raised by recent excavations [1], the timing of the dune formation process is of interest to understand the evolution of communities of fishers-hunters-gatherers on the Atlantic coast, in particular in Beg-er-Vil.

To resolve this question, we employed radiocarbon dating to infer the timing of human occupations and OSL dating to date the dune aggradation. However, to ensure that the lowermost sediment sample, taken by inserting a metal tube in the stratigraphic section, does not include material from the underlying archaeological layer, it was taken a few cm above the visible boundary between the two units. As a result, age-depth modelling is required to determine the onset of the dune formation.

'BayLum' [2,3] is a modelling tool allowing to combine OSL and radiocarbon ages to infer the chronology of a site. Among the advantages offered by 'BayLum' is the possibility to include both stratigraphic constraints and shared errors across sets of samples measured with the same equipment, by estimating all ages jointly. In this paper, we build chronologies with and without taking shared errors into account. We then perform non-parametric age-depth modelling on the two sets of data, to illustrate the effect of modelling shared errors on the chronological output. We demonstrate that age-depth models are better constrained when systematic errors are taken into account.

Keywords Bayesian modelling; age-depth modelling; shared errors; OSL; radiocarbon

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O.9-2: Chronological reference datasets: reasoning, creation and application

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Methodological progress in trapped-charge dating methods hardly ever leads to reduced complexity of their applications. Advances usually require additional measurement or protocol parameters to be monitored, new tests to be performed, often on top of multiple signals and models to compare. These requirements increase the number of checks made, while the effect on the confidence in the dating results may remain blurry at best. Various software tools released over the years, alongside new methodological developments, support data treatment and help to visualise results [e.g., 1,2].
However, in recent years, software tools themselves have enabled significant methodological progress [e.g., 2,3]. This development is fuelled by free and advanced open-source software frameworks, the open-access data movement, and abundantly available computation power (for instance, allowing for sophisticated statistical modelling). Unfortunately, this situation introduces new challenges for a dating study, and multiple analytical pathways seem to present themselves when solving a single problem. Understanding the merits and differences of different tools is challenging. Finding the origin of diverging results in complex analytical pathways is time-consuming at best and often impossible even to experts without scrutinising the software code.

Reference datasets are collections of well-known static, artificially generated or measured data, explicitly created as test instances. By providing a common basis for evaluating analytical procedures, these datasets help maintain trust and confidence in the dating process. Moreover, they allow one to test model parameters and benchmark their output without in-depth knowledge of the tool.

Our contribution addresses the reasoning, creation and application of (chronological) reference datasets in the context of luminescence dating. We present sets of reference data generated using the statistical programming environment R and available modelling packages, such as 'RLumModel' [4] or 'RLumCarlo' [5]. We show how these datasets can be applied to test standard models and assumptions used in luminescence dating studies.

Keywords Luminescence dating; Modelling; Reference datasets; R; Testing

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O.9-3: Dating pre-Quaternary sediments using ESR: some attempts

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Dating of Quaternary sediments is now well constrained by numerical methods such as electron spin resonance (ESR) among others, which can cover the last 2.6 Ma. Nevertheless, beyond the Quaternary timescale, the application of ESR becomes extremely challenging. At earth surface, some deposits exist, such as alluvial outwash, fluvio-lacustrine fillings or marine beaches whose age could be earlier than the Quaternary and for which dating is currently very complicated in the absence of faunal remains, plants or volcanic effluents.

In ESR dating of optically-bleached quartz, the two most commonly used paramagnetic centres are [AlO4] and [TiO4/Li+]0, usually named Al and Ti-Li centres, respectively. Whether these centres can provide accurate dating results is mostly conditioned by their thermal stability and saturation to the received radiation dose. The thermal stabilities of the Al and Ti-Li centers were studied very early in the development of the method and were back then estimated to be of ca. 7.4×10^9 and 8×10^6 years respectively [1]. Similarly, the apparent saturation of the signal with the radiation dose may be reached > 10,000 Gy for both Al and Ti-Li centres [2, 3]. Consequently, this combined evidence suggests that there is no theoretical obstacle to date pre-Quaternary silico-clastic sediments by ESR.

We report here a series of dating attempts performed on quartz samples whose expected age ranges from about 50 Ma to the earliest part of the Pleistocene. These samples come from various types of depositional environments (e.g. marine, fluvio-deltaic, fluvial), and independent, numerical or (bio)-stratigraphic age control is sometimes available. In all the dated samples, the multiple aliquot additive dose method was applied, while the regeneration approach was also tested for a few of them.

Our preliminary result show that that these quartz samples overall display a very good dose response curve to irradiation, and do not reach apparent saturation. However, if a good adequacy is obtained between calculated ages and the preliminary estimate given by the geology for marine sediments aged between 5 and 2 Ma, a great majority of the ESR ages are younger than expected. Morevover, dating tests performed on sediment from the Miocene and Paleocene-Eocene boundaries show significant age underestimations. These dating results will be discussed in relation to the expected ages, depositional environments or the composition and geochemical history of the sediment from which the dated quartz was extracted.

Keywords: ESR dating; quartz; Pre-Quaternary; thermal stability

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O.9-4: Pleistocene sea-level highstands and coastal uplift in westernmost Iberia: characterization and dating of the Peniche marine terrace staircase

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This study provides a geological and geochronological data of the Peniche peninsula (Portugal), a resistant rocky limestone headland subjected to high-energy Atlantic Ocean coastal processes. We have used a multidisciplinary approach, combining geomorphology, sedimentology, paleontology and geochronology (electron spin resonance [ESR]; U-series), in order to 1) reconstruct styles and timing of paleoenvironmental changes, 2) correlate to Marine Isotope Stages (MIS), and 3) quantify coastal uplift rates during the Quaternary. The marine terrace deposits, comprising calcite cemented siliciclastic conglomerates and sandstones, sometimes capped by travertines, were studied in detail along the SW sector of the peninsula, building upon research undertaken at the Furninha Cave site [1].

The mapping and dating results presented in this work characterise: 1) a culminant wave-cut platform at 29-33 m (above mean sea level) (Pm), with a probable age of ~3.7 Ma [2]; 2) a wave-cut platform at 24-28 m (Tm1), dated as 883±120 ka (ESR), probably correlated with high sea level conditions spanning ~1000-770 ka (MIS 25-19); 3) a wave-cut platform at 19-21 m (Tm2), with beach conglomerate and sandstone, dated as 707±32 ka (ESR) and correlated to 740-675 ka (MIS 17); 4) a wave-cut platform at 14-16 m (Tm3), with a beach conglomerate and sandstone, and capping travertine, probably recording aggradation during 620-460 ka (MIS15-13) (ESR ages: 598±160, 563±63, 490±44 ka; U-series: >438 ka, >620 ka); 5) a wave-cut platform at 11-13 m (Tm4), with beach conglomerate and sandstone followed by travertine, dated as 315±48 ka (ESR), probably recording 420-275 ka (MIS 11-9); 6) a wave-cut platform at 6-9 m (Tm5), with beach conglomerate, sandstone and travertine, dated as 288±53 ka ($pIRIR_{225}$), probably spanning 240-180 ka (MIS 7); 7) a wave-cut platform at 4.0 m (Tm6), probably spanning 125-75 ka (MIS 5); 8) Upper Pleistocene and Holocene aeolian sand units; 9) modern beach sediments. For the last ~1 Ma the inset Pleistocene marine terrace levels (Tm1-Tm6) indicate apparent short-term uplift rates between 0.02 and 0.05 m/ka (means of 0.03 to 0.04 m/ka) and corrected short-term uplift rates between -0.05 and 0.05 m/ka (means of -0.02 to 0.05 m/ka). This demonstrates that the compressive reactivation of the Western Iberian Margin has determined the genesis of Pleistocene marine terrace staircases, recording uplift superimposed onto global sea-level oscillations.

Keywords: ESR, OSL and U-series dating; marine terrace staircase; crustal uplift; western Iberia.

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O.9-5: Plio-early Pleistocene ESR chronology of Ganyanchi Gravel Layer, Haiyuan fault, China: implications for transformation from compressive fault to sinistral strike slip fault

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Uplift of the Tibetan Plateau has profoundly affected the tectonic deformation, geomorphologic pattern and environmental evolution of Asia in the Late Cenozoic. Haiyuan fault is an important active sinistral strike-slip fault in the northeastern margin of the plateau, and Hiayuan earthquake occurred at 12:05:55.42 UTC 16 December 1920 resulted in 230,000 casualties. Therefore, study of the Haiyuan fault structure and its kinematic characteristics is of great significance not only to the study of the Tibetan Plateau itself, but also to the correct understanding and analysis of the late Cenozoic tectonics and even the deformation and mechanism of the modern active tectonics in North China [1].

After 1920, geoscientists have carried out a series of detailed studies on Haiyuan fault and obtained a lot of results. After more than a hundred years of research, it is generally believed that the Haiyuan fault has experienced two deformation stages since the late Cenozoic, namely early compression thrust and later sinistral strike slip. However, it is worth noting that the time when the Haiyuan fault began to sinistral strike-slip is still confusion, which has become a hot topic in recent Haiyuan fault research [2].

As the largest pull-apart basin in Haiyuan fault, the beginning time of Ganyanchi pull-apart basin may well record the earliest sino-lateral activity information of the boundary fault, making it an ideal place to study the beginning time of sino-lateral strike-slip of Haiyuan fault.

Our ESR measurement results show that quartz ESR signal intensities of various options of Ti-Li center and Ti-H center are saturation of the Ganyanchi Gravel Layer. However, Al center signal intensities increased with added gamma ray dose. Therefore, the Al center ESR dating results show that Ganyanchi Gravel Layer accumulated between 2.4~2.8 Ma, which indicate that the Haiyuan fault transferred from compressive fault to sinistral strike slip fault at no later than 2.8 Ma.

Keywords: Ganyanchi Gravel Layer; ESR dating; Plio-early Pleistocene; Haiyuan fault; sinistral strike slip fault

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P.9-1: Luminescence dating of loess-paleosol sequences containing the Bag Tephra from the Northern-Carpathian Basin – Can the Bag Tephra be used as a marker horizon?

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Two tephra horizons have been used in the Hungarian loess stratigraphy as marker horizons to support the correlation between different loess-paleosol sequences. The older one is called 'Bag Tephra' described at thirteen locations in the Carpathian Basin. The 'Bag Tephra' has been correlated to the Villa Senni Tuff (Colli Albani) with an age of 351 ka. Although Sági et al. (2008) [1] proposed that both the origin and the integrity of 'Bag Tephra' is questionable, the layer is still usually referred to as a strong marker horizon in the Carpathian Basin.

Five loess successions, Basaharc, Hévízgyörk, Galgahévíz, Pásztó and Isaszeg were dated and geochemically and petrographically reinvestigated. Luminescence dating (pIRIR-290) and amino acid racemization (AAR) were applied to obtain age constraints for the deposition and formation of loess and paleosol at each location. K/Ar dating of one of the tephra layers is in progress.

Luminescence and AAR results are in agreement at Basaharc, but some discrepancy was found at Hévízgyörk. The Bag Tephra horizon can be divided into two groups (Basaharc, Galgahévíz and Isaszeg, called Isaszeg Tephra – Pásztó and Hévízgyörk, called Pásztó Tephra) by petrographic properties of the investigated tephras. The pIRIR-290 minimum ages and the luminescence properties of the investigated samples support the petrological results. Petrographical and chronological differences imply that the eruption centres and/or the eruption times were different which produced the two types of tephra.

Keywords loess; tephra; Carpathian Basin; pIRIR-290; AAR;

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P.9-2: Improving the chronology of marine cores: IRSL dating and Bayesian modelling of a core from the Bay of Biscay (NE Atlantic)

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Evaluating the relationship between cultural and environmental/climate changes implies the search of a potential synchrony between environmental changes and cultural transitions. Archaeologists use quite often sea surface temperature and other environmental reconstructions from marine sediment cores to compare with archaeological archives. These comparisons are hampered by the low temporal resolution and chronological uncertainties of both environmental and archaeological records. The age models of North Atlantic sedimentary sequences are mostly based, before 45 ka, on the combination of radiocarbon dates with the ages of marine isotopic stages and dated SST changes based on the assumption that these changes are contemporaneous with the $\delta^{18}O$ changes in the Greenland ice record. Moreover, ^{14}C age inversions are frequently removed without reliable criteria. These chronologies are often compared with that of the Greenland ice core record, potentially leading to a circular reasoning.

Here, we propose the application of IRSL dating on a marine sedimentary core (MD04-2845), retrieved in the Bay of Biscay to improve the previous chronology available in the ACER pollen database of the interval between 30 and 120 ka. The sampling was done by selecting the layers with high amount of coarse sediments, namely the Heinrich layers marked by the presence of ice rafted debris as the result of iceberg discharges, to optimize the quantity of measured grains. 13 samples were taken between 9 and 24 meters under controlled lighting and sampling conditions. Silt-sized (20-60 µm) grains and coarse-sized (100-140 µm) grains were extracted following standard procedures for IRSL measurements. pIR-IR_{290} measurements on K-feldspars have been carried out to estimate the equivalent dose (D_e). The measurements of the samples, that have been performed on the 41-60 µm and 100-140 µm-fractions, show that most of the IRSL ages are coherent according to the stratigraphy, despite some stratigraphic inversions. For these samples, another granulometric fractions were dated to evaluate the reliability of the ages obtained or the reflection of different deposits. Then, we have performed a Bayesian chronological modelling of the MD04-2845 core constrained by the stratigraphic position of the available ^{14}C and IRSL ages, to obtain an accurate chronology and reduce uncertainties (in comparison to individual ages). The ^{14}C ages with smaller uncertainties than those of IRSL ages better constrain the latter for the 9-12 meters' part of the core. The ages as a function of the depths were estimated] from the chronological model, allowing to estimate different sediment accumulation rates within the core, in the different parts of the core.

Keywords: marine sedimentary sequences, IRSL dating, Bayesian modelling, depth-age model

P.9-4: Getting the right age?

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When luminescence dating was being developed much scientific effort was invested in showing it could achieve the correct ages for known age sediments. As time has passed so methods and approaches used in luminescence dating have been refined but notably fewer checks against known age sediment are now made. This paper uses known age deposits to explore whether we are always get the correct age using both quartz and feldspars. If we don't get the known age what can we learn about our approaches? What are the causes of the discrepancies?

To explore this a detailed study has been made using the Storegga tsunami deposit found in Eastern Scotland which has been dated by radiocarbon at multiple sites to 8.2 ka. This deposit was sampled with a 5 cm diameter tube driven in horizontally into it as well as vertically through the whole deposit. The latter was then sub-sampled at ~1 cm thick slices to provide multiple samples for comparative dating both using quart and feldspar both at small aliquot and single aliquot levels. Whilst the correct age could be achieved this study also revealed a surprising amount of inter-sample variability given all samples are of the same age.

In a second case study at the young end of the luminescence age range samples were collected from Barcan dunes on the Tibet Plateau. Using conventional aliquot approaches young ages were measured for both quartz and feldspars. However it can be proven these are still age over-estimate as these are fast moving Barcan dunes with rapid over-turn rates. Satellite data show they are moving at ~8 m per year are unlikely to have had sediment buried in them for more than 50 years.

P.9-5: The performance of the existing statistical models on the palaeodose distribution: Observations from laboratory controlled samples

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Although dose estimated to be a single value with its error, multiple measured equivalent dose, D_e, values comes with options to choose an appropriate D_e for the age calculation [1,2]. Models are developed for single grain measurement. However, poor sensitivity of grains and/or unavailability of single grain facility, we mostly end up with single aliquot measurements. In both single grain and single aliquot, we get a large scatter in the dose distributions, the possible causes for the scatter are, 1) partial bleaching of grains before burial 2) heterogeneity in of beta dose from K- feldspar grains 3) intermixing of the grains from different strata. Many a times the scatter in D_e distribution is complex and choosing the true dose objectively renders difficult. As there is no straightforward way of choosing the right D_e, there is a vulnerability that a convenient D_e may be chosen. We use different types of statistical models e.g., minimum 5%, minimum+2sigma, minimum age model, finite mixture model, the leading-edge model, the central age model, and arithmetic mean model etc. [2-5] to find the correct age. These models are advised to apply at specific situations of respective depositional environments. So, these models lead researchers and users to confusion, and makes difficult to decide which model predicts the reliable and reproducible dose values.

Here we attempted to test these statistical models to find the true representative dose for the age calculation from the data based on single aliquots. For this study we included following samples 1) a well bleached sample from aeolian sediment (best scenario), 2) partially bleached from tsunami sediment (worst scenario) and, 3) a controlled sample, bleached in the laboratory. Laboratory controlled samples were the quartz grains that were bleached using solar simulator and irradiated with gamma source. De values were measured using SAR procedure from 248 aliquots. Out of which 35 aliquots were drawn randomly and analyzed using different age models. The observations made on each scenario using different models will be discussed in the meeting.

Keywords: Statistical models, Dose distribution and, Luminescence dating

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P.9-6: Seeking chronological precision for a Holocene loess sequence

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The loess sequence at Jingbian, on the Chinese Loess Plateau, was deposited over several glacial cycles. Luminescence dating of the site has shown that the depositional sequence contains some major hiatuses – lasting tens of thousands of years each – that are thought to reflect erosional episodes forced by global climatic change [1]. OSL dates have also been presented for the Holocene part of the sequence, and these dates give some hints that smaller hiatuses may also be present in the Holocene section. However, identification of these features is more difficult, because their possible duration is short compared to the random uncertainties in OSL ages.

Here we attempt to increase the precision in the chronology for the Holocene sequence at Jingbian. Dose rates have been estimated with unusually high precision, using a new beta-counting procedure [2] together with gamma spectrometry measurements [3]. Luminescence measurements are obtained using pseudo-single-grain aliquots: the 300 µm grain holes of the Risø 'single-grain' sample discs were filled with 63-90 µm grains. Due to the skewed sensitivity distribution of quartz, the equivalent dose distribution is equivalent to a genuine single-grain distribution, but requires much less measurement time. The chronology is defined using an integrated Bayesian age-depth model, which accounts for the single-grain dose distributions and the random uncertainties in dose rate.

With the high-precision chronology, we find that hiatuses are clearly present in the Holocene sequence, appearing at ~4 ka and ~8 ka. The age of the hiatuses suggests they are climatically significant, corresponding to periods of deteriorating climate found elsewhere in the northern hemisphere.

Keywords Loess; Bayesian chronology; beta counting; gamma spectrometry.

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P.9-8: Utilising optically stimulated luminescence and radiocarbon dating to investigate depositional scenarios and relative sea level change at Ruddons Point, Fife, Scotland

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Ruddons Point, situated along the southern edge of Largo Bay on the Firth of Forth coastline, Scotland, is a laterally extensive terrace of glacial and marine sediment deposits which are raised above current sea level. The raised marine deposits of Ruddons Point are composed of sand, shell, gravel and cobble horizons, which have been deposited unconformably on glacial tills and clays. 1 km inland, incised by a small stream (the Cocklemill Burn), numerous cut banks reveal further raised deposits. A multidisciplinary study was conducted to provide a detailed geochronology and interpretation of this diverse field area, ranging from the dating of glacial clays, thought to be deposited during the early phases of sedimentation leading up to the Last Glacial Maxima (LGM), through to establishing the timing of marine sediment deposition in the Mid to Late Holocene. Quartz optically stimulated luminescence (OSL) dating was carried out, including initial rapid screening of the sediments using a portable OSL reader [1], laboratory characterisation [2], and full dating of 16 samples, following the SAR protocol [3]. In addition, 10 radiocarbon dates were obtained at selected horizons within the raised deposits and subsurface cores. Results from both dating techniques were used to suggest depositional scenarios and to provide a chronometric framework. Results demonstrate that subsurface clay horizons date to ~29 ka, indicating deposition at the onset of the last glacial. Inland raised deposits along the Cocklemill Burn preserve periods of sedimentation ranging from ~8.5 ka to ~4.5 ka, overlain by younger windblown sediments dated to <300 yrs. The nearshore raised sands and gravels of Ruddons Point are dated to ~3.5 ka. The study concludes that the combination of detailed fieldwork and utilising both OSL and radiocarbon dating techniques allow the scope for complex landscape changes to be identified and further the understanding of the interplay between glacial isostatic adjustment and relative sea level changes across the postglacial coastlines of Fife.

Keywords Optically stimulated luminescence dating; radiocarbon dating; coastal landscape evolution; relative sea level change; Scotland

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P.9-9: Revisiting quartz natural and laboratory electron spin resonance (ESR) dose response curves from Chinese loess

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We present a comparison between natural and laboratory dose response curves for quartz samples from Luochuan section, China. For constructing the natural dose response curves the electron spin resonance (ESR) signals of $[AlO_4/h^+]^0$, $[TiO_4/Li^+]^0$, and $[TiO_4/H^+]^0$, E' and "peroxy" centers were recorded for natural samples, collected at different depths, and compared to the expected equivalent doses computed based on ages reported in literature [1]. Additive laboratory dose response curves were constructed by irradiating two samples collected from S1 and S3, with expected equivalent doses of about 400 Gy and 1000 Gy, respectively, with doses ranging from 100 to 8000 Gy.

Preliminary results show that standard ESR additive dose equivalent dose estimation using $[AlO_4/h^+]^0$ signals is problematic, as previously reported by others [2]: (i) the amplitude of the signals recorded for Holocene samples amounted to about 70% of the signals recorded for a sample collected from MIS 5 soil, suggesting that modern analogues hold significant residuals either due to incomplete light exposure or due to a considerable unbleachable component of the signal and (ii) while laboratory dose response curve show no sign of saturation in the investigated dose range, the natural signals seem to reach field saturation for samples older than MIS 6, suggesting a hitherto unexplained form of instability of the signal. Pulse annealing ESR experiments have been carried out and differences in the thermal stability of the signals, between the low doses, investigated for the natural signal of the Holocene sample, and the higher doses (about 1000 Gy), investigated for older samples, both natural and laboratory irradiated were observed. The cause and implications of these findings are currently under investigation.

Keywords ESR; quartz; loess; Luochuan

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P.9-10: Problems encountered in ESR dating on quartz extracted from Upper Pliocene and Lower Pleistocene sedimentary formations in central Portugal

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Electron spin resonance (ESR) dating on quartz sedimentary grains is usually applied to Pleistocene fluvial terraces and other sandy formations. This method yielded important results for Middle Pleistocene formations in England and in France, which were compared with combined ESR/U-series applied on dental enamel providing a chronological framework for Earliest Acheulian in Europe [1].
In this study, we present new ESR ages obtained from the culminant unconformity bounded sequence (UBS13 unit) in the Mondego and Lower Tejo Cenozoic sedimentary basins (Western Iberia). This unit was dated at the base to ~3.7 Ma and the top has a probable age of 1.8 Ma [2].
The sedimentary deposits of this Upper Pliocene to Lower Pleistocene unit were used to test the potentialities of the ESR method for such old formations. Several samples were taken in a well-contextualized geological frame and dated by ESR on optically bleached quartz, using both the aluminium and titanium centres [3].
All these ESR data, obtained for the first time in the culminant sedimentary unit of the Mondego and Lower Tejo Cenozoic basins, are here discussed.
The ESR age estimates, ranging between 1.8 and 3.0 Ma, were obtained by using the Al centre, while the Ti centre clearly underestimates the expected burial ages [3].
The main problems encountered were due to the measurement of the external dose rate, to the fitting of the growth curves and to a good exploitation of ESR signals measurement, sometimes superimposed by manganese or iron coatings.

Keywords: ESR dating, lithostratigraphic unit, Upper Pliocene, Lower Pleistocene, Western Iberia.

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P.9-11: Evaluation and application of multiple centers ESR dating method on Plio-Quaternary fluvial sediment: A case study from core ZL in Jianghan Basin, middle Yangtze River Basin, China

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The multiple centers electron spin resonance (ESR) dating method on quartz grains has been wildly applied to fluvial and lacustrine deposits since first proposed and provides a precise chronology framework for further studies. However, the potential and reliability of this method on quartz grains derived from borehole sediments of large river basins, which usually deposit continuously and significantly record information for the tectonics, geomorphic evolution, and climate change, has not been systemically assessed yet.

In this present study, we have initially performed this method on ~3 Ma B.P. borehole sediments from the core Zhoulao (ZL), depocenter of the Jianghan basin, Middle Yangtze River, China. The results show that: 1). The multi-centers ESR dating method on quartz grains shows great potential in chronological framework establishment of Plio-Pleistocene borehole sediment and yields a consistent estimated age compared with the palaeomagnetic dating results. 2). For middle Pleistocene samples (i.e. ~0.13 - ~0.8 Ma), the Ti-Li center provides a more precise age, while the estimated ages of the Al center are overestimated. For early Pleistocene samples (i.e. ~0.8 - ~2.6 Ma), both Al center and Ti-Li center deduce highly consistent estimate ages, indicating a favorable dating range for the multiple centers ESR dating method. Meanwhile, the Al center exhibits a promising prospect for dating Pliocene samples, whereas the Ti-Li center is more suitable for middle-early Pleistocene (~0.13 - ~2.6 Ma) sediments dating. 3). SSE function could provide a similar fitness equal to the Ti-2 function for the Ti-Li center and an even better goodness-of-fit superior to the EXP+LIN function for the Al center at a low artificial addition dose (~15000 Gy).

In addition, the attenuation of deposit rate is identified at ~170 m in core ZL, and the phenomena may be caused by the large number of sediments attributed to the upper Yangtze River.

Keywords: Multiple centers ESR dating; Ti-Li centers; Al center; Plio-Quaternary; borehole sediments

P.9-13: Research on ESR chronology of lacustrine sediments from Taoyuan paleo-lake, middle reaches of Jinsha River

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In the middle reaches of the Jinsha River, southeastern Tibetan Plateau, thick lacustrine sediments are widely distributed in the valleys and basins along the Jinsha River and its tributaries. Such like the Xigeda formation, which is a set of hundred-meter-thick lacustrine sediments widely distributed in Luding, Hanyuan, Panzhihua and other areas. In recent years, the lacustrine sediments distributed at Taoyuan in Yongsheng County has attracted more and more attentions with an altitude difference of more than 300 m. Especially, the controversial confusion focused on the formation mechanism of the paleo-lake. Someone proposed that the Taoyuan paleo-lake belonged to the Xigeda paleo-lake and was a big lake caused by the diversion of the ancient Jinsha River, while others reported that this was a small paleo-dammed lake. The distribution and stratigraphic characteristics of Taoyuan lacustrine sediments are similar to those of Xigeda formation, however there still lack systematic chronological studies. In recent years, ESR dating method, has been successfully applied into Quaternary fluvial and lacustrine sediments dating, which provide an ideal approach for dating those lacustrine sediments.

In this study, eight ESR samples were collected from the Taiji profile, in where the lacustrine strata were exposed completely along the slope from 1540m above sea level to 1230m. We measured the Al and Ti-Li centers to evaluate the reliability of the ESR results by the “multiple center method”. The results showed good agreement between the age obtained from the Al and Ti-Li centers, indicating the age of the lacustrine sediments of Taoyuan paleo-lake from 565±56 ka to 624±66 ka. The dating results and stratigraphic features demostrated that those lacustrine sediments were rapidly deposits. Combined with the geomorphic features of the study area, it is speculated that those lacustrine sediments may be Paleo-dammed lake deposits, and the Dawa landslide in the downstream of Taoyuan may be the landslide mass blocking the river.

Keywords: lacustrine sediments; ESR age; Xigeda formation; Taoyuan paleo-lake; Jinsha river

P.9-14: The luminescence chronology of the Yellow River terraces in Gonghe Basin and its tectonic and palaeoclimate implications since Mid-Pleistocene

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The Yellow River terraces have long been recognized as geomorphic markers of the regional tectonics of north-eastern Tibetan Plateau during the Quaternary. A flight of terraces that well developed along the Longyang Gorge in Gonghe Basin have been commonly considered as the evidence of the first occurrence of the Yellow River in present pattern. Multiple dating methods, such as Thermoluminescence dating, electron spin resonance (ESR) dating and ^{10}Be and ^{26}Al cosmogenic isotope dating, have been previously applied to date either directly the terraces or the overlying loess. However, very different age frameworks have been obtained, suggested that the onset of the Yellow River incision in Gonghe Basin varied from 2.47 Ma to ca. 200 ka [1,2], which led to distinct interpretations of no doubt. Hence, refining the ages of these terraces is of essential importance for deciphering the geomorphological evolution of the Yellow River and its driving forces.

In the current study, seven clearly visible terraces with the elevation from 3190 m to 2732 m a.s.l. were identified around the Longyang Gorge. Fluvial sand and the overlying loess were sampled for luminescence dating. Besides, one lacustrine sample of the large ancient lake that once inundated the Gonghe Basin was also obtained. Both quartz OSL and feldspar pIRIR dating techniques have been employed. The preliminary results demonstrate that the onset of the terraces formation was around 140-160 ka and the rapid incision of the Yellow River persisted during the entire last interglacial period. The age of the ancient lake sediment was ca. 156 ka, suggests that the change from a lacustrine to a fluviatile environment shall not be early than this time in Gonghe Basin. It is noteworthy that the ages of overlying loess were restricted to the past 15 ka, regardless of the elevation and the age of the underlay fluvial terraces, indicating that using the loess ages as the minimum age of the terraces is not plausible at least in the case of Gonghe Basin. This new luminescence-based chronology of the Yellow River evolution in Gonghe Basin could be well fitted into the reginal tectonic regime of the latest rapid uplift of the Qinghai-Tibet, named the Gonghe Movement at 0.15 Ma [3], which triggered the strong headward erosion of the Yellow River at the time.

Keywords Luminescence dating, Yellow River terraces, Longyang Gorge, Tectonic uplift, Palaeoclimate change

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Session 10:
Provenance Studies and patterns of sensitivity change

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2	Tammy Rittenour	Quartz Sensitivity across Varied Geologic Provenances and Processes; a near-global survey
3	Jintang Qin	Variation of luminescence characteristics of quartz grains from the Cenozoic sedimentary rocks of Western China
4	Tomas Capaldi	Downstream Change in Quartz OSL Sensitivity in Modern River Sand Reflects Sediment Source Variability
6	Ed Rhodes	MET-IRSL used to track pre-depositional sediment transport history

Poster Presentations

	Presenter	Title
1	Natascia Pannozzo	Testing the use of luminescence as sediment tracer and provenance tool in coastal settings
2	Qiuyue Zhao	Provenances of Paleosol deposits in the Central Shandong Mountains region of northern China inferred from Optically Stimulated Luminescence chronologies and grain sizes
3	Anna-Maartje de Boer	Development of EMCCD approaches for single-grain feldspar measurements and future applications for sediment tracing
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7	Rhys Watkins	Luminescence as a sediment provenance tool for the former British-Irish Ice Sheet (BIIS)
8	Kaja Fenn	Integrated provenance approach: Combining OSL data with bulk sample geochemistry and zircon U-Pb ages

O.10-1: Determining the provenance of sediments using TL and OSL sensitivities, and hyperspectral cathodoluminescence of quartz grains associated with heavy mineral analysis: the case of Nahal Aqev, Israel

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The Nahal Aqev archeological site is located in a coarse, fluvial terrace in the Negev desert, Israel. To appraise the provenance of the sediments at this location, 11 samples from an 8-m section were subjected to a multi-proxy approach that included sedimentological and luminescence analysis. Preliminary data revealed that quartz was the major siliciclastic component of the sediments that showed a primary grain-size mode between fine and very-fine sand. This distribution suggests that quartz in this size range was transported along with heavy minerals, mostly in the coarse-silt size fraction. Heavy minerals in this size fraction were then separated and analyzed for mineral assemblage and selected frequency ratio of minerals. These type of analyses have been extensively used for provenance investigations. To determine the provenance of the accompanying very-fine quartz grains, we opted for OSL and TL sensitivity and cathodoluminescence analysis. Multi-grain TL sensitivity was measured in a RISO reader using six aliquots per sample with a protocol consisting of a TL bleach followed by a 40-Gy irradiation dose before two measurements of 0−500 °C TL in sequence made to determine the sensitivity signal and the background. TL sensitivity values were obtained by integrating the temperature ranges of 30−130 (110 °C peak) and 200−400 °C followed by the background subtraction. Multi-grain (MG) and single-grain (SG) OSL sensitivity data were appraised in RISO readers from the test-dose measurements of a dating sequence [Data not published], in which irradiation of 7 Gy and 20 Gy for the MG and SG analysis, respectively, was applied to measure the OSL signal after pre-heating. OSL sensitivities were calculated by integrating the first 0.8 s of the decay curves minus a background subtraction. A Gatan MonoCL4 Elite cathodoluminescence system attached to a SEM platform was used for hyperspectral cathodoluminescence analysis of 15−21 selected quartz grains per sample. Seventy-two spectra per grain were obtained in 360 s (1 spectrum every 5 s) in a uniform area of 30 x 30 µm. The determination of the nature of luminescence centers was appraised through a global fitting of the spectra acquired over time by extracting the wavelength components of the signal and the half-life of each component. The proposed fitting function comprises up to six activation-decay gaussian components, allowing us to discriminate the data from each sample.

We will present the sedimentological and luminescence results and propose a likely origin of the sediments.

Keywords: OSL sensitivity, TL sensitivity, cathodoluminescence, heavy minerals, provenance

O.10-2: Quartz Sensitivity across Varied Geologic Provenances and Processes; a near-global survey

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The luminescence properties of quartz sand in sediments has been show, in some settings, to vary with source-rock geology [1], source-area weathering and erosion rates [2] and fluvial transport distance [3], allowing sediment fingerprinting using quartz luminescence [4]. Laboratory experiments have shown that luminescence sensitivity (magnitude of luminescence per dose of radiation) in quartz can be enhanced through repeated cycling of exposure to light, heat and radiation [5], providing some insight into the processes that enhance quartz sensitivity, particularly the fast-decay component desired for optically stimulated luminescence (OSL) dating of quartz. However, the specific or cumulative geologic and environmental conditions and processes that lead to natural quartz sensitization remain elusive.

Here we examine the quartz sensitivity from >3500 samples collected globally to test for linkages to geologic source rock and processes. Quartz sensitivity (initial OSL signal minus background) from each sample was normalized by dose (typically ~5-10 Gy) and sample volume per aliquot (grains per aliquot, based on aliquot and grain size). The Fast Ratio [6] was calculated for all samples and characterization of the fast-decay component were assessed using linear-modulated OSL (LM-OSL) on select samples [7].

Results indicate a large variance in quartz sensitivity between samples (up to 4 orders of magnitude). Regional and global distributions of the quartz sensitivity data were assessed in relationship to geologic provenance and tectonic settings. Deposit type and mode of transport were examined to test for relationships. Where possible, we also tested for linkages with transport distance (fluvial samples) and source-rock lithology and geologic age. While quite noisy, results depict the strongest association with tectonic setting; displaying an inverse relationship between regions with high uplift and erosion rates and generally lower quartz sensitivity, lower Fast-Ratio values and reduced fast-decay components. While this survey is not a complete assessment of all regions, it provides key insight into the broader geologic controls on quartz sensitivity, and therefore suitability for OSL dating applications.

Keywords Quartz sensitivity; Fast-ratio; source-rock lithology; transport mechanism; tectonic processes

References:

O.10-3: Variation of luminescence characteristics of quartz grains from the Cenozoic sedimentary rocks of Western China

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Quartz grains from various origins show diverse responses to radiation, with respect to their luminescence emissions resulted from unit dose of unit mass, as well as their characteristic saturation doses of luminescence signals. The diagenesis processes, dosing-bleaching cycles, residence time on Earth surface, as well as thermal histories, are all identified to affect the luminescence characteristics of quartz grains, which makes it possible to use quartz luminescence characteristics as tracers or as environment proxies. The Cenozoic sedimentary rock sequences of Western China are intensively investigated and their tectonic and climatic contexts are largely established, which set an ideal reference frame to inspect the co-variation of luminescence characteristics. In this study, the quartz grains are extracted from the Cenozoic sedimentary rock sequences with contrasted lithology from Western China in tectonically active regions, which span from fluvial conglomerates and sandstones to lacustrine muddy-silt stones. The quartz luminescence characteristics are investigated on grain level, with respect to their luminescence sensitivity and characteristic saturation dose. Our preliminary results show that the luminescence characteristics vary significantly across the sedimentary sequences, which implies different environmental configurations. The luminescence characteristics will be compared with other indices for variation in tectonics, surface denudation and climate to pin down the cause of their variation. Finally, the feasibility of employing luminescence characteristics as finger print for significant reorganization of tectonic configuration will be evaluated.

Keywords Luminescence characteristics; Quartz grains; Sedimentary rocks; Tectonic configuration

O.10-4: Downstream Change in Quartz OSL Sensitivity in Modern River Sand Reflects Sediment Source Variability

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This study leverages a suite of modern river samples from the northern Basin and Range extensional basin system of western USA (Bear River), and southern Central Andes of Argentina foreland basin system (Rio San Juan) to understand the relationships among quartz luminescence sensitivity, catchment lithologies, climate conditions, and geomorphology in different tectonic settings. Luminescence sensitivity of quartz has been shown to either be a function of source geology, presenting a potential tool to track sediment erosion and provenance, or record downstream sediment transport related to increased number and duration of light exposure cycles. We compare our results with detrital zircon geochronology and petrographic analysis of the river sands composition, and characterization of river catchment climate, lithology, and morphometrics. Samples taken along the Bear River and major tributaries show a progressive downstream decrease in quartz sensitivity that records variation in sediment provenance and steady contribution of lower sensitivity quartz recycled from Palaeozoic passive margin stratigraphy (Fig. 1). River sand samples from the Rio San Juan network exhibit pervasive low sensitivity quartz derived from Andean arc volcanic rocks and recycled foreland basin strata. Determining the controlling factors of quartz sensitivity in river sand provides a modern baseline for resolving paleogeographic and paleo-drainage histories in the sedimentary record and provides further understanding of how sediments are eroded, transported, and deposited in fluvial systems in both extensional and contractional tectonic settings.

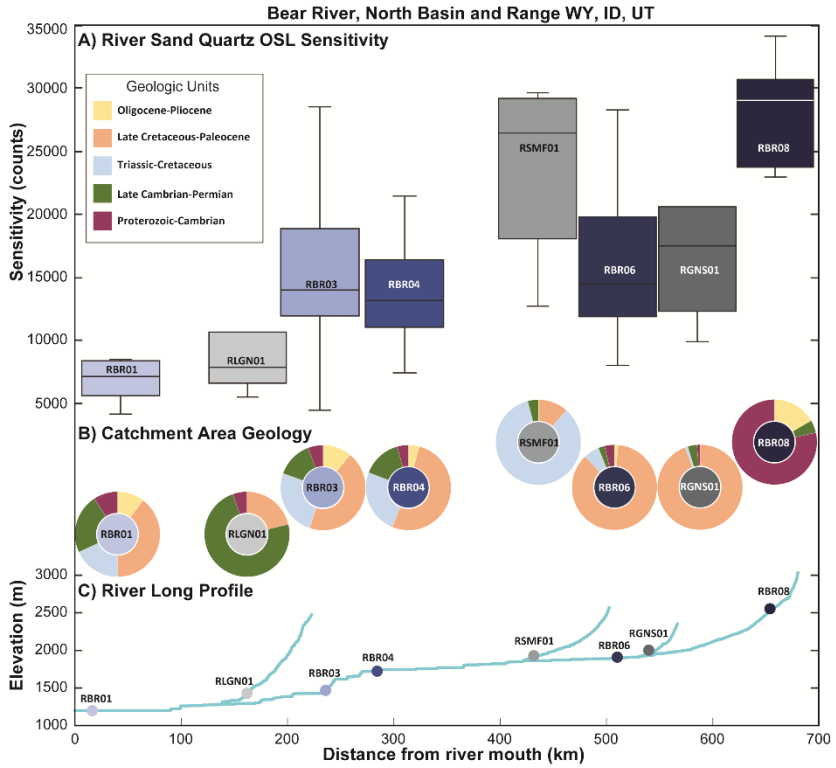

Figure 1: Comparison between quartz OSL sensitivity results, catchment area geology, and river profile for the Bear River in WY, ID, UT. (A) Quartz OSL sensitivity results from samples of the main trunk (blue) and tributaries (grey). (B) Ring diagrams showing the relative proportions of geologic units in their respective catchment areas. (C) Sample locations relative to the Bear River mouth at the Great Salt Lake

Keywords quartz; OSL sensitivity; modern river; provenance

O.10-6: MET-IRSL used to track pre-depositional sediment transport history

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Multiple Elevated Temperature (MET) IRSL is useful in several ways, including assessing thermal stability of determined ages by allowing comparison of signals with different lifetimes and fading susceptibilities, as originally developed by Li and Li (2011). A similar protocol was used by McGuire and Rhodes (2015a, b) to assess patterns and rates of sediment transport in the Mojave River, California, USA, relying on differences in daylight bleaching for the five IRSL signals measured.

In this presentation, we examine new possibilities for understanding the prior history of individual K-feldspar sediment grains using MET-IRSL. Using groups of statistically indistinguishable D_e values measured at different temperatures within individual grains we can define a "plateau", and tentatively interpret this as representing a bleaching event of sufficient duration to reset multiple signals with varying bleaching susceptibility ("bleachability"). Several interesting applications are possible using this approach including assessing the relative timing and durations of past bleaching events within the catchments that contributed to the sampled sediment unit.

We have also examined the MET-IRSL signal patterns for grains that display no apparent plateau; for these grains signals typically continue to provide older apparent age estimates for higher temperature signals. The steepness of the observed increase in age across the five MET-IRSL signals is related to the ratio of the average time buried to the time exposed over multiple burial-bleaching cycles. In a study to investigate the chronological and sedimentary origins of sandy deposits located beneath blanket peat on a high plateau at Ilkley Moor in Northern England, we have compared MET-IRSL determinations to traditional particle size analysis (PSA). To assist with interpretation of these samples of unknown origin, we also measured a calibration dataset, including samples from well-established aeolian, fluvial and glacial contexts, as well as determinations of grains from local bedrock. We observe interesting relationships between the MET-IRSL data and PSA data, suggesting that we may be able to place chronological constraints on the acquisition of particular sedimentary characteristics; we also speculate on the likely origins of the unknown sandy sediments from Ilkley Moor. We examine the limits for useful interpretation, and possible role of thermal transfer in causing apparent age inversions within the MET-IRSL responses for individual grains.

Keywords MET-IRSL; sediment transport; particle size; bleaching; Ilkley Moor

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P.10-1: Testing the use of luminescence as sediment tracer and provenance tool in coastal settings

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This study investigates the use of luminescence signals of coarse-grained quartz and K-feldspar as a tool for investigating the source and travel pathways of salt marsh sediments. This tool could be of high value for investigating morphodynamic processes occurring at river-ocean boundaries where it is difficult to determine the origin and pathway of sediments deposited in the intertidal areas during ordinary meteorological conditions or extreme events. Luminescence has the potential to be exploited as a sediment tracer because of the relative differences in bleaching rates of the optically stimulated signal (OSL) emitted by quartz and the multiple-elevated temperature (MET) post-infra-red infra-red stimulated luminescence (post-IR IRSL) signals measured at 50°C, 150°C and 225°C emitted by K-feldspar grains [1]. Where sediments are transported long distances, or more slowly deposited (i.e. ordinary meterological conditions), we expect that the D_e values determined using the OSL signal of quartz and post-IR IRSL signals of K-feldspar to be more similar than sediments that were transported over shorter distances or were more rapidly-deposited (i.e. extreme events). Luminescence can be used as provenance tool because luminescence signal resetting (or bleaching) occurs at different rates in different geomorphological settings [2]. Within coastal environments this can be used to understand whether the origin of the sediments is fluvial or marine. However, there is a lack of studies comparing the luminescence properties to well-established provenance and tracing techniques to evaluate its efficacy. Here, we use an unrivalled, well-constrained test scenario provided by Hesketh Out Marsh, in North West England. Optically stimulated luminescence (OSL) dating of coarse-grained quartz has shown an initial fast deposition of sediment, followed by a slower accumulation. Geochemical analysis showed that the origin of the sediment was marine and particle size distribution analysis revealed that the slow accumulation occurred during ordinary conditions while the fast deposition occurred due to an infilling of the estuary. As such, Hesketh Out Marsh has known datasets for provenance and tracing of sediments within a saltmarsh derived from the well-established proxies of geochemical and particle size distribution analysis.

Keywords salt marshes; coastal environments; sediment provenance; sediment tracers

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P.10-2: Provenances of Paleosol deposits in the Central Shandong Mountains region of northern China inferred from Optically Stimulated Luminescence chronologies and grain sizes variations

Zhao,Q.Y.[1*], Peng, S.Z.[1], Ding, M[1]., Wang,L.[2],Hao, Q.Z.[2], Zhang, W.[1], Zhou, R.[3], Yue, J.S.[1], Li, X.L.[1]

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Abstract

The aeolian sediments affected by the East Asian Monsoon in the Central Shandong Mountains region of northern China are significant for reconstructing paleoclimate. However, the continuity and provenances of the paleosol from the Central Shandong Mountains area is still unclear. Optically Stimulated Luminescence (OSL) chronology, climatic proxies and chemical compostions of Heishan, Shao Zhuang and Fo Cun sections were studied. Quartz SAR and feldspar post-IR IRSL dating results were obtained to develop what is currently the most detailed chronologies in the Central Shandong Mountains region. The OSL results suggesting that the CSM loess was deposited with ages ranging from the penultimate glacial period to the Holocene, characterized by a depositional hiatus during the last galcial period; and the interglacial paleosol is discontinue. OSL ages and median grain sizes indicated that the dust provenances of the interglacial paleosol is mainly from the weathering of the underlying loess in this humid and semi-humid climatic region. Compared with the median grain size and colorness parameters, the CIA index of loess is more sensitive to the indication of stratigraphy and paleoclimate, which correlate well with the marine SPECMAP $\delta^{18}O$ record, demonstrating that the climatic changes in the CSM region during the late Quaternary was mainly controlled by the East Asian monsoon.

Key words: high sampling density; paleosol; grain sizes; provenance; deeply weathering

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P.10-3: Development of EMCCD approaches for single-grain feldspar measurements and future applications to sediment tracing

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The ability to trace the movement of sediment in nature is key to predicting geomorphic change associated with a vast and diverse range of fluvial, coastal, and anthropogenic processes. In the Dutch Wadden Sea, an ebb-tidal delta nourishment project aims to compensate coastal erosion and prevent drowning of intertidal areas. This provides a unique opportunity to develop and test novel sediment tracing approaches to study nourishment sand dispersal, and to investigate off site geomorphic and ecologic impacts of the nourishment. The TRAILS project seizes these research opportunities through interdisciplinary research, also involving key stakeholders in the Wadden Sea area.

As part of the TRAILS project, we will develop single-grain feldspar luminescence as a sediment tracer. Our key objective is to distinguish two populations of grains (native and nourished) with potentially unique luminescence signatures arising from slow- and fast-to-bleach post-infrared infrared stimulated luminescence (pIRIR) signals. We envisage that our approach may reveal both provenance (deep time) and transport history (modern time) of sediments on a grain-by-grain level, thus providing insight in coastal dynamics and supporting coastal management.

A primary challenge in our work involves obtaining large numbers of informative feldspar signals on a single grain level. To meet this need, the early stages of methodological development for the project focus on the challenges and potential benefits of a novel luminescence imaging system, the electron multiplying charge-coupled device (EMCCD). Grains are stimulated simultaneously and the EMCCD images the resulting luminescence signal, instead of conventional single-grain laser stimulation and detection with a photomultiplier (PM) tube. Similar to conventional single grain methods, EMCCD detection allows rapid repeated measurements without user interference. Moreover, the EMCCD provides extreme low-level light detection for dimmer signals [1]. The EMCCD approach has the additional advantage of simultaneous measurement of all grains on the disc, minimizing thermal erosion during prolonged elevated-temperature post-IR measurements. In addition, the EMCCD camera also enables exploring the TL signals of individual grains [2].

Preliminary results reveal the EMCCD has lower returns than conventional single-grain approaches, whereas the equivalent dose distributions obtained by the measurement devices are similar. This suggests that EMCCD application is promising but requires additional tailoring to meet the aims of our work.

Keywords sediment tracing; nourishment dispersion; EMCCD; pIRIR; degree of bleaching

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P.10-4: Luminescence characteristics of Scandinavian quartz, their connection to bedrock provenance and influence on dating results

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The success of optically stimulated luminescence (OSL) dating relies to a large extent on suitable characteristics of the analysed mineral, in this case quartz. Previous OSL dating of Quaternary sediments in Scandinavia has shown that these characteristics (e.g. signal strength) vary widely across the region, resulting in dating studies with varied success (e.g. [1]). In this study, we have analysed luminescence and mineralogical data with the aim of getting an overview of quartz luminescence characteristics in Sweden and Norway, evaluating their effect on dating results and trying to unearth their causes.

A qualitative assessment of luminescence signal characteristics of quartz from Late Quaternary sediment deposits, from a range of geological and geographical settings in Sweden and Norway, has been made by re-analysing data from samples previously dated at the Lund Luminescence Laboratory, Sweden. This allowed a general characterisation of signals (presence of a fast signal component, signal intensity and signal change during measurement) and to study the relationship of these properties to dating result 'quality' (e.g. dose estimate uncertainty). To better quantify the results, selected samples have been further analysed with single-grain measurements at the Department of Geography, Sheffield University, UK and at DTU Risø, Denmark, as well as with controlled small aliquots at the Lund Luminescence Laboratory.

The results show that the luminescence signal characteristics have a spatial variation across Sweden and Norway, which appears to correlate with large-scale bedrock units, such as Caledonian orogen bedrock and Proterozoic provinces. To investigate any causal relationship between luminescence signal and mineralogy, grains from the single-grain luminescence measurement of four type samples were examined with SEM-EDS, for grain-specific geochemical composition.

In this presentation, we will give an overview of the luminescence characteristics of Scandinavian quartz and discuss their relationship to mineralogy and bedrock origin, as well as the implications for luminescence dating and potentially provenance studies of Late Quaternary sediments in various parts of Scandinavia.

Keywords quartz; OSL; geochemistry; provenance; Scandinavia

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P.10-6: Spatial variations in luminescence sensitivity of quartz extracted from source rocks and fluvial sediments of the Sabarmati River basin, Western India: Implications for provenance studies

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Investigation of the source or provenance of grains in a specific environment has long been one of the most important queries to better understand the Earth Surface Processes and dynamics of the landscape. Crucial information about transport pathways and environmental conditions are recorded in sediments as they get dispersed through various surface processes. In this study, we have used luminescence sensitivity of quartz grains to decode their provenance and long-term history.

Quartz grains possess different impurities in the crystal structure depending on the nature of source rock and its formation. These crystal impurities result in variations of luminescence sensitivities which offers a noble way to track signature of the provenance [1]. Limited attempts are made so far to use thermoluminescence (TL) and optically stimulated luminescence (OSL) sensitivity (luminescence per unit mass per unit radiation dose) of quartz grains as a tool to infer their provenance and transport history. The present study is focussed on the Sabarmati River sediments to understand the effect of variation in provenance on luminescence sensitivity and subsequent sensitization of quartz grains along the river. The upper catchment of Sabarmati basin is marked by the Proterozoic Aravalli Range. The basin is characterised by semi-arid climate and seasonal rivers.

The quartz TL and OSL sensitivities, and their characteristics are analysed with variable stimulation parameters as preheat and BLSL (Blue Light Stimulated Luminescence). The results so far indicate that TL and OSL sensitivities of quartz grains of fluvial nature exhibit significantly higher sensitivity than that of source rocks. Initial analysis suggests that as sediment grains travel farther, they exhibit higher OSL sensitivity. These possible variations in the luminescence sensitivity of quartz grains can be attributed to repeated cycles of irradiation and bleaching that occur during the continuous cycle of transportation, deposition, and remobilisation of sediments as they travel downstream. Thus, OSL sensitivity of quartz in such settings promise to provide crucial information on fluvial transport processes. However, sensitivity variations and their mechanism still need to be explored to pinpoint the definite roles of governing factors. More experiments are being conducted to understand the sensitization of quartz and link it to sediment fingerprinting.

Keywords: Quartz; Luminescence sensitivity; Provenance; Fluvial processes

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P.10-7: Luminescence as a sediment provenance tool for the former British-Irish Ice Sheet (BIIS)

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Current climatic challenges stress the need for robust understanding of the mechanisms of ice mass loss, particularly in regard to the current stability of Antarctic and Greenland Ice Sheets [1]. Effective modelling and reconstruction of Quaternary ice sheets offers a useful opportunity to assess the reliability of ice sheet models. As a result of the BRITICE-CHRONO project (2011 – 2018), the retreat pattern of the former British-Irish Ice Sheet (BIIS) is now well constrained [2]. The extensive sedimentary and geochemical data collected from this research offers an excellent opportunity to test whether luminescence can be used as a novel proxy of glacigenic sedimentary provenance across the British-Irish Ice Sheet, alongside geochemical provenance methods. Sediment provenance techniques, whether geochemical or luminescence-based, offer the opportunity to infer past sediment transportation and depositional pathways, in addition to interpreting the conditions of localised ice-divides or flow lines that may have existed within the BIIS. These relationships are all set within the context of the local bedrock geology. This project will explore the potential for luminescence and geochemistry as provenance tools of glacigenic sedimentary provenance across the extent of the former BIIS. Geochemical data was acquired using inductively coupled plasma mass spectrometry (ICP-MS) on the large suite of sedimentary samples collected by BRITICE-CHRONO, totalling 171 samples across eight transects of ice retreat. Optically stimulated luminescence (OSL) dating was also conducted on single grain quartz from these samples, which provide the opportunity to use sensitivity and overdispersion luminescence properties as a provenance tool. Elemental geochemistry and luminescence properties were scrutinised using multivariate statistical analysis to identify linear structures and inter-elemental relationships within the dataset, building on previous methodologies [3,4,5].

Keywords British-Irish Ice Sheet; provenance; geochemistry; Optically stimulated luminescence dating

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P.10-8: Integrated provenance approach: Combining OSL data with bulk sample geochemistry and zircon U-Pb ages

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Sediment sources are of great interest to geoscientists as they provide information on transport and deposition, and through them identifying erosion patterns and drivers, landscape evolution, and transport distance, medium, and pathway, and in turn climate and environment[1][2].
One of the commonly cited benefits of quartz optically stimulated luminescence (OSL) dating is the abundance of quartz in rocks and sediment and therefore the applicability of OSL to a range of sediments. At the same time however, there are not many methods that can use quartz as a precise sediment tracer. In recent years researchers have demonstrated that luminescence characteristics, including luminescence sensitivity (i.e. the luminescence measured per unit dose), can be linked to the sources of material[3][4] and sedimentary history[5, 6]. Whilst various luminescence characteristics have been used as sediment tracers, to date no comparison has been carried out between geochemical and luminescence properties. The benefits of this approach are two fold:

1. Verifying and testing two independent provenance approaches;
2. Building a fuller picture of sediment sources, and potentially identifying source differences between light and heavy minerals.

Here results of integrated geochemistry and luminescence sensitivity approaches are applied to a total of 30 loess samples from Serbia[7] and Bulgaria. Quartz sensitivity was calculated using data from the Single Aliquot Regenerative dose (SAR) dating protocol. Additionally, signals from various parts of the dating protocol (i.e. natural, regenerative, test doses) were compared. Quartz luminescence sensitivity was combined with traditional fingerprinting approaches, including bulk sample elemental composition (ICP-MS) and zircon U-Pb ages, to test if changes in one tracer correspond to changes in another. The provenance results from all approaches were statistically combined using multidimensional scaling (3-way MDS) to extract geological insights.

Keywords Quartz, luminescence signal sensitivity, provenance, geochemistry, U-Pb zircon ages

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Session 11:
Novel applications of luminescence and ESR: Part 1

Oral Presentations

	Presenter	Title
1	Aditi Krishna Dave	E' and peroxy paramagnetic centres in quartz as a proxy for provenance: Examples from Central Asia
2	Alida Timar-Gabor	Luminescence and electron spin resonance (ESR) characterisation of quartz from different lithologies of different ages
3	Andre Oliveira Sawakuchi	Appraising the variability of OSL and TL sensitivities of quartz from rocks and sediments using spatially-resolved luminescence measurements
4	Nathan Brown	Developing an internally consistent methodology for K-feldspar MAAD TL thermochronology
5	Magdalena Biernacka	How to effectively isolate the OSL component in the OSL depletion curve measurement?
6	Chloé Bouscary	Optimisation of measurement conditions for the derivation of thermal kinetic parameters using isothermal holding experiments

Poster Presentations

	Presenter	Title
1	Luke Gliganic	Direct dating of lithic surface artefacts using luminescence
2	Warren Thompson	Luminescence dating of an ancient circular stone walled enclosure complex at Sönneböe, northern Scania, Sweden: combined dating of coarse-grained sediment

O.11-1: E' and peroxy paramagnetic centres in quartz as a proxy for provenance: Examples from Central Asia

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Lattice defects and impurities in quartz, in addition to their importance in age determination, also show potential for sediment provenance. In this study, we investigate a novel approach by using the natural accumulation of E' and peroxy defect centres in quartz as a proxy for provenance. This is based on the premise that E' and peroxy centres arise from Frenkel-Schottky defect pairs in granitic quartz and increase with the age of the rock [1]. We examined the signature of E' (≡Si·, an unpaired electron at an oxygen vacancy) and peroxy defect centers (≡Si-O-O· and ≡Si–O· non-bridging oxygen) using Electron spin resonance (ESR), on fine grain quartz from five loess sites located in two different basins in Central Asia, the Ili Basin and the Tajik depression. Recent studies [2,3] based on geochemical fingerprinting and dust transport models suggest contribution from different source areas for these regions [2, 3], therefore making it ideal test sites to look for spatial and temporal variability in source change through time.

Our results indicate a significant difference in E' and peroxy signals between the Kazakh and Tajik samples, which agrees with the hypothesis regarding potential source areas and dust transport pathways for the basins. In addition, site-specific down-profile measurements of these signals suggest potential shift in dust source through time and space. We also tested the suitability of our approach to the commonly used protocol in ESR provenance studies based on irradiation and heat-treatment [4], which shows that the natural signature of these defect centres holds great potential for sediment provenance as well as simplifies measurement protocols used in ESR based provenance studies.

Keywords Electron Spin Resonance; Provenance; Quartz

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O.11-2: Luminescence and electron spin resonance (ESR) characterisation of quartz from different lithologies of different ages

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Paramagnetic defects such as E` [1], as well as optically stimulated luminescence sensitivity [2] of quartz were proposed as potential indicators for the provenance of the sediments. However, most of the previous studies are targeting minerals deposited in sinks and focus only on observing the characteristics of signals displayed by different samples, followed by clustering. Also, there is no proper explanation of the variability of luminescence sensitivity (by up to ten orders of magnitude) observed between samples in the luminescence dating community, and in most dating studies it is implicitly or explicitly assumed that transport history is the main factor increasing the sensitivity. Based on the observations that quartz from young metamorphic rocks displays poor luminescence properties [3] and based on the fact that we observed a clear increase in the sensitivity of OSL signals of quartz from loess (windblown sediment, thus by its nature transported over long distances) in areas where the source material has components from cratonic areas we hypothesize that the defects of quartz in the host rock (formed during crystallisation as well as due to subsequent exposure to radioactivity in time) are an important factor controlling the type and abundance of the defects that characterise quartz grains in sediments, consequently dictating their luminescence properties.
Here we perform in depth characterisation of electron spin resonance signals (due to extrinsic defects such as $[AlO_4/h^+]^0$, $[TiO_4/M^+]^0$, as well as intrinsic defects such as E' and "peroxy" centers, an overlap between the peroxy radical and the nonbridging oxygen hole centre) as well as luminescence properties (OSL and TL) of quartz extracted from different lithologies of varied ages. By analysing granite samples of different ages (information provided by U-Pb zircon chronology) ranging from ~25 Ma to 1.4 Ga as well as by the analysis of quartz from well identified metamorphosed protoliths we have observed an increase in both the OSL sensitivity as well as the concentration of intrinsic defects with the age of the sample, in the absence of metamorphic events. We show that changes in ESR properties that can be attributed to annealing of intrinsic defects and migration of compensating ions occur during metamorphic events. These are not reflected however in a dramatic change of OSL sensitivity. The analysis of sediments derived from these lithologies is in progress and results will be presented at the time of the conference.

Keywords quartz; defects; luminescence; ESR; different lithologies

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O.11-3: Appraising the variability of OSL and TL sensitivities of quartz from rocks and sediments using spatially-resolved luminescence measurements

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The optically stimulated luminescence (OSL) and thermoluminescence (TL) sensitivities of quartz have been increasingly used for sediment provenance analysis. This application is based on observed variation in quartz OSL and TL sensitivities (photon counts mg^{-1} Gy^{-1}) covering five orders of magnitude within sediment grains derived from different geological settings. The large variation in OSL and TL sensitivities is observed both at the multi-grain and single-grain levels. Laboratory experiments demonstrate that quartz can be sensitized by irradiation and light exposure treatments designed to simulate solar exposure and burial irradiation during sediment transport, respectively. However, such experiments have been incapable in reproducing the range of quartz OSL and TL sensitivities observed in nature and in explaining the large variability of OSL and TL sensitivities across quartz single grains. Here, we use spatially-resolved luminescence measurements to improve our understanding about the micro-scale variability of OSL and TL sensitivities in quartz crystals hosted in their primary source rocks (igneous and metamorphic) and in quartz sediment grains from different provenances. Thus, we aim to characterize the variability in OSL and TL sensitivities within and across single quartz crystals. For this purpose, we used samples of granitic and gneissic rocks, considered as primary sources of quartz, and quartz sediment grains with contrasting OSL sensitivities. Micro X-ray fluorescence (XRF) was used to map mineral phases surrounding quartz crystals in rock slices. Quartz sensitivity-depth profiles were acquired for rock samples to check if sensitization starts in the source rocks before quartz becomes sand grains. Rock slices and sediment grains were also submitted to bleaching (blue or ultraviolet light) and irradiation (beta radiation) cycles to evaluate the sensitization behaviour of quartz crystals (rock slices) and quartz single grains (sediments). The results will be discussed in terms of the potential natural controls leading to the OSL and TL sensitization of quartz in nature and to the large variation of sensitivity at the single grain level.

O.11-4: Developing an internally consistent methodology for K-feldspar MAAD TL thermochronology

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Natural TL signals from K-feldspars contain rich information about the thermal history of bedrock samples, but it remains challenging to represent TL kinetics in a physically meaningful, internally consistent, and empirically robust manner. In this study, we propose a workflow to relate multiple-aliquot additive-dose (MAAD) TL signals and fading measurements to erosion rates (Fig. 1). This workflow assumes a localized transition model for TL kinetics and then iteratively quantifies the relevant kinetic parameters: radiative recombination center density, activation energy, and characteristic dose. The resulting erosion rates from this workflow match well independent estimates from basin-averaged cosmogenic ^{10}Be and apatite (U-Th)/He measurements, which estimate erosion at younger and older timescales, respectively.

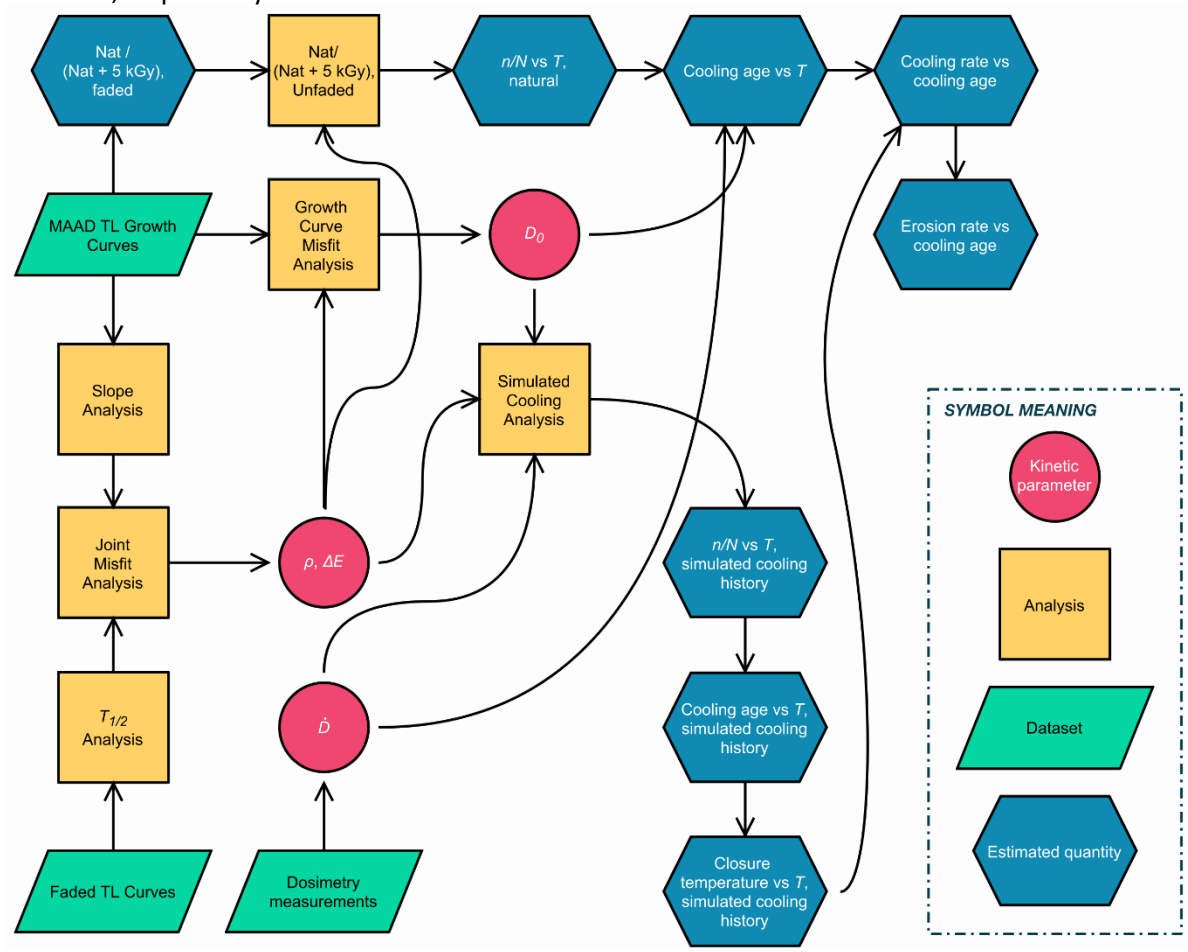

Figure 1: Proposed workflow for K-feldspar MAAD TL thermochronology.

Keywords Thermochronology; Thermoluminescence; K-feldspar; Tectonics; Erosion

O.11-5: How to effectively isolate the OSL component in the OSL depletion curve measurement?

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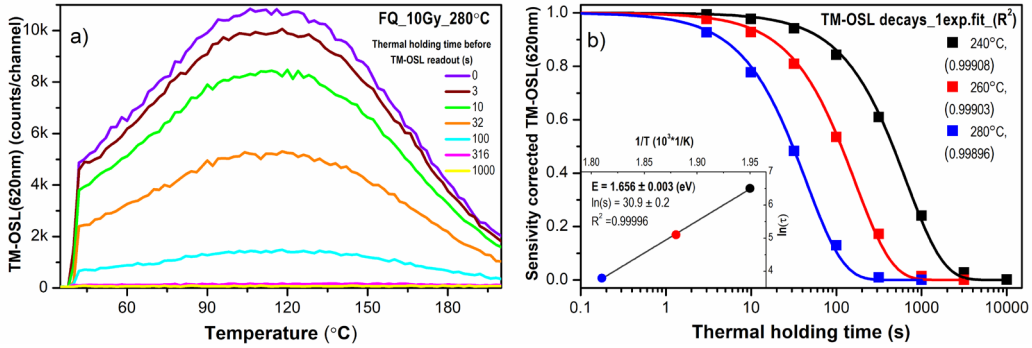
The possibility of experimental separation of the fast OSL component is important in dating and when the thermal stability of traps should be precisely determined e.g. in thermochronology. Recently, the experiment of thermal depletion of the OSL signal is often used to determine the thermal stability of OSL components. It allows estimating parameters of traps taking part in OSL when one interprets the OSL thermal depletion curve correctly. This work presents a new approach to measuring the thermal depletion curve that relies on replacing the usually used CW-OSL method with the thermally modulated OSL (TM-OSL) method which is a combination of thermal and optical stimulation. Recently, it was found that it is possible to separate the fast OSL component in quartz when the TM-OSL method is conducted using a wavelength of 620 nm [1]. The typical TM-OSL (620 nm) curves obtained for quartz sample, dominated by the fast OSL component, measured after the various durations of the thermal storage are depicted in Fig. a. Sensitivity corrected thermal depletion curves (the integrated TM-OSL signal from 41°C to 150°C) for this quartz fitted by single exponential decays are depicted in Fig. b. The obtained mean value of activation energy of the main OSL trap about 1.66±0.03 eV (see the result for one aliquot in inset Fig. b) is consistent with the literature data, for example, 1.59±0.05 eV [2].



Additionally, the TL signal bleached during the TM-OSL measurement so called *TL difference curve* was analysed by a fitting procedure. Generally, one first-order kinetic peak was fitted with satisfying quality to an experimental TL difference curve using trap parameters obtained independently in the OSL thermal depletion and VHR methods. The determined thermal stability of the main OSL trap in quartz stays in agreement in all methods used and in three quartz samples from sediments of different origins. The provenance of quartz grains was investigated using combined methods of optical microscopy and panchromatic scanning electron microscopy – cathodoluminescence (SEM-CL) analysis.
Acknowledgments: This work was supported by the National Science Centre, Poland, no. (2018/31/B/ST10/03917).

Keywords thermal stability, quartz, TM-OSL method, provenance, thermochronology

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O.11-6: Optimisation of measurement conditions for the derivation of thermal kinetic parameters using isothermal holding experiments

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Beyond the calibration study of Guralnik et al. (2015) [1], the validity of the luminescence thermochronometry method has not been confirmed. Furthermore, no independent validation of the use of multi-signal feldspar protocols for luminescence thermochronometry has been made, despite their use in a number of studies (e.g., [2], [4]).

Here we use a multi-elevated-temperature infra-red-stimulated luminescence (MET-IRSL) protocol on feldspars ([6], [3]) to extract thermal histories. These thermal histories depend on the thermal stabilities of the samples, and are based on the thermal kinetic parameters extracted from isothermal decay experiments. However, the thermal kinetic parameters derived depend on the experimental conditions, and specifically on the number and range of isothermal temperatures used. Following King et al. (2016.a) [3] we measure isothermal decay following seven different isothermal holding temperatures between 170 and 350 °C, and fit the data with the band-tail states model [5]. To test the validity of this protocol, we use samples with independent thermal histories, together with synthetically developed known-thermal history samples and unknown-thermal history samples. We contrast the thermal kinetic parameters obtained from different combinations of isothermal holding data by inverting the data for steady-state temperature.

We find that inverted temperatures change, depending both on the number of isothermal temperatures and on the highest isothermal temperature used for thermal kinetic parameter derivation. Na-feldspar minerals are generally more sensitive to the inclusion of higher-temperature isothermal holding measurements than K-feldspar minerals. The samples analysed validate the MET-IRSL protocol for extracting thermal histories. However, the seven isothermal temperatures of King et al. (2016.a) [3] underestimate the temperatures of Na-feldspar minerals with well constrained thermal histories. We propose a more limited range of isothermal holding temperatures be used for appropriate thermal kinetic parameter derivation and luminescence thermochronometry results.

Keywords luminescence thermochronometry; kinetic parameters; isothermal holding experiments

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P.11-1: Direct dating of lithic surface artefacts using luminescence

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Archaeological surface assemblages composed of lithic scatters comprise a large proportion of the archaeological record. Dating such surface artifacts has remained inherently difficult owing to the dynamic nature of Earth-surface processes affecting these assemblages and because no satisfactory chronometric dating technique exists that can be directly applied to constrain the timing of artifact manufacture, discard, and thus human use of the landscape. Here, we present a dating approach based on optically stimulated luminescence (OSL)—OSL rock-surface burial dating—and apply it to a lithic surface scatter in Tibet. We show that artifacts can be effectively bleached by sunlight and generate OSL burial ages (age-depth profiles) for each artefact. The methodological complexities are outlined and the artifact burial ages are discussed in the context of local-scale Earth-surface dynamics. The oldest age cluster between 5.2 and 5.5 thousand years is likely related to quarrying activities at the site and thus represents the oldest chronometric age constraints for human presence on the south-central Tibetan plateau

Keywords Rock surface burial dating; OSL; direct dating; lithic artefact; artefact scatter.

P.11-2: Luminescence dating of an ancient circular stone walled enclosure complex at Sönneböe, northern Scania, Sweden: combined dating of coarse-grained sediment and rocks.

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During routine conservation works on an ancient circular stone walled enclosure complex at Sönneböe, northern Scania, Sweden, a decision was made to collect samples from its interior for radiometric dating. With no material suitable for radiocarbon dating, optically stimulated luminescence dating of sedimentary coarse grains, and surficial rock chips were used to determine the time of construction.

Dose recovery plateau experiments from the sedimentary quartz grains indicated that a 260/220°C preheat/cut-heat combination would give satisfactory results (DR ratio 1.033±0.009 n=90). IRSL signals measured at 50°C were recorded in the rocks to obtain L/T burial profiles, and these indicated prior light exposure in 6 of the samples (4 granite, 2 felsic gneiss). All six had apparently been exposed for sufficient time for us to be confident of obtaining accurate IRSL ages. IR_{50} fading corrections were undertaken by determining the field saturation, irradiating the same aliquots with a 2kGy dose in a ^{60}Co gamma cell, remeasuring the L/T ratio and finally comparing this with the original data. The resulting fading corrections were typically ~30%. Post-IR $IRSL_{180}$ signals were also measured in the rock samples. The measurements were unsuccessful, with profiles from opposite surfaces on each rock indicating that any bleaching front was very shallow, and the signal was not sufficiently reset to allow accurate determination of D_e on any of these rocks.

In total 12 ages were considered acceptable; 6 quartz OSL ages from disturbed coarse grained sediments surrounding the structure, and 6 fading corrected IR_{50} ages from rocks (2-3mm chips) used in the construction of the structure itself. In all of the sedimentary coarse-grained samples, both the post-IR IRSL and IR_{50} signals over-estimated the quartz age. Preliminary OSL data from coarse-grained sediments sampled beneath two large foundation stones indicate that wall construction took place ~0.7ka; good agreement between the fading-corrected IR_{50} ages from rock derived K-rich feldspar and the sedimentary quartz OSL further supports a ~0.7ka age for this structure.

Keywords: Rock surface dating; L/T burial profiles; granite; fading correction; Sweden.

Session 12:
Novel applications of luminescence and ESR: Part 2

Oral Presentations

	Presenter	Title
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2	Pavao Andričević	Light Propagation in Cracks: Insight from Luminescence
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Poster Presentations

	Presenter	Title
2	April Phinney	Heated Up: Assessment of Historic and Recent Wildfire Intensities on the Kaibab Plateau, Arizona, USA
3	Ian del Rio	Exploring the potential of TL signals from K-feldspar to estimate subsidence rates in the Amazon Basin
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6	Jiao Li	The Variation of Quartz Optically Stimulated Luminescence Sensitivity in Xifeng Section of Chinese Loess Plateau Since the Last Interglacial

O.12-1: Developing a new brittle fault slip paleothermometer using quartz luminescence

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Quantifying coseismic temperature rise from exhumed brittle faults can identify past seismicity, with implications for modern seismic hazards. This study aims to develop and test a new fault slip paleotemperature proxy using quartz luminescence techniques to identify thermal signatures associated with deformation in natural fault rocks. We are applying quartz luminescence to the seismically active Hurricane fault, Utah, USA, locally characterized by >10 m^2 silica and iron-oxide-rich fault mirrors (FM) that cut the Rock Canyon Conglomerate of the Moenkopi Formation. Scanning electron microscope microtextural analysis and hematite (U-Th)/He thermochronometry from these FMs suggest mechanical and hydrothermal processes accompany up dip propagation of earthquake ruptures at ~300 m depth ~0.65-0.4 Ma [1]. Two FM samples, one exposed to sunlight (light sample) and one never exposed to light (dark sample), were cut in the dark using a slow speed saw to isolate quartz in thin (~2 mm) slabs parallel to the slip surface. Quartz natural luminescence and equivalent dose from the light exposed FM yield depth patterns consistent with a sunlight bleaching profile. These data are modelled using the mathematical equation for light bleaching as a function of depth in rocks [2] and compared to bleaching profiles from the Navajo sandstone [3]. This comparison will help determine if the depth profile trends are consistent with only sunlight bleaching and/or other fault related processes, as well as to constrain surface exposure ages. Data from the dark sample do not exhibit a sunlight bleaching profile but have internal variations in the natural luminescence and equivalent dose that may be related to fault slip thermal processes. We compare the light and dark sample results to evaluate if signatures of coseismic temperature rise and/or hydrothermal fluids can be detected. Our preliminary data suggests that quartz luminescence in fault rocks may be a viable approach to recovering qualitative and quantitative information on coseismic temperature rise with potential to directly date past seismicity. However, more data and determination of sample specific physical parameters are necessary and will be the goal of future work.

Keywords quartz luminescence; brittle faults; paleothermometry; earthquakes

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O.12-2: Light Propagation in Cracks: Insight from Luminescence

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Cracks play an important role in landscape evolution by providing conduits for chemical weathering and making rocks susceptible to erosion. The mechanisms behind the formation of cracks, particularly in surface and near-surface rocks have been debated for almost a century [1]. This lack of consensus is attributable, in part, to our inability to reliably establish exact fracture chronologies with current available dating techniques. Documenting the temporal evolution of the initiation and propagation of fractures would allow us to directly link factors like changing climates to periods of crack acceleration or stabilization, thus increasing our understanding of crack evolution overall.

Optically stimulated luminescence (OSL) dating is a widely used and well-established tool for dating sediments. Recently, a complementary method called luminescence rock surface dating (RSD) has been developed to estimate the exposure age, burial age and hard-rock erosion rates. However, in order to apply this technique to establish the chronology of cracks (i.e. the time of initiation), it is important to understand how luminescence bleaching occurs inside a crack. This in turn requires an understanding of how light flux attenuates and illumination geometry varies within a crack. These aspects are to the best of our knowledge not known currently.

To address this problem, we designed an experiment using rock cores cut perpendicular to the surface, to emulate the appearance of cracks. The cores were first heated to remove all naturally trapped charges and subsequently given 5 Gy gamma irradiation to create a homogeneous distribution of trapped charges in the entire core. The pairs of half's were then positioned next to each other with varying gaps of 0.05, 0.3 or 1 mm. Lastly, the samples were encapsulated on the sides, allowing only the top surface to be exposed under a solar simulator. To estimate the amount of light, which will propagate into the crack, we used the infrared photoluminescence (IRPL) technique [2]. This method allows us to take 2D IRPL images of the complete crack inner surface and study their bleaching profiles. Furthermore, as this is a non-destructive imaging technique we are able to track the progression of the bleaching front over a period of 10 days or more. Subsequently, from the bleaching rate both in the direction of the crack as well as in the plane perpendicular to the crack surface and the top surface, we estimate the distribution of light flux in the crack. We then discuss the implications of these data for adapting luminescence exposure dating models to obtain absolute fracture chronologies.

Keywords Optically stimulated luminescence; Rock surface dating; Infrared photoluminescence; Light propagation in cracks; Crack width

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O.12-6: Constraining past bedrock surface temperatures in the Western Alps using feldspar thermoluminescence paleothermometry.

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Our ability to quantify past climate conditions is useful for predicting future climate scenarios. Few methods capable of directly measuring past temperature histories exist, particularly in terrestrial settings, and most reconstructions of Earth's past climate have relied on the use of climate proxies (e.g. [1] for a review). Here, feldspar thermoluminescence (TL) surface paleothermometry [2], [3] is applied to exposed bedrock in the Alps.

The thermal history experienced by a rock surface can be calculated by exploiting the dynamic equilibrium between trapped-charge growth and decay [3]. For feldspar TL surface paleothermometry, five thermometers (200 °C - 250 °C in 10 °C) shown to be sensitive to typical surface temperature variations (e.g. ~10°C) are targeted from the TL glow curve [3]. These give thermometers are used together as a multi-thermometer, and subsequently combined with a Bayesian inversion approach to constrain thermal histories over the last ~50 kyr [3].

In this study, the temperature histories of bedrock samples collected down two vertical transects in the Western Alps and exposed progressively since the Last Glacial Maximum will be presented. The aim is to develop our understanding of surface temperature fluctuations across the Central and Western Alps, from the Last Glacial Maximum to the present day. Preliminary results are promising and in agreement with past surface temperatures obtained from other studies.

Keywords Feldspar; Paleothermometry; European Alps; Bedrock samples.

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P.12-2: Heated Up: Assessment of Historic and Recent Wildfire Intensities on the Kaibab Plateau, Arizona, USA

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Wildland fires are increasing in area, frequency, seasonal distribution, severity, and human impact. Such wholistic shift in fire behaviour appears to be driven by climate change and management practices [1]. A century of fire suppression may have allowed dead material, understory vegetation, and medium-height trees to accumulate. These fuels easily ignite, burn at high intensities, and serve as bridge between ground fires and stand-replacing crown-fires [2]. This research investigates the apparent tie between fuel accumulation and recent extreme fire behaviour by using luminescence resetting of rock, 110C TL luminescence sensitivity change, rock-color alteration, and charcoal reflectance to measure modern and pre-suppression fire intensities in northern Arizona, USA.

In June 2020 the Mangum Fire ignited the Ponderosa pine forest of the Kaibab Plateau Arizona, on the north rim of the Grand Canyon, consuming 71k acres. This high-severity stand-replacing fire is characteristic of the modern fire regime. My research tests the hypothesis that the Mangum Fire burned at greater intensities than nearby pre-suppression fires (> 1900 AD). If this is true, the increased intensity of the Mangum fire may be caused by accumulated fuels from forest management practices.

The intensity of the Mangum Fire and older pre-suppression fires (> 1900 AD) are assessed using corresponding samples of surface rocks, soil cores, and surface charcoal (5 samples/site). Methods include: 1. Optically Simulated Luminescence (OSL) of internal quartz grains (0.5-1cm depth) from fire-exposed surface rocks will be measured to test for thermal resetting; rocks heated to >500C are expected to produce anomalously young internal OSL ages [3]. 2. Surface soil samples will be tested for changes in luminescence sensitivity (brightness) following exposure to heat (thermal activation characteristics, TAC); The ratio of 110C TL signal sensitivity change is expected to increase at the temperature of previous heat exposure for temperatures >200-500C [4]. 3. Rock color thermally alters when exposed to fire; temperature-color relationships will be calibrated using native rocks from outside the burn area that are systematically heated in a muffle furnace. 4. The optical reflectance of surface charcoal has been shown to be proportional to the temperature and duration of past fire intensity; microscopic % reflective grains from each fire will be assessed [5]. Preliminary OSL apparent age, 100C TL sensitivity, rock-alternation color, and charcoal reflectance results will be presented.

Keywords Fire; fire intensity; temperature; luminescence sensitivity.

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P.12-3: Exploring the potential of TL signals from K-feldspar to estimate subsidence rates in the Amazon Basin

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Luminescence thermochronology is an emerging field, with promising demonstrations in areas with the highest exhumation rates on Earth, such as the New Zealand Alps, the Himalaya, and the Japanese Alps [1]. Since thermoluminescence (TL) signals from potassium feldspar are sensitive to small temperature variations [2], they can potentially be used for subsidence rate estimation. However, there are no studies about the suitability of this method to assess subsidence in sedimentary basins as yet. We present preliminary results for samples extracted from a drill core that spans the Late Cretaceous and Cenozoic succession of the Amazon Basin, Brazil. The drill core was retrieved near the confluence between the Amazon and Madeira Rivers and currently is being analysed through different techniques which will provide information about the geological history of the area. Three samples (L1483, L1484 and L1485, respectively collected at 100, 200 and 400 m below the sediment surface, modern geothermal gradient of ~20-30 °C/km) were analysed following a single-aliquot regenerative (SAR) dose measurement protocol using TL signals measured at a heating rate of 5 °C/s on potassium feldspar grains (180-250 μm). TL glow curves were integrated in steps of 10 °C in the region between 220 and 320 °C to evaluate fading rates and model parameters such as activation energy and frequency factor. Natural TL signals are below the saturation level at laboratory dose rates. The temperature corresponding to the half of TL peak intensity ($T_{1/2}$) increase with increased depth, being located at 288, 282 and 304 °C for samples L1483 (100 m), L1484 (200 m) and L1485 (400 m), respectively. Equivalent doses have a plateau around 320 for sample L1484 and 500 Gy for samples L1483 and L1485 for TL emission between 220 and 270 °C, after which doses start decreasing down to 100-150 Gy at 320 °C TL. Characteristic dose values vary between 1500 and 900 Gy for TL from 220 to 320 °C, respectively. Fading rates varied from 7.1-4.8 %/decade at 220 °C to 3.8-2.5 %/decade at 320 °C. Fading rates increase with increased depth consistently throughout the studied temperature intervals. Though the equivalent doses suggest that samples are at equilibrium, the natural TL glow curve shape (peak position and intensity) show an apparent thermal erosion between samples from which the storage time at a certain burial temperature could be recovered.

Keywords
Low temperature thermochronology; Amazon Basin; Potassium feldspar; Thermoluminescence

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P.12-4: Assessing changes in northeastern South American hydroclimate during Termination II through OSL and TL sensitivities

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The Atlantic meridional overturning circulation (AMOC) plays a fundamental role in global climate, in particular in the climate of the continents surrounding the Atlantic Ocean. A potential future slowdown of the AMOC would cause major changes in surface heat distribution in the Atlantic Ocean, strongly affecting tropical South American hydroclimate, similarly to past abrupt climate change events.

Northeastern (NE) South America is a climate change hot spot hosting both the Caatinga and the Cerrado biomes in a high seasonality and low precipitation belt that separates the Amazon and Atlantic rainforests. Thus, a comprehensive understanding of NE South American responses to changes in AMOC strength on different time scales is a key issue. Glacial-to-interglacial transitions (or terminations) are unique targets for past climate reconstructions since they were marked by major shifts in the strength of the AMOC. For Termination I, Mendes et al. (2019) [1] successfully used the optically stimulated luminescence (OSL) and thermoluminescence (TL) sensitivities from polymineral silt deposited off NE South America to reconstruct past fluvial discharge and continental precipitation changes. The authors have suggested that NE South America precipitation was affected by changes in the AMOC.

Here we assess changes in NE South American hydroclimate during Termination II by investigating marine sediment core CDH-89, collected off NE South America. For this core, we analyse luminescence signals of quartz and feldspar (i.e., OSL, TL and infrared stimulated luminescence). Silt-clay samples were freeze-dried, weighted to 0.5 g, treated with H_2O_2 27% and HCl 10% to remove organic matter and carbonate ($CaCO_3$). Luminescence sensitivity calculation is based on the intensity of emitted light per unit of radiation dose and mass obtained as the mean of three aliquots per sample. Measurements were performed on an automated Risø DA-20 TL/OSL reader with built-in $^{90}Sr/^{90}Y$ beta source (dose rate of 0.079 Gy/s), blue light-emitting diodes (470 nm), and infrared light-emitting diodes (870 nm) for stimulation and light detection in the ultraviolet band using Hoya U-340 filters (290–370 nm), at the Luminescence and Gamma Spectrometry Laboratory of the Institute of Geosciences, University of São Paulo, Brazil. Finally, the results are compared to X-ray fluorescence elemental ratios (e.g. Ti/Ca and Fe/Ca), a worldwide well-established precipitation proxy, obtained from the same marine sediment core.

Keywords Atlantic meridional overturning circulation; penultimate glacial-to-interglacial transition; northeastern South America; quartz luminescence sensitivity; past precipitation

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P.12-6: The Variation of Quartz Optically Stimulated Luminescence Sensitivity in Xifeng Section of Chinese Loess Plateau Since the Last Interglacial

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In this study, the changes of optically stimulated luminescence sensitivity (OSLS) of different particle sizes of quartz in S0, L1 and S1 layer since the last interglacial in the Xifeng section of the Chinese Loess Plateau were studied. By comparing the variation of OSLS of Jingyuan section and Luochuan section in the same layer, the change mechanism of this index was discussed, and the following preliminary understanding was obtained:

(1) In the time series, the variation of OSLS in each layer of the Xifeng section is largely correlated with the magnetic susceptibility, and its gap between maximum and minimum is about 6 times. The fast, medium and slow components of the samples were decomposed, and it was found that the fast components of the palaeosol with high sensitivity which accounted for more than 90%, and the differences among the samples were small. In contrast, for loess with low sensitivity, the ratio of fast components varies greatly, and the difference between samples is large.

(2) Compared with the same section of Luochuan loess section in the east of Liupan Mountain, it is found that OSLS in Luochuan section is higher than that in Xifeng section, while OSLS is correlated with magnetic susceptibility. Moreover, the difference of paleosol between the two section (about 7 times) is much larger than that of loess (about 2 times). Compared with the Jingyuan section in the west of Liupan Mountain, the OSLS of loess-palaeosol sequence in Luochuan and Xifeng sections is similar to that in loess-soil layer, that is, the OSLS of loess-palaeosol sequence did not change significantly during glacial to interglacial periods.

(3) Based on the rule of loess deposition changing with glacial-interglacial OSLS, the change mechanism of loess deposition is closely related to the change of climate and environment pattern during glacial-interglacial. Provenance changes, transport processes, and post-sedimentation wildfire may affect loess-palaeosol sequence OSLS in the Chinese Loess Plateau.

Key words: Quartz; Optically Stimulated Luminescence Sensitivity; Chinese Loess Plateau; Glacial-Interglacial

Ancient TL

ISSN 2693-0935

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