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Applications to Fluvial Sediments Grand Wash/Grand Canyon

INTRODUCTION

By Shannon Mahan

Optically stimulated luminescence (OSL) is one of a class of measurements known as stimulated phenomena. Such phenomena may be stimulated thermally or optically and the reader is referred to works by Aitken (1998) and Botter-Jensen and others (2003) for more detail. In recent years OSL has become a popular procedure for the determination of environmental radiation doses absorbed by archeological and geological materials in an attempt to date these materials. The first OSL measurements on quartz and feldspar were made using an argon ion-laser (Huntley et al., 1985). However, the development of cheaper stimulation systems based first on filtered lamps and then on light-emitting diodes (LEDs) (Spooner, et al., 1990; Botter-Jensen, and others, 1999) has led to a massive expansion in OSL dating applications. The abstracts in this volume represent presentations from a workshop held in May-June 2006, at the Denver Federal Center, Denver, Colorado, in which OSL methodologies and applications were summarized and integrated to provide a current synthesis of the OSL science being applied throughout North America.

The workshop, sponsored by the U.S. Geological Survey Crustal Imaging and Characterization Team and North Dakota State University, was open to all scientists interested in OSL dating techniques and radiation dosimetry. Participants included thirty-six research scientists and students in geology, archaeology, and physics from the U.S. Geological Survey, Los Alamos National Labs, Kentucky Geological Survey, eight universities in the United States, one university in Canada, one university in India, and Riso National Labs of Denmark.

The workshop included two keynote speakers: Dr. Ashok Singhvi (Physical Research Laboratory, Ahmedabad, India) spoke on “Some Unexplored Methodological Aspects and Some New Applications of Luminescence Dating”**,** while Dr. Jim Feathers (University of Seattle, WA) spoke on OSL Dating of Sediments From Paleoindian Sites in Brazil”**.** The workshop encouraged everyone to interact more to develop a broader perspective on the types of research and the problems encountered when reporting OSL ages. This meeting follows the first North American Luminescence Dating Workshop held in Tulsa, OK, by Oklahoma State University (2001), in Albuquerque, NM, by Los Alamos National Labs (2002), and in Halifax, Nova Scotia, by Dalhousie University (2004, with a name change to New World Luminescence Dating Workshop). These workshops were interspersed with the international meetings on luminescence that were held in Reno, NV, (2002), and Cologne, Germany; (2005).

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Aug. 2003 23 abstracts/presenters
July 2004 23 abstracts/presenters
May/June 2006 22 abstracts/presenters

SOME UNEXPLORED METHODOLOGICAL ASPECTS AND SOME APPLICATIONS OF LUMINESCENCE DATING

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The presentation will deal with the methodological aspects and new applications of luminescence dating so as to provoke a discussion on some of these ideas. Some of the factors described below can be a potential source of systematic errors which have been overlooked, so far.

A. Methodological Aspects:

1. Natural Sensitivity Correction for SAR De Values

The SAR protocol is now used extensively and we have investigated two aspects of systematic errors within its application in some detail. The first one relates to the change in the sensitivity during the measurement of natural signal. Presently the sensitivity is tracked only after the measurement of natural signal and it is therefore not clear if the natural signal and regenerated signal are measured with the same sensitivity. Our measurements indicate that such changes in sensitivity can be up to 30% and hence can cause systematic errors of the same magnitude. We have been using a natural sensitivity correction factor (NCF) with good results.

2. The Standard Growth Curve in SAR

We also examined the concept of a Standard Growth Curve (SGC) on a large number of samples and found that samples which provide a regression coefficient of 0.9 in the SGC are likely to provide sensible SGC based De values. One point remains as to how the identification of samples with poor recycling ratios be identified apriori for samples where only the normalized natural is measured. While this needs to be investigated further, it appears that samples providing a reasonable regression value in their SGC are also the samples that are well behaved with respect to their recycling ratios.

3. Component Specific Paleodose

We examined the initial work on components of quartz BGSL. An effective deconvolution algorithm was developed and we applied this to the derive component of specific SAR ages. Initial studies indicate that the ages based only on the fast component provide a tighter distribution when compared to the conventional SAR ages. The application and implication of this for poorly bleached and/or feldspar contaminated samples, will be discussed.

4. Age determination using Single Grains

Possibilities for analyzing single grains brought hope for identifying the most bleached grains. However, it also brought back the difficulties in dosimetry that have been so far ignored. Most of the beta dose is provided by a few hotspots of K rich feldspar grains. At low K concentration, the distance between hotspots can be compared to a beta range that gives only the heterogeneity of the beta dose. This implies that the least De values can correspond both to the most bleached grains and to grains that see the lowest dose rate and perhaps the use of average dose rate in such cases may not be appropriate. This aspect has been investigated mathematically and some results and an analysis protocol will be presented

B. New Applications:

1. Direct and Indirect Dating of Gypsum using Luminescence and ESR

Chemical precipitates such as Gypsum, ($CaSO_4.2H_2O$) are climatic event markers indicating periods of desiccations. However, their dating was not possible with the conventional methods. We were successful in dating these deposits via the traces of quartz in them and the dating of gypsum itself with ESR. In addition, techniques such as XRD, Fourier transform infrared spectroscopy and Thermogravimetry helped development of methodologies to date gypsum samples as well as to deduce information on their formation pathways. Successful applications have been obtained at White Sands, New Mexico (USA), the Thar Desert and from Australian. The ESR ages match with stratigraphic controls provided by the sediment contexts overlying and underlying the gypsum beds.

2. Analysis of Tsunami Sands

Analysis of recent (2004) tsunami sands using component specific analysis of the BLSL of quartz indicated low paleodose values of 0.6 Gy, reaffirming the suggestion that OSL can be a potential method for the dating of paleo-tsunami deposits. Given the catastrophic nature of the event, such low values suggest that most of sediment was derived from the shelf region where daylight exposure during tidal reworking would have bleached the geological signal of the sands to a low value.

A THEORETICAL MODEL FOR A NEW DATING PROTOCOL FOR QUARTZ BASED ON THERMALLY TRANSFERRED OSL (TT-OSL).#V. Pagonis[1], A.G. Wintle[2], R. Chen[3], X.L. Wang[4]

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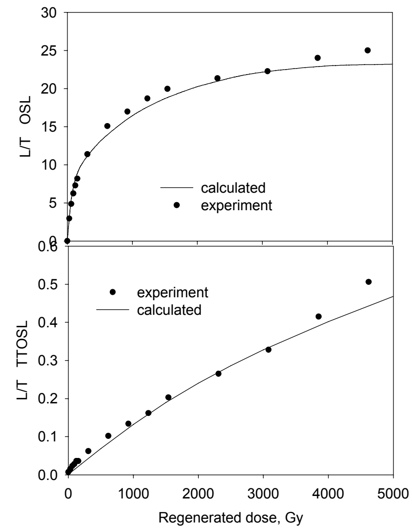
Introduction: Although the optically stimulated luminescence (OSL) signal in quartz has been established as the basis of an accurate and precise luminescence dating method [1], its use is limited by the saturation of the measured OSL signal. However, another OSL signal has been proposed as the basis of a new OSL dating procedure [2]. The newly-studied signal is the thermally-transferred OSL (TT-OSL) that is measured after irradiated quartz is optically bleached and then preheated [3]. Using the TT-OSL signal, the dating range for fine-grained quartz extracted from Chinese loess can be extended by almost an order of magnitude [2].

Wang et al. [2] used a TT-OSL signal obtained after a high temperature preheat (260°C for 10 s) following an optical bleach at 125°C for 270 s to deplete the fast and medium OSL components. They used the subsequent TT-OSL signal measured for 90 s at 125°C in order to avoid the effect of re-trapping of electrons in the 110°C trap. The luminescence sensitivity related to this TT-OSL measurement was determined by the OSL response to a subsequent test dose.

In this paper, we use the model of Bailey [4] to fit the experimental data for the OSL and TT-OSL signals that were obtained when using the protocol of Wang et al. [2], and we compare directly the experimental results with the results from the model.

The model: The original Bailey [4] model used in the present simulation consists of 5 electron traps and 4 hole centers. In terms of OSL-traps, the model contains traps for the fast and medium-OSL components of quartz (OSL_F and OSL_M), but does not contain traps for the slow-OSL components of quartz. The absence of these additional energy levels does not limit the applicability of the present model, since the phenomena described here involve exclusively the fast and medium OSL traps. The values of E and s for these traps were taken from the updated experimental data set of Singarayer and Bailey [5].

Results: The complete sequence of steps in the new TT-OSL protocol was simulated using the Bailey model with modified parameters, and the simulated normalized L/T dose response graphs for both conventional OSL and TT-OSL are shown in the figure, together with a set of experimental data for fine grain quartz from Chinese loess [3]. From these dose response curves, the advantage of using the TT-OSL signal for older samples can be seen.



Conclusion: The simulation presented here provides a mathematical description of the high temperature charge transfer processes taking place during the new TT-OSL protocol. By modifying the parameters in the original Bailey [4] model, it is possible to get a good quantitative agreement between the experimental and simulated OSL and TT-OSL dose response curves.

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EQUIVALENT DOSE DISTRIBUTIONS FROM MAAD DATA SETS. Kenneth Lepper[1] and Anne Denton[2]. [1]Department of Geosciences, North Dakota State University, 218 Stevens Hall, Fargo, ND, 58105 (ken.lepper@ndsu.edu); [2]Department of Computer Sciences, North Dakota State University, 258 IACC, Fargo, ND, 58105 (anne.denton@ndsu.edu).

Background: Over the past decade a great deal of attention and developmental effort has been focused on equipment, experimental procedures, and analytical tools for use with quartz sand. SAR data collection procedures and equivalent dose (D_e) distribution analysis, in particular, are increasing the accuracy and reproducibility of OSL ages as well as extending its utility to numerous depositional environments.

There are deposits, however, from which it is difficult to isolate clean quartz sand due to the mineralogy of the sediments or depositional constraints on the sediment grain size distribution. In these situations OSL dating has been carried out on poly-mineral fine silts (4-11 microns). The most widely utilized experimental procedures for data collection from fine-grained samples has been multi-aliquot additive dose, or MAAD. This method required data collection from numerous aliquots in order to calculate one age. Using conventional MAAD methods it was impractical to collect statistically meaningful D_e data sets. In cases where multiple ages were determined from one field sample, reproducibility was often poor.

Methods: In order to extend the remarkable advantages of dose distribution analysis to dating of fine-grained polymineral sediments, we have developed an analytical method for generating equivalent dose distributions from data collected by standard MAAD procedures.

Results: The fine-grained dose distributions obtained exhibit meaningful, interpretable shape characteristics and in many cases exhibit remarkable structural similarities to quartz sand distributions from the same fluvial sediment samples. This talk will present the conceptual framework for the analytical method, compare polymineral fine-grained D_e distributions with quartz sand D_e distributions obtained from the same field samples, as well as discuss the approach(s) for selecting a representative dose from the fine-grained distributions.

Conclusion: Dose distribution analysis has the same potential to improve age accuracy and reproducibility for polymineral fine silts as it has for quartz sand. We anticipate that an analytical method capable of generating dose distributions from conventional MAAD data, such as the one we have developed, can be applied retroactively to a wealth of existing data in the luminescence dating community and used to re-examine numerous data sets that have defied sensible interpretation without the benefit of dose distribution analysis.

REDUCTION OF UNCERTAINTIES IN THE MEASUREMENT OF EQUIVALENT DOSES AND ANOMALOUS FADING RATES IN IRSL DATING OF FELDSPAR. M. Lamothe and M. Auclair. Laboratoire de luminescence Lux, Département des sciences de la Terre et de l'atmosphère, Université du Québec à Montréal, PO 8888, Succ. Centre-Ville, Montréal, Québec, H3C 3P8, Canada. lamothe.michel@uqam.ca

Introduction: The application of the Single Aliquot regeneration (SAR) procedure for dating feldspar, as developed in the Montréal laboratory, is based on an elaborate sequence of laboratory measurements. These were described by Lamothe et al. at the first NALDW in Tulsa [1,2]. Our procedures have been recently improved and some of these developments are described below.

Equivalent dose: After preheating and optically stimulating the feldspar aliquots, an internal halogen ("white") light is now used for bleaching before each irradiation step. This procedure has a significant effect on the reduction of sensitivity changes. However, to limit thermal transfer, further thermal and optical IR stimulation steps are necessary to fully drain the dating trap, before the administration of the next radiation dose.

In order to increase the overall reproducibility in the equivalent dose measurements, we have carried out a systematic analysis of our procedures to identify the main sources of IRSL variability. The parameters that seem to generate the most variability are those affecting the reproducibility of the preheat temperature, as well as that of the heating rate. There is no critical variability in the "optical environment" (diodes, filter optics, PM stability, etc.). We also compared the variability of the sensitivity-corrected luminescence for homogeneous aliquots (mostly fine grains) between those preheated in the Risø and Daybreak readers, and others preheated in an external oven.

This investigation confirms that the thermal stability of the luminescence readers is a critical factor in the reproducibility of the natural luminescence intensity of feldspar. For example, using low heating rates in the order of 1°C/sec increases significantly the reproducibility of luminescence measurements. It is further found that, using 24 aliquots, one could determine the sensitivity-corrected natural luminescence within a standard deviation for the mean of less than 0.5 %, using an external oven for preheating.

Anomalous fading: The fading tests developed in our laboratory [3] require another large number of measurements. Several data points are needed to find a reliable fading rate value, and as each measurement carries a significant uncertainty, the error in the assessment of the *g* value could be relatively large for some heterogeneous material (i.e. 10-15%), and low precision corrected ages are commonly calculated. At each step, a similar bleach is introduced in the procedure to empty the traps not drained by the IR stimulation but that are sensitive to visible light. The occupancy of these non-IR sensitive traps is of consequence to the measured anomalous fading rate. Again, the thermal dependence of IRSL following preheating may generate unwanted scatter and a different procedure is being developed. Herein, the decay of luminescence is assessed by documenting the ratio SS/SD, from two luminescence measurements, a "prompt" short shine (SS) following preheating and a shine down (SD) after some time delay. This approach integrates method B of Huntley and Lamothe [4] and the SAR approach of Auclair and others [3].

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THE LUMINESCENCE EFFICIENCY OF COSMIC RADIATION AT THE SURFACE OF MARS AND IN THE MARTIAN REGOLITH – A STUDY WITH QUARTZ AND FELDSPAR.

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Introduction: Pictures taken by the Mars Orbiter Camera show that the surface of Mars has been, and continues to be, shaped by fluvial, eolian and glacial processes. To understand the planet's geomorphologic and climatic history we need information about the age of these events. In this context, efforts are being made to create a miniature dating device for in situ luminescence dating of Martian sediments [1]. A direct measure for the absorbed dose is the optically stimulated luminescence signal (OSL) from the minerals. However, the other necessary component for an in-situ luminescence dating device for Mars is the knowledge of the radiation environment on the surface of Mars and in the Martian regolith. The main source for the dose rate on Mars is galactic cosmic rays (GCR). Since the equivalent dose will be determined in relation to an X-ray or beta source in a robotic instrument, the relative efficiency of the GCR in producing OSL relative to the on-board radiation source needs to be determined. We present experiments with mineral mixtures that are used as Martian soil simulants, and irradiation with simulated cosmic rays.

Samples and Instrumentation: Experiments were carried out with quartz and various feldspar minerals. Furthermore we devised two mineral mixtures as surrogates for Martian sediments. The two mixtures are known as OSU-Mars-1 and OSU-Mars-2. The compositions (in vol. %) are described in the following table; further details can be found in [2].

	Mars 1	Mars 2
Andesine	22 %	15 %
Labradorite	22 %	15 %
Bytownite	22 %	15 %
Augite	15 %	5 %
Diopside	15 %	5 %
Hematite	5 %	5 %
Obsidian		40 %

Measurements were conducted using a Risø TL/OSL-DA-15 reader, Risø National Laboratory, with a bialkali PM tube (Thorn EMI 9635QB) and Hoya U-340 filters (290-370 nm). The built-in ^{90}Sr/^{90}Y beta source gives a dose rate of ~100 mGy/s. Optical stimulation was carried out with blue LEDs (470 nm), delivering 45 mW/cm^2 to the sample; IR stimulation was from an IR LED array at 875 ± 80 nm with 36 mW/cm^2 power at the sample. The heating rate used was 5 °C/s.

Experiments: The GCR spectrum consists of approximately 85 % protons, 12 % alpha particles and 1 % heavier nuclei, and about 2 % electrons and positrons [3]. Dose rates expected on the Martian surface (dependent upon altitude) are typically on the order of 200–300 mSv/year ([4]; ~80 mGy/year). At a depth of 700 g/cm^2, the dose rate is expected to be reduced to approximately 0.5 mGy/year [5].

The minerals described above were irradiated with a variety of heavy ion beams at HIMAC, Japan, and NSRL, Brookhaven. Among others, the minerals were irradiated with known doses of 1 GeV protons, 150 MeV/u He, 500 MeV/u and 200 MeV/u Fe. During the irradiations, small containers with the mineral mixtures were sandwiched between columns of Martian soil simulant of various thickness, simulating a variety of burial depths in the Martian regolith. As a reference, additional experiments were carried out with water instead of Martian regolith. The OSL signals induced by the single types of ions were measured and compared to ^{90}Sr beta irradiations to determine the luminescence efficiency of different types of radiation.

Results: The experiments indicate that there is a significantly lower efficiency for heavy charged particles compared to ^{90}Sr beta irradiations. With increasing ionization density, described by the linear energy transfer of a particle, more charge carriers are released in the same crystal volume. The limited number of crystal defects leads to an increasing number of instantaneous recombinations. The result is a smaller percentage of trapped charges and a lower luminescence signal for heavy charged particles when compared to beta radiation or X-rays. The experiments and results will be presented in detail.

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LOW TEMPERATURE EFFECTS ON THE OSL PROCESS OF MARTIAN SIMULANTS. M. W. Blair[1], R. Kalchgruber[2], E. G. Yukihara[2], and S. W. S. McKeever[2]. [1]Los Alamos National Laboratory, Earth and Environmental Sciences Division, EES 2 MS J495, Los Alamos, NM 87545 (e-mail:mblair@lanl.gov); [2]Oklahoma State University, Physics Department, 145 PS II, Stillwater, OK 74078.

Introduction: As the technology within the field of OSL dating continues to improve, the OSL technique is being applied in many new situations. Some new situations for OSL dating involve sediments from low temperature environments. Terrestrial sediments from ice cores [1] fall into this category, and the project to develop OSL dating for Martian studies [2] involves low temperature conditions as well.

The current work explores some of the effects that irradiation and/or stimulation temperature may have on expected Martian minerals. We investigated if stable temperature control is necessary for an in-situ instrument or if experiments can be conducted at ambient temperature.

Equipment and Samples: We use the low-temperature TL/OSL system developed at Oklahoma State University. The system can irradiate (with 35 keV X-rays), stimulate with a green laser (532 nm), and measure RL, TL, and OSL in the temperature range -150 to +200°C.

Two different Martian soil simulants, named OSU Mars-1 and OSU Mars-2, were used in this study. For a detailed description of these simulants see Kalchgruber et al. [3].

Methods: To measure the luminescence efficiency of the simulants, the RL of the sample was monitored under constant irradiation as the sample was cooled from room temperature to -100°C Optically-active traps with a peak temperature below room temperature were also identified. The samples were irradiated at –100°C with 10 Gy and heated to room temperature at a heating rate of approximately 0.3 ºC/s. The same procedure was repeated with a laser bleach for 300 s at –125 ºC after irradiation. The effect of varying the irradiation and stimulation temperature was studied as well. First, irradiations were performed at various temperatures while the stimulation temperature was held constant (25°C). Then, the irradiation temperature was held constant (25°C) while the stimulation temperature was varied. Finally, the irradiation and measurements temperatures were varied simultaneously. The final set of experiments tested recovering a known dose under various conditions. The temperatures for known dose irradiation, regeneration dose irradiation, and stimulation were all varied as outlined in Table 1. The dose ratio (recovered/given) for both simulants was also calculated.

Results: Both simulants showed changes in RL over the studied temperature range. The increases could be a result of thermal quenching or the presence of multiple recombination centers. Both soil simulants show an optically-active peak near -30°C, and OSU Mars-1 shows an additional peak near 20°C. However, none of the traps were completely bleached by optical wavelengths. Variation of the stimulation and irradiation temperatures affected the simulants in different ways, but competition effects induced by the low temperature traps seem to be the dominant effect.

The known dose could be effectively recovered under various circumstances as detailed in Table 1.

Table 1. Results of dose recovery experiments.

Known Dose T (°C)	**Reg. Dose T (°C)**	**OSL T (°C)**	**Dose Ratio OSU Mars-1**	**Dose Ratio OSU Mars-2**
25	25	25	1.01±0.25	1.02±0.14
-100	-100	-100	1.07±0.77	0.98±0.11
-100	25	25	1.01±0.04	0.94±0.32
25	-100	-100	0.33±0.64	0.26±0.01
-100* -50 25	-100	-100	0.60±0.09	0.39±0.15
-100* -50 25	25	25	0.95±0.52	1.04±0.28

*1.7 Gy delivered at each temperature

Conclusions: Stable temperature control is necessary for a robotic OSL dating instrument deployed to Mars. First, the irradiation and stimulation temperatures need to be controlled. Also, the influence of low temperature traps needs to be considered in the luminescence process and appropriate heating procedures must be developed. Finally, the stimulation temperature used in the dose recovery process needs to be at least as high as the highest temperature experienced during natural irradiation.

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USING LOW INTENSITY BLUE LIGHT TO STIMULATE HIGH-AND MID-LATITUDE WATERLAIN SEDIMENTS. J. Pierson[1], S. L. Forman[1], and J. Gomez[1]. [1] University of Illinois at Chicago, Department of Earth and Environmental Sciences (M/C 186), 845 West Taylor Street, Chicago, Illinois 60607-7059 [1] (jpierson@uic.edu).

Introduction: An accurate assessment of paleodose is necessary to generate a credible age estimate in luminescence dating studies. This is particularly difficult to achieve for sediments with a trapped electron population that is not fully diminished with sunlight exposure upon deposition. Preferentially accessing the "fast component", the luminescence derived from highly photosensitive and thermally stable traps, would yield a credible chronometer for sediments that are partially solar reset. For quartz, one of the most photosensitive components is related to the 325°C TL peak, suggesting that its parent traps are thermally stable over geologic time

scales (lifetime >3 x 10^7 years at 20°C) [1], [2]. These same traps have been shown to be extremely photosensitive, resetting in ~10 seconds when exposed to high-intensity (~25 mW/cm^2) blue light (470 ± 20nm) [3], making them preferred targets for luminescence dating.

Separating the fast component from the rest of the luminescence signal has been achieved by using curve-fitting techniques to deconvolute the OSL signal *e.g.* [2], [4]. Unfortunately this approach is impractical for luminescence dating because of the long stimulation times needed for peak resolution and the inability of the fitting algorithm to distinguish between nearly coincidental components. Isolation of the fast component has been attempted experimentally in other recent studies by using intense (115-230 mW/cm^2) infrared (830 ± 10nm) laser light to stimulate sediments at temperatures between 100°C and 200°C [5], [6]. However the long stimulation times (>1500 seconds) needed to reduce the fast component at elevated temperatures also makes this approach impractical for luminescence dating studies.

Proposal: We suggest using a blended approach to isolate the fast component of the quartz signal using low intensity blue (470 ± 20nm) photo-stimulation. The traps responsible for the fast component are more sensitive to blue light, requiring less intense illumination to produce a measurable luminescence signal. The emissions from the mixed-signal, continuous-wavelength OSL (CW-OSL) curves, commonly used for dating, are spread over an extended time period by decreasing photo-stimulation intensity and thus increasing resolution. Any significant excess in the luminescence intensity attributable to the less photosensitive components would be reflected in the CW-OSL decay curve shape. As a result, processes that could create these excesses, such as incomplete optical bleaching, can be monitored and compensated for analytically, given an appropriate model. An examination of the differences between the CW-OSL decay curves generated from natural, unaltered sample portions and those generated from laboratory irradiated aliquots, after complete optical bleaching, provides the basis for this model. Laboratory experiments designed to test the veracity of the proposed model suggest that this approach could successfully compensate for residual luminescence in sediments with as little as 10 seconds of sunlight exposure with deposition. Optical ages based on these model calculations for quartz extracts from poorly solar reset sediments are consistent with known depositional ages. Successful application is limited to sediments that retain no electrons within the most photosensitive traps at burial, with natural CW-OSL decay curves that exhibit sufficient component resolution and can be adequately described by the proposed model.

Our presentation will feature the description and application of the proposed model, including results from supporting laboratory experiments and conditions under which this approach is valid.

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MEASURING FELDSPARS OSL IN A HELIUM ATMOSPHERE: POTENTIAL FOR IMPROVED REPRODUCIBILITY Sébastien Huot and Andrew S. Murray, Nordic Laboratory for Luminescence Dating, Department of Earth Sciences, Aarhus University, Risø National Laboratory, DK-4000 Roskilde, Denmark. sebastien.huot@risoe.dk and andrew.murray@risoe.dk

Introduction: Anomalous fading hampers accurate luminescence dating with feldspars by introducing a significant source of systematic error. It also acts as a substantial source of uncertainty in the age calculation, even if a correction model is applied. The level of instrumental measurement reproducibility provides a lower limit to the achievable precision. It is suggested here that poor thermal reproducibility during heat treatment stages is a major source of dispersion in the subsequent OSL, thus reducing the precision of any fading measurements based on these signals.

Methods: Analysis was performed on coarse K-feldspars grains, separated with a heavy liquid solution (< 2.58 g/cm^3) and etched with 10% HF and mounted on stainless steel disk. Optical measurements were performed with infrared LEDs and detected with a combination of BG39 & 7-59. Heat treatments of 250ºC/60s were identical for both dose and test dose [1,2,3,4], and were undertaken in a Risø TL/OSL DA-15 reader, either in a nitrogen or helium atmosphere. Fading measurements followed the procedure recommended by Auclair et al. [2], with a preheat performed before storage. Results are presented for samples collected from various locations (Russia, Portugal, Taiwan, Denmark).

Observations: A simple superposition of glow curves recorded during preheating can show significant variability in the position of the peak maximum. Peak shift is especially pronounced during the first heating although it is also observed after delayed measurements. We find that what looks like an outlier OSL measurement often corresponds to an unusual preheat glow curve.

Prompts luminescence measurements, where the OSL is measured immediately after a dose – preheat sequence, may show very good reproducibility, of the order of 0.5 – 1.0 % RSD. The reproducibility of delayed luminescence measurements (where the OSL is measured after a significant delay after a dose – preheat sequence) is often worse. For example, in sample H22546 (Russia), we observed a good reproducibility for the prompt measurements, averaging at 0.41 % RSD (σ = 0.09, n = 12 aliquots). The reproducibility is worse the delayed measurements (90 hours), with a RSD of 2.6 % (σ = 1.6, n = 12 aliquots).

Steps can be taken to improve the thermal reproducibility. For instance, reducing the heating rate should reduce the thermal lag between the heating plate and the grains. A longer duration of preheat should help to minimize variations in thermal contact. We have found that the most significant improvement is achieved by replacing the gas atmosphere in the sample chamber with helium, rather than the more usual nitrogen. Helium has a thermal conductivity [151 mW/(m·K)] that is 6x greater than nitrogen [26 mW/(m·K)]. It is known that essentially all the energy transfer from the heater plate to the sample disc takes place through the surrounding gas atmosphere (very large thermal lag is observed under vacuum) [5]. Hence, using a gas with a higher thermal conductivity helps reduce the thermal lag [6]. We have been able to observe significantly lower RSD from delayed measurements when heating is performed in helium (0.6 %), compared to a nitrogen atmosphere (2.6 %).

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THE SAND RIDGES OF CURRITUCK COUNTY, NORTHEASTERN NORTH CAROLINA. Burdette, K.[1], Mallinson, D.[2], Brook, G.[3], Mahan, S.[4]. [1]Department of Geology, University of Delaware, Newark, De 19716 (keburd@udel.edu); [2]Department of Geology, East Carolina University, Greenville, NC 27858; [3]Department of Geography, University of Georgia, Athens, Ga 30602 (gabrook@uga.edu); [4]U.S. Geological Survey, MS 974, Box 25046, Federal Center, Denver, Co 80225 (smahan@usgs.gov).

Introduction: The depositional characteristics and ages of two sand ridges in southern Currituck County on the North Carolina coastal plain of the U.S. mid-Atlantic continental margin were investigated. Optically stimulated luminescence (OSL) ages show that the Land of Promise Ridge was deposited between 65.3 ± 10.2 and 59.7 ± 10.2 ka, and the Powells Point Ridge between 54.9 ± 6.3 and 43.2 ± 7.9 ka. Three OSL ages indicate dune reactivation before and after the onset of the Last Glacial Maximum Sampling: Sandy depositional strata were chosen for sampling based on sharp, well-defined discontinuities indicative of (i) a change in transport processes, and (ii) a lack of post-deposition bioturbation. The samples were collected at the "top, middle, and bottom" of each sandy unit**.**

Methods: Thirteen samples were analyzed at the University of Georgia (UGA) Luminescence Dating Laboratory and three duplicate samples were analyzed at the United States Geological Survey (USGS) Luminescence Dating Laboratory in Denver, Colorado using the single-aliquot regenerative dose (SAR) protocol.

At the UGA lab, dose rate calculations relied on the thick source ZnS (Ag) alpha counting technique for U and Th. Potassium was measured by ICP90 using the Sodium Peroxide Fusion technique at the SGS Lab in Toronto, Canada. In the USGS lab, the bulk samples were counted on a high-level resolution gamma ray spectrometer for measurements of U, Th, and K. These measurements were checked with Instrumental Neutron Activation Analyses (INAA) obtained from Jim Budahn at the USGS TRIGA reactor.

Results/Conclusions: Importantly the UGA luminescence ages increase with depth at all four sites if age uncertainties are taken into account. The same applies to the USGS age data set. However, the ages from the two laboratories do differ but not outside of the uncertainties of the determinations.

The OSL ages cluster in marine isotope stage (MIS) 3 of the Taylor Dome $\delta^{18}O$ ice core record [4] (Table 1). However, the age distribution, with 8 ages lying between ca. 40-55 ka, and 7 between 40-51 ka, suggests a major ridge formation episode centered at 40-50 ka, approximately coinciding with the warmest interval of climate during MIS 3 in the Taylor Dome record at ca. 47 ka. This major phase of ridge formation was apparently followed later by dune reactivation from ~29- to ~10 ka, with ages constrained by TCK-13 and TCK-4, which were collected above paleosols.

Table 1. Luminescence Ages from Currituck Co.

Sample	**Expected Age**	**Age (ka)**
Lane Pit		
TCK-1	**MIS 5a**	**65.3±10.2**
TCK-2	**MIS 5a**	**59.6±10.2**
		54.26±6.73*
TCK-3	**MIS 5a**	**81.8±8.8**
#330 Bluff		
TCK-4	**Early Holocene**	**12.5±2.7**
TCK-5	**Early Holocene**	**48.2±9.2**
		26.37±2.32*
TCK-6	**Early Holocene**	**51.7±7.8**
		41.92±4.02*
TR Equipment Pit		
TCK-7	**MIS 5a**	**28.2±6.2**
TCK-8	**MIS 5a**	**43.2±7.9**
TCK-9	**MIS 5a**	**45.2±5.6**
Green Acres Pit		
TCK-13	**Early Holocene**	**33.7±4.6**
TCK-11	**Early Holocene**	**48.8±6.2**
TCK-12	**Early Holocene**	**50.6±7.3**
TCK-10	**Early Holocene**	**54.9±6.3**
***-indicate ages analysed by the USGS lab**		

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OPTICALLY STIMULATED LUMINESCENCE AGES OF MARINE ISOTOPE STAGE 5, 3 AND 1 COASTAL LITHOSOMES: NORTH CAROLINA, USA.

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Introduction: The ridges, scarps, and associated coastal and nearshore depositional units along the passive margin coastal plain of the eastern U.S. have been a subject of study and debate for decades. It is apparent that these siliciclastic deposits are coastal features formed in response to sea-level highstands. The ridges and scarps have previously been defined as paleoshorelines based on their geomorphological and geological characteristics. As such, they can potentially provide important data points for Pleistocene sea level curves, and improve the understanding of global ice volume changes, paleoclimate, and glacio-hydro-isostasy during the Pleistocene.

Sampling: Samples for OSL analyses were acquired from exposures in borrow pits in the case of the Hickory Scarp, or from natural cut banks in the case of the Suffolk Scarp, and one location on Powell's Point Ridge. In the case of the Kitty Hawk beach ridges, a 0.8 m deep pit was dug into the flank of each sampled beach ridge. Samples were obtained by scraping away ~10 cm of soil and hammering a 6.35-cm diameter black opaque PVC tube horizontally into the pit wall. The sediment cylinder recovered was capped and wrapped with black plastic for transport. Additional sediment was collected from inside the core hole for moisture and dose rate determinations. Samples were double sealed in airtight bags to prevent loss of moisture.

Thirteen samples were analyzed at the University of Georgia (UGA) Luminescence Dating Laboratory. OSL analysis was carried out in subdued red-light conditions. Three duplicate samples were dated at the USGS Luminescence dating Laboratory in Denver, CO under sodium vapor low-intensity light conditions. Samples were analyzed using Duller's ANALYST PROGRAM [1].

Results and discussion: Newly acquired optically-stimulated luminescence (OSL) ages using quartz from a variety of coastal features on the North Carolina coastal plain provide age control for paleoshoreline formation and relative sea level position during the late Pleistocene. Two samples from the Suffolk Scarp, and one sample from the adjacent shelf deposits of the Norfolk Formation yield dates corresponding to Marine Isotope Stage 5A (OSL ages of 81.8 ± 8.8 to 68.6 ± 7.2 ka). Features east of the Suffolk Scarp/Ridge, including Dillon's Ridge, Hickory Scarp, the Currituck Ridges, and Roanoke Island yield ages corresponding to MIS 3, and may correlate to highstands associated with Dansgaard-Oeschger cycles [2-4]. The Kitty Hawk beach ridges, on the modern Outer Banks, yield ages of ca. 3 to 2 ka.

Conclusions: OSL ages are consistent with many previously reported U-series and AAR ages. The SPECMAP oxygen-isotope curve and GISP2 ice core data are used to place these deposits in the context of global climate and sea level change. The occurrence of the MIS 3 shorelines suggests either that glacio-isostatic uplift of the study area is large (>30 m), or MIS 3 sea level was significantly higher than recorded by coral reef terraces, or some combination of those two factors. The age of the Kitty Hawk beach ridges places the Holocene (MIS 1) shoreline well west of its present location at ca. 3 ka.

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LUMINESCENCE DATING OF PALEOLIQUIFACTION FEATURES IN THE WABASH RIVER VALLEY AREA OF INDIANA Shannon A. Mahan, U.S. Geological Survey, MS 974, Denver Federal Center, Denver, CO 80225, smahan@usgs.gov, and Anthony J. Crone, U.S. Geological Survey, MS 966, Denver, CO 80225. crone@usgs.gov

Introduction: In the winter of 1811-1812, the central Mississippi Valley was sparsely populated and contained few man-made structures, and as a result, the great New Madrid earthquakes (M 7.5-8) caused minimal damage. These earthquakes stimulated seismic hazard studies throughout the central U.S., which eventually led to the discovery of large sand blows caused by liquefaction that occurred during prehistoric earthquakes in the lower Wabash River Valley of southern Indiana and Tllinois [1]. As part of continuing efforts to characterize the seismic hazard in the central U.S., the U.S. Geological Survey (USGS) is working to better understand the causes and the chronology of paleoearthquakes throughout the region, including the Wabash River Valley.

Sand blows are lenticular sand bodies that were erupted onto paleo-ground surfaces and were fed by sand-filled dikes that were sourced from subjacent liquefied sand beds. Previous studies in the Wabash River Valley area have bracketed the ages of the sand blows using radiocarbon samples collected from exposures of Holocene alluvium in river banks. We collected samples at two sites on the Wabash River: Peankishaw Bend, and the Black River site. Sand blows and sand dikes in the cut bank exposures at these sites have been dated using radiocarbon [2]. We are using optically stimulated luminescence (OSL) dating from these `calibration sites' to test the possibility of using OSL to date sand blows where either conflicting radiocarbon data exist or where there is no datable organic material in the exposed section.

Methods: We analyzed fine sand-sized quartz grains using blue-light OSL dating by single aliquot regeneration features (SAR) [3] with blue-light excitation. Dose recovery and plateau tests ensured that the sediments were responsive to optical techniques and that the proper temperatures were used to produce the equivalent dose values. We made our blue-light OSL measurements on an automated Riso "Minisys" TL/OSL DA-15A reader equipped with blue light-emitting diodes (470 ± 30 nm) for illumination and a $^{90}Sr/^{90}Y$ beta source for irradiation. We measured OSLsignals after they passed through three 3 -mm Hoya U-340 filters, for 40 seconds at 125°C with an EMI 9235 photomultiplier tube.

Estimation of the equivalent dose: Lomax and others [4] review the different methods of estimating the equivalent dose and propose that the arithmetic mean is an inappropriate measure to describe the equivalent dose if the histogram shows a broad and positively skewed distribution. The weighted mean, on the other hand, underestimates the equivalent dose of older samples and might be erroneously biased toward low equivalent-dose values in a distribution [5].

The central age model accounts for individual error but uses standard errors of log doses, which are independent of the size of the dose [6]. Bateman and others [7] used the high probability peak to calculate a mean equivalent dose by fitting a normal distribution to the data for their samples affected by pedoturbation. Lomax and others [4] fitted a Gaussian curve over the weighted histogram, and all values outside of this curve were removed from the data set, ımtil the remaining data could be fitted with a R^2 value of at least 0.95.

We compare these different approaches to calculate the equivalent dose and evaluate the resulting ages with the radiocarbon evidence.

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OSL CHRONOLOGIES FOR AEOLIAN ACTIVITY IN THE CONTEXT OF LAKE-LEVEL FLUCTUATIONS, DRAINAGE REORGANIZATION AND GLACIAL RETREAT, NORTH-CENTRAL MJNNESOTA.

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Introduction: Dunes and stratified eolian sediments are a significant component of the postglacial landscape across the mid-continent. During the 1970s, a benchmark study in north-central Minnesota inferred a period of eolian activity 8,000 — 5,000 years ago (i.e., the Altithermal Hypsithermal periods), based upon radiocarbon dates on charcoal and organic material preserved within paleosols developed in dunes [1]. We revisited a classic locality at Lake Winnibigoshish (N 47°27'; W 94°12'), and sample other dune-forms to hypothesis-test whether eolian landform development occurred during the middle Holocene. Optical luminescence techniques can better resolve Minnesota's eolian chronologies by directly dating the emplacement of bed forms; sediments are typically oxidized and lack preserved organic materials suitable for ^{14}C dating.

Sampling: After extensive field reconnaissance and GPR (ground-penetrating radar) imaging of subsurface contexts, we described stratigraphic relationships at 8 sites across north-central Minnesota. Using natural exposures and hand-dug pits, we targeted >20 contexts for optical dating. Samples were collected with PVC tubes and lightproof bags.

Methods: Under amber light, samples were wet-sieved and treated with dilute HC1 to remove carbonates, and then floated in 2.7 g/cm^3 sodium polytungstate to isolate heavy minerals, which were identified by XRD (x-ray diffraction). We used a standard pretreatment to refine the sample: 1) initial etch and removal of feldspars using 10% HF for 1 hour; 2) etch with 48% HF in a mechanical shaker for ~50 minutes; 3) react with 47% HC1 to remove fluorides; 4) re-sieving to remove the <75 gm fraction; 5) infrared stimulation test (IRSL) to verify removal of feldspar grains; and 6) possible repeat of refinement steps to assure sample purity.

The primary luminescence techniques employed included a preheat plateau test and single aliquot regenerative-dose measurements (OSL SAR) [2] on prepared quartz of the average grain size represented in the sediment sampled. Measurements were conducted using a RISO TL/OSL DA-15 reader (470 nm, 2 U-340 filters). The SAR protocol used four regenerative dose points (5, 10, 20, 40 Gy) with an initial preheat (PH_I) of 260°C/10 sec, after which the natural dose (L.) was measured using 90% blue diodes (60 sec) at 125°C. The irradiations were followed by a preheat (PH_2) of 260°C/10 sec, and a small test dose.

Values for dose rate (D_r) were calculated from ICP-MS and AAS measurements of the concentrations of K, U and Th in bulk sample splits treated with an HF-HNO_3 $HC1O_4$ digestion, and dilution [3]. The *in situ* water content was measured after oven-drying the sediment at 100°C.

Conclusion/References: Replicate optical dates suggest there was a period of dune mobilization during the late Pleistocene (13-12 ka), followed by a cessation. Eolian dynamism then peaked after 8 ka, which is a time period characterized by aridity across the mid-continent region [4]. These new dates from Minnesota can be compared with other published records from the Great Lakes region [5].

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DATING EPHEMERAL STREAM AND ALLUVIAL FAN DEPOSITS ON THE CENTRAL GREAT PLAINS: COMPARING MULTIPLE-GRAIN OSL, SINGLE-GRAIN OSL, AND RADIOCARBON AGES.

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Introduction: This research compares the use of luminescence (both multiple-grain and single-grain methods) and radiocarbon dating techniques for providing age control for ephemeral stream and alluvial fan deposits in western Nebraska. Age estimates were determined for channel, overbank, and alluvial fan deposits using the multiple-grain luminescence (37 ages), single-grain luminescence (13 ages), and radiocarbon (4 ages) dating techniques.

Results and Discussion: The multiple-grain data showed problems associated with partial bleaching based on their high degree of equivalent dose (D_e) spread, and the poor correspondence of these ages with those from relative age estimates. The single-grain results confirmed these bleaching problems, showing that all of the alluvial fan and channel and some of the overbank samples had highly asymmetrical histograms (Fig. 1) and much younger ages relative to those determined using the multiple-grain techniques.

Based on the single-grain ages, multiple-grain ages were over-estimated by ~ 1,500-800 and 1,500-0 years for channel and overbank sediments, respectively. Furthermore, sediments that likely were deposited in the 20th century had multiple-grain ages of ~ 1,500-1,400 years BP, while the ages from single-grain dating were 150-70 years BP. Four radiocarbon ages from detrital charcoal were analyzed to provide independent age control for the optical methods. In two cases ^{14}C ages corresponded with age estimates from the multiple-grain and single-grain techniques. However, in two others single-grain or multiple-grain ages suggested the radiocarbon ages were over-estimated by ~ 750-650 years. Based on these comparisons, the single-grain optical dating technique provides the most consistent ages for these alluvial deposits, and those that best agree with the relative age control in this field area. These results suggest that the single-grain technique may be useful in improving late-Holocene alluvial chronologies in the central Great Plains, and in similar alluvial settings.

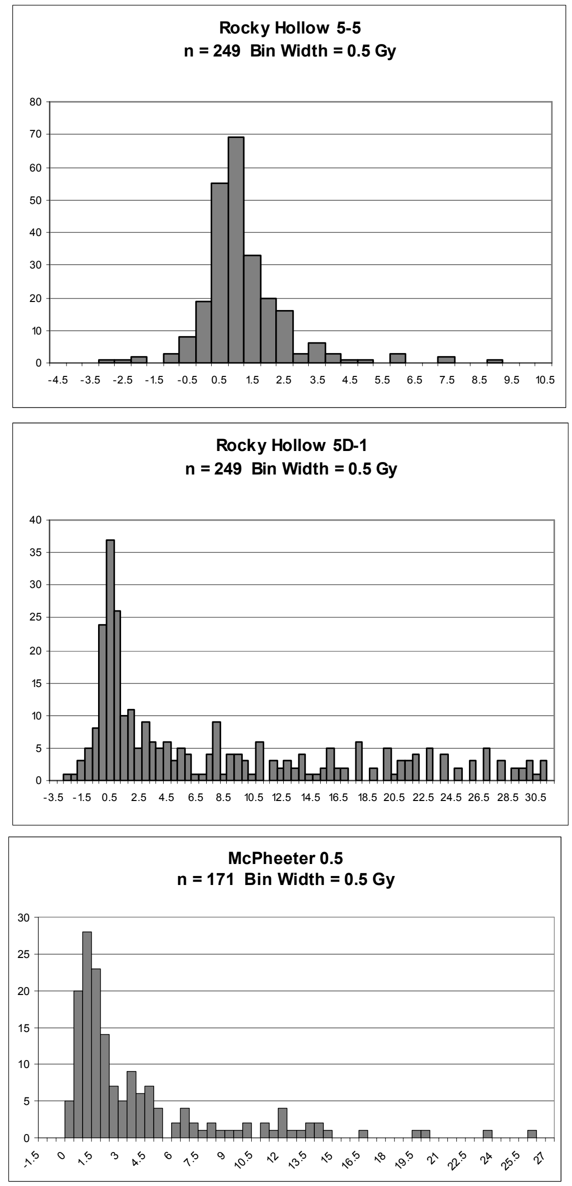


Figure 1. Single-grain equivalent dose distributions for representative overbank (upper histogram), channel (middle histogram), and alluvial fan (lower histogram) samples from western Nebraska.

OSL DATING OF SEDIMENTS FROM PALEOINDIAN SITES IN BRAZIL. James K. Feathers, University of Washington, jimf@u.washington.edu

Introduction: In the ongoing debate about human colonization of the New World, increased attention has been paid to South American evidence. This is not only because the oldest, widely accepted site is located in South American, but also because the largest – by an order of magnitude – sample of paleoindian skeletons is found in Brazil. These skeletons have been shown to be morphologically distinct from modern Native Americans. Brazilian physical anthropologists have argued that they represent an earlier migration to the New World than that from which modern Native Americans are descended. A large portion of these skeletons are found in the limestone rockshelters of Lagoa Santa in Minas Gerais state.

A problem with South American paleoindian evidence is poor documentation, particularly in terms of reliable dating. In conjunction with a research project being conducted in Lagoa Santa by the University of São Paulo, our laboratory has been attempting to obtain OSL dates from sediments in the rockshelters.

The limestone in which the rockshelters are formed is overlain by a shale that includes pockets of quartzite cobbles. Most sediment in the rockshelters is either of anthropogenic origin or represents colluvium that has washed into the shelters from the eroding shale. The amount of sand-sized quartz, while not abundant, is sufficient for OSL dating, particularly if single-grain measurements are employed. In many of the shelters, the sediments are largely of paleoindian age, as evidenced from artifacts and radiocarbon dates. The possibility of mixture of the sediments and questions about the reliability of the radiocarbon dates has led to the application of OSL.

Methods: Equivalent dose (D_e) is determined by single-grain analysis using the SAR protocol. Attempting to understand the D_e distributions that result from single-grain analysis is the focus of research, particularly experimenting with mixture models to isolate single-age populations. Radioactivity is measured by alpha counting, beta counting, and on site dosimetry.

Results: Many of the measurements have not been completed as of this writing. Work is concentrating at three shelters: Lapa Vermelha (which is well-known for containing the reputed oldest human skeleton in the New World), Boleiras and Lapa do Santo. Samples from Lapa Vermelha are distinguished from samples from the other two sites by displaying high over-dispersion in the D_e distributions. Some simplified D_e (t) plots suggest the problem is not partial bleaching, but probably relates to turbation, a conclusion supported by the widespread occurrence of insect burrows in the sediments. This is being tested by looking at recently collected samples from a portion of the rockshelter where the insect burrows are absent. Samples from the other two sites, while showing moderate dispersion, probably represent single-aged populations. Over-dispersion values may be overestimated if no account is taken of spatial heterogeneity in the dose delivered by the ^{90}Sr beta source. We have found a systematic variation in the calibration of the source for single grains, varying by a factor of almost two from one end of the single-grain disk to the other.

Using the central-age model to determine D_e for age calculations, broad agreement at all three sites is obtained when comparison is made with radiocarbon dates. The agreement at Lapa Vermelha, where the central age model may be less appropriate, is only rough because of uncertainties in the association of the radiocarbon dates, obtained 30 years ago, with the OSL samples. But at Boleiras samples dated 9.7 to 12.1 ka by radiocarbon compare with OSL samples dated 8.4 to 11.4. One OSL age is anomalously low and not in stratigraphic agreement with the others. At Lapo do Santo, an OSL age of 9.2 ka compares to a radiocarbon range of 9.8-10.2. (All radiocarbon dates are calibrated.)

This work is funded by the National Science Foundation

USING OSL TO DATE FINE-GRAINED CERAMICS. M. Aksel Casson, University of Washington, casson@u.washington.edu, and James K. Feathers, University of Washington, jimf@u.washington.edu

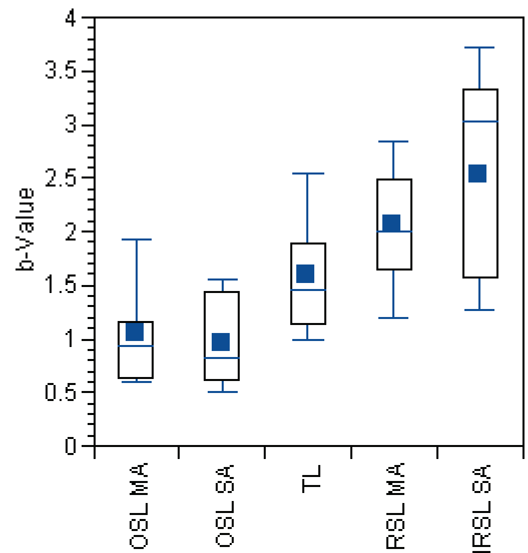
Introduction – Luminescence dating was first developed in the context of dating archaeological ceramics. Research has largely shifted to dating unconsolidated sediments, but ceramic dating remains important for archaeology. Dating of fine-grained ceramics using TL often results in less than satisfactory results, because of high scatter, ill-defined equivalent dose (D_e) plateaus, sensitivity changes between first and second glow outs, and anomalous fading. Our laboratory in the last two years has been applying single-aliquot OSL to fine-grained ceramics. OSL measures the fastest bleaching component and single-aliquot methods have higher precision than is possible with multi-aliquot TL.

The double SAR method was developed for dating fine-grained sediment samples [1,2]. The method involves at each measurement step of the SAR protocol, two exposures, an initial infrared followed by blue light. The rationale is that the infrared exposure will remove most of the feldspar signal so that the blue exposure produces a signal from mainly quartz, thereby getting around the problem of anomalous fading.

Effectiveness of infrared exposure – Feldspar also responds to blue light, and part of the uncertainties in the double SAR method is how much the initial infrared exposure reduces the feldspar signal. Is the blue stimulated signal really free from anomalous fading? Two approaches to insuring that the infrared exposure fully reduces the feldspar signal have been tried: (1) conducting the infrared exposure at higher temperatures [3] and (2) prolonging the infrared exposure [4]. We have experimented with both approaches and have found that heating above 60°C for the infrared exposure or prolonging the infrared exposure to longer than 100 seconds makes little difference in the resulting blue-stimulated signal. Preliminary fading tests indicate that the blue signal does not fade, while the infrared signal does.

Alpha efficiency – D_e values from TL, IRSL and blue OSL from the same sample often differ significantly. This should not be surprising, given that alpha efficiency is likely to vary between quartz and feldspar. We have attempted to measure alpha efficiency, using b-value, for IRSL, OSL as well as TL. An alpha "equivalent dose" has been measured using an SAR protocol. This is compared to the D_e obtained using beta irradiation, also using SAR. The b-value does not vary significantly for several samples tested from that obtained using multi-aliquot data. The results show that b-value differs significantly among all three, being generally high for IRSL and generally low for OSL, while somewhere in between for TL, probably varying depending on relative amounts of quartz and feldspar (see figure).

Ages – A comparison of ages for the same sample calculated using TL, IRSL and OSL suggests that OSL should become an important complement to TL in assessing the age of prehistoric ceramics.



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LUMINESCENCE DATING OF ANCIENT MONUMENTAL ARCHITECTURE AT CHAVÍN DE HUÁNTAR, PERU. J.A. Johnson[1], J.K. Feathers[2], S. R. Kembel[3]. [1,2]University of Washington, Box 353100, Seattle, WA 98195-3100 ([1]anamgorm@u.washington.edu, [2]jimf@u.washington.edu), [3]Dept of Anthropology, Univ of Pittsburgh, Pittsburgh, PA 15213 (silvia@kembel.com)

Introduction: Monumental architecture is a common feature of ancient Peruvian archaeological sites, but our understanding of the chronology of these complex monuments has been limited by difficulties in obtaining reliable dates for monument construction episodes. Primarily, these difficulties have been caused by a paucity of carbon or ceramic materials in clear association with architectural construction events. At the Peruvian formative site of Chavín de Huántar, located in the central Peruvian Andes, we have attempted to address these limitations by utilizing OSL methods to directly date multiple monumental construction events.

The site chosen is in some ways ideal for this project, as the relative sequence of construction events at Chavín is quite well understood, and extensive radiocarbon samples have been obtained directly from architectural features at the site. This information will provide independent evidence with which the dates we have obtained can be evaluated, allowing us to check the validity of our OSL dates before applying the method to the numerous monumental sites where such information is unavailable. The site chosen also posed several unique challenges to the collection, processing, and analysis of OSL samples, and this paper discusses these challenges and our solutions to them in detail.

Sample Collection: Mortar seams in stone-and-mortar architectural walls were targeted for sampling. Preservation concerns and the small width of mortar seams restricted collected samples to unusually small volumes. Samples were collected with small diameter tubes driven into wall faces, and dosimeters were placed at maximum depth. Wall geometry and precise sample provenience were recorded in detail. Rock fragments from wall stones were collected to aid in laboratory estimation of dosimetry.

Sample Processing: Laboratory processing was governed by the concern for isolating samples of known depth from wall surface. Degree of compression as a product of collection was estimated mathematically, and samples were segmented to isolate subsamples expected to have been at least 15 cm deep in wall matrix.

D_e Analysis: Single-grain SAR OSL was used on quartz grains to obtain equivalent dose estimates. Partial bleaching was identified and addressed with the use of the minimum age model. Sample sizes were quite small in many cases due to small sample volume and the scarcity of "bright" grains during analysis. Feldspars and fine-grained OSL were also attempted in some cases, but failed to produce any useable signal.

D_r Analysis: Complex wall geometry at collection points made estimation of dose rate an involved process. Radioactivity of collected mortar and stones was measured directly, and an estimate of each sample's composite dose rate was derived from these measures using digital imaging software and the geometric configuration of wall surfaces at sampling locations. To help gauge potential error in projecting these surface-derived estimates to depth, this process was repeated for each sample using a second, hypothetical, sample placement, and the two surface estimates were compared. Dosimeters collected from sample locations have provided an additional check on dose rate estimates.

Results: Full results are available for a sample taken from the Ofrendas Gallery at Chavín, and this sample's age falls within error terms of known ^{14}C dates for this same construction episode. Numerous other samples will be finished soon, and will be discussed in detail. These data will also be systematically compared with forthcoming ^{14}C data from Chavín to assess the potential of OSL for dating archaeological monument construction episodes in Peru.

Table 1. Comparison of OSL and ^{14}C Dates for the Ofrendas Gallery

OSL Sample	Minimum Age
UW1175	1101± 285
^{14}C Sample	1σ Cal. Range (BC)
GX1128 [1]	970-790
TX18 [1]	1440-1120

References: [1] Lumbreras, L.G. (1993) Chavín de Huántar: Excavaciones en la Galeria de las Ofrendas. *Materialien zur Allgemeinen und Vergleichenden Archaologie* bd. 51. P. von Zabern, Mainz Am Rhein.

EOLIAN SAND DEPOSITIONAL RECORDS FROM WESTERN KANSAS AND NEBRASKA, AND EASTERN COLORADO: A POTENTIAL LANDSCAPE RESPONSE TO DROUGHTS IN THE PAST 10,000 YEARS. S. L. Forman, L. Marín and J. Gomez, Luminescence Dating Research Laboratory, Univ. of Illinois at
Chicago, Chicago, IL 60607-7059.

The Great Plains are dominated by presently stabilized dune fields that are indicators of extreme drought in the late Holocene. This study focused on evaluating geomorphological, stratigraphic and chronological evidences of dune reactivation for stabilized ergs in southwestern Kansas and southeastern Colorado adjacent to the Arkansas and Cimarron Rivers. Dunes occur on multiple-aged terraces, with modified star dunes at the upper valley margin and reverse and transverse dunes at lower topographic positions. Parabolic and blow dunes are also common and appear to reflect the latest period of dune reactivation. This complex of eolian landforms reflects a variety of paleowinds with dominant directions from the northwest and northeast and secondary directions from the southeast and southwest. Multiple stratigraphic exposures reveal eolian sand separated by up to three paleosols indicating repeated eolian activity followed by landscape stability. Most paleosols show minimal horizonation with either a sole A horizon and/or a weak cambic B, indicating pedogenesis for < 1 ka. The chronology of eolian-sand depositional events is constrained by optical stimulated luminescence, single aliquot regeneration method (SAR) on 150-250 micron quartz grains. The oldest eolian sand stratigraphically above high fluvial terrace gravels yielded SAR ages of ca. 8000-6000 yr, indicating significant eolian activity in the early Holocene. Basal eolian sand from a stratigraphic exposure within Arkansas River dune field yielded the SAR age of 1490 ± 130 yr BP, indicating pervasive late Holocene reactivation. Widespread dune reactivation occurred at 230 ± 20 and 190 ± 15 yr BP, possibly coincident with a multi-decadal (?) tree-ring identified drought in the 19th century. There is compelling evidence that these systems in Colorado, Nebraska and Kansas reactivated <300 yr ago. Independent confirmation of the timing of dune movement is derived from analyses of mosaiced and georeferenced aerial photograph time series spanning the past 70 years. Pure quartz aliquots from eolian sand associated with dune movements in the 1930's and later in the 20th century were dated by optically stimulated luminescence using two different single aliquot regeneration (SAR) protocols. Initial analyses were completed using standard SAR protocols with blue excitation (BL) of quartz aliquots. Subsequent analyses used a modified SAR protocol by adding a high-temperature step under blue excitation (BL-IR) with a prior infrared (IR) "wash" step. There is a variable response of quartz aliquots to these protocols with the BL-IR treatment for all samples yielding concordant ages. IR excitation yielded the greatest range of responses with quartz grains from Colorado yielding an older component, from west Kansas, an age underestimate and from Nebraska ages consistent with BL and BL-IR protocols. This study indicates that a pre-infrared wash step and an elevated temperature step under blue excitation minimized spurious feldspathic components and potential recuperation affects. SAR protocols are significantly robust to resolve ages for eolian sands deposited in the past century on the Great Plains, USA.

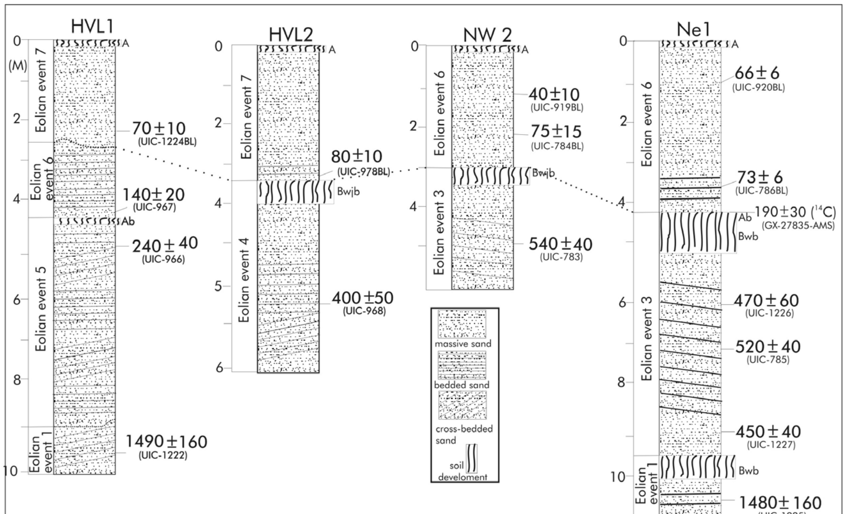

Figure 6. Stratigraphic sections of eolian depositional events on the northern margin of Cottonwood Lake (NW2 and Ne1), and Home Valley Lake (HVL1 and HVL2), western Nebraska Sand Hills

LUMINESCENCE CHRONOLOGY FOR LATE QUATERNARY AND HOLOCENE RECORDS OF EOLIAN DEPOSITION FROM A "MEGA-TRENCH" ACROSS THE ANTON SCARP, EASTERN COLORADO, USA. Jeaneth Gomez[1], David Noe[2] and Steven L. Forman[1] [1]Luminescence Dating Research Laboratory, Univ. of Illinois at Chicago, Chicago, IL 60607-7059. [2]**Colorado Geological Survey 1313 Sherman St, Rm 715, Denver, CO 80203**

Introduction: The Anton Scarp is an enigmatic, potentially tectonic structure, buried by late Quaternary sediments on the High Plains of eastern Colorado, approximately 160 km east of Denver. A mega-trench with tiered sidewalls was excavated into the lower slope of this scarp, revealing multiple eolian sedimentary units.

Geochronology: Single and multiple aliquot regeneration protocols on the fine and coarse fractions were used under green, infrared and blue-light excitation to yield luminescence ages. Independent chronologic control is provided by the presence of paleo-indian (~11-13 ka) artifacts in the upper part of the trench. The lowest observed stratum is a well-developed paleosol with a meter-thick carbonate-rich, argillic horizon (see Fig. 1). Periglacial sand wedges are intruded into the paleosol. These wedges show distinctive vertical beds of silty sand associated with cracking of sediments upon freezing and subsequent infilling by the eolian transport of grains. The wedges also exhibit sidewall collapse structures with melting of permafrost and subsequent colluvial deposition. The presence of these periglacial features indicates at least a 12°C temperature depression from the current mean. Quartz grains from the sand wedge infill yielded the optical age of 20,365 ± 1635 yr (UIC1677IR), consistent with much colder climates during the Last Glacial Maximum.

The top of the lowest paleosol is eroded, marked by a lag of rounded pebbles, and grades into a horizontally-stratified very coarse to medium sand. Quartz grains from above the truncated paleosol surface yielded the optical age of 13,035 ± 910 yr (UIC1675IR). A correlative bed of eolian strata, which caps a sandy fluvial channel deposit associated with landscape erosion, yielded a similar age of 13,150 ± 900 yr (UIC1679IR). A prominent compound paleosol occurs in the upper 1 m of the eolian/fluvial sand unit, which is buried by a conspicuous loess. Fine grains from the basal 10 cm of this loess yielded optical ages of 7020 ± 460 yr (UIC1676IR) and 7750 ± 500 yr (UIC1680IR), and 6120 ± 395 yr (UIC1676GR) and 6660 ± 710 yr (UIC1680GR) by infrared or green stimulation, respectively.

Conclusion: This Holocene loess appears only within the area of a filled depression at the base of the scarp, and may be correlative to Bignell and younger loess in western Nebraska.

Figure 1. Partial stratigraphy from trench

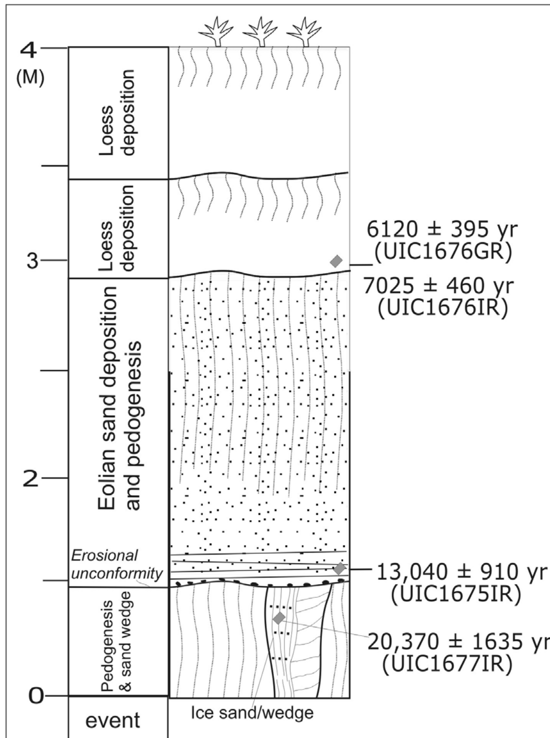

Fig. 1: Schematic cross-section of southern part of east wall showing basal well-developed buried soil (Btkb) with ice/sand wedges intruded. Top of this soil is eroded and is associated with Clovis age artifacts, consistent with the IRSL age on overlying eolian sand. Top of section is defined by loessial silt, deposited ca. 7 to 6 ka ago.

USING OSL GEOCHRONOLOGY TO CORRELATE STREAM AND HILLSLOPE DEPOSITS TO CLIMATE CHANGE IN EASTERN GRAND CANYON TRIBUTARIES.

B. DeJong[1], J. Pederson[1], T. Rittenour[1] and R. Goble[2]. [1]Department of Geology, Utah State University, Logan, UT 84322 (bddejong@cc.usu.edu; bolo@cc.usu.edu, tammyr@cc.usu.edu); [2]Department of Geosciences, University of Nebraska, Lincoln NE 68588 (rgoble@unlnotes.unl.edu)

Introduction: The Pleistocene stratigraphy of eastern Grand Canyon (EGC) provides insight into desert landscape responses to climate change. For example, hillslope and fluvial deposits in the Lava Chuar and Comanche tributary drainages record strong cycles of aggradation and incision in response to changing sediment production, storage, and transport. Anders et al. [1] produced a chronology for these tributaries and the mainstem Colorado River using OSL and cosmogenic dating methods. Results show different responses of the tributary drainages and the mainstem river that may indicate responses to differing controls; namely local climate forcing for tributaries and glaciation in the headwaters for the Colorado.

Hillslope and stream components of the Lava Chuar and Comanche drainages offer a unique opportunity to explore the timing and mechanisms of tributary sedimentation. For example, field relations in the short, steep Comanche drainage indicate the massive colluvial C3 deposit grades to the fluvial S3 deposit, suggesting contemporaneous fluvial and hillslope deposition. By contrast, the younger S2 deposit has no correlative hillslope deposit and issues from gullies cut into the S3. The goals of this project are to develop a more robust chronology for these deposits using OSL in order to determine temporal patterns in deposition along the length of drainages.

Sampling/Methods: OSL samples were collected by pounding metal tubes into fluvially re-worked colluvium and fluvial terraces. Priority was placed on collecting samples from the basal portions of deposits in order to determine the onset of deposition and to test for transience. Additional sand was collected for dose rate analysis and water content determination. OSL samples were processed at the University of Nebraska and analyzed using a modified single aliquot regenerative-dose (SAR) protocol [2] with a 280ºC bleach after each cycle [3].

Results: The transport mechanisms associated with hillslope colluvium and terrace materials in EGC tributaries are expected to produce partially bleached sediment. For example, fluvial sediments are often transported under turbid water conditions in these ephemeral streams. Similarly, sand lenses in hillslope colluvium are the result of fluvial reworking of debris flow material during small pulses of stream flow activity. These difficult bleaching conditions are reflected both in equivalent dose (De) distributions and in the rejection rate for disks. Despite these challenges, the SAR OSL dating method is yielding preliminary ages for samples collected in EGC tributary deposits (fig. 1). For example, results indicate two new distinct deposits (S2o, S3o) that reveal a picture of surprisingly complicated stratigraphy and unexpected timing of sedimentary responses.

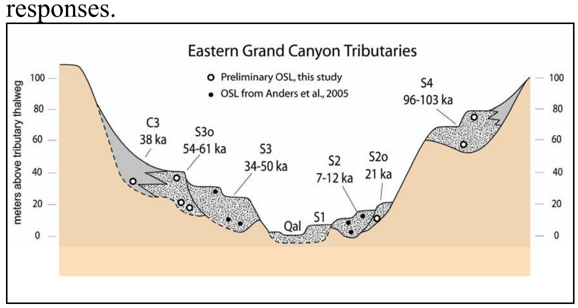

Figure 1. Schematic cross-section of terraces in eastern Grand Canyon showing preliminary OSL ages

Conclusion/References: Preliminary OSL results suggest that a high-resolution picture of tributary sedimentation can be produced for the tributaries studied. This will help to explore the potential transience of tributary sedimentation and uncover a stratigraphy that is apparently more complicated than field observations suggest. Further fleshing out this record will ultimately provide a window to help us better understand dryland responses to climate change

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[3] Murray, A.S., Wintle, A.G. (2003) The single aliquot regenerative dose protocol: potential for improvements in reliability: Radiation Measurements 37, 377-381.

USING OSL TO SOLVE THE RIDDLE OF VARIABLE INCISION RATES ACROSS THE COLORADO PLATEAU. J. Pederson[1], T. Rittenour[1], S. Cragun[1], and R. Goble[2]. [1]Dept. of Geology, Utah State University, Logan, UT 84322 (bolo@cc.usu.edu, tammyr@cc.usu.edu); [2]Dept. of Geosciences, University of Nebraska, Lincoln, NE 68588 (rgoble@unlnotes.unl.edu).

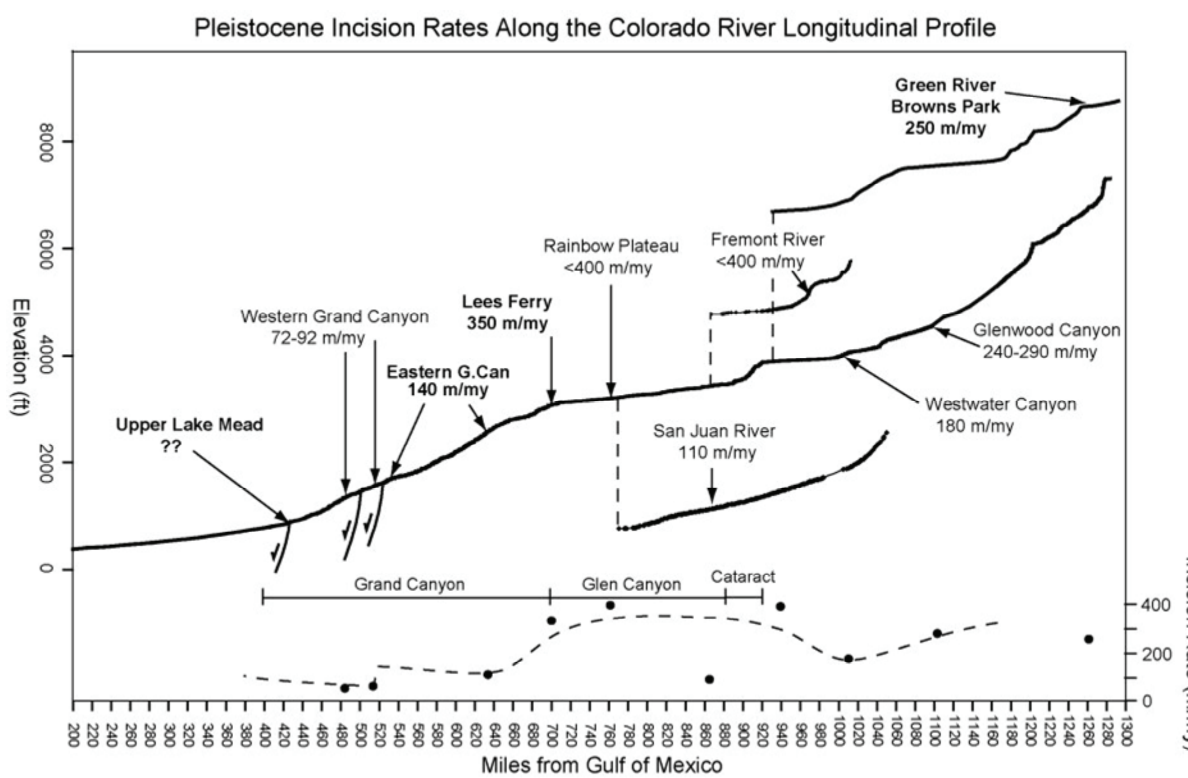
Introduction: Optical dating is superior to other geochronometers for studying the history of fluvial systems that are strongly controlled by climate oscillations and marked by fill-terrace records. The depositional ages obtained are suited to studying climate controls, as well as for deciphering the signature of the longer-term incision that creates terrace records.

For example, OSL-augmented studies in the Colorado Plateau highlight a geomorphic riddle about spatially-variable incision rates in this region that lacks active faulting. Here we summarize our studies involving OSL dating, describe the apparent patterns of incision along the river, and provide hypothetical explanations.

Methods/approach: We are combining careful mapping, stratigraphic work, and topographic surveys with OSL dating that is complimented locally by cosmogenic and U-series dating methods. Thus far our study sites ranging from Lake Mead to the Rocky Mountain headwaters have produced reconstructions of fluvial history over 10^5 yr timescales that allow us to quantify the trend of incision integrated over climate oscillations (our sites utilizing OSL are bold in figure). Single-aliquot regenerative dose OSL analyses were done at the University of Nebraska laboratory.

Results: Highly variable incision rates are apparent from the combined results of our studies and other recent incision estimates in the central Plateau based on cosmogenic or Ar-Ar volcanic ages (fig). Changes in the western Grand Canyon have been described as a result of mild normal faulting in that area. But specifically confounding is an apparent ~400 km reach of high incision rates in the Glen Canyon region.

Discussion: Some common tectonic controls on baselevel can be ruled out for this region. We therefore submit two hypothetical mechanisms that remain to create reaches of high incision: a) epeirogenic rock uplift regionally enhanced by erosional unloading; and b) transient knickzone dynamics due to drainage-integration events in combination with reaches of measurably low bedrock resistance. Finally, part of the solution to the riddle lies in problematic comparisons of studies with different approaches in terms of what exactly is being dated, how rates are calculated geometrically, and different timescales of rate calculation.



OSL CHRONOLOGY FROM COLORADO RIVER TRIBUTARIES IN THE WESTERN GRAND CANYON AND GRAND WASH TROUGH: COMPARISON TO U-SERIES AGES AND APPLICATION TO FLUVIAL DEPOSITS ≥300 KA. T. Rittenour[1], W. Sharp[2], J. Pederson[1], G. O'Brien[1], and R. Goble[3]. [1]Dept of Geology, Utah State Univ, Logan UT 84322 (tammyr@cc.usu.edu; bolo@cc.usu.edu; gobrien@cc.usu.edu); [2]Berkeley Geochronology Center, Berkeley CA 94709 (wsharp@bgc.org); [3]Dept of Geosciences, Univ of Nebraska, Lincoln NE 68588 (rgoble@unlnotes.unl.edu).

Introduction: Small fluvial systems in the arid southwestern US may provide insight into catchment response to past climate-related changes in precipitation and sediment supply. Recent research by Anders et al. [1] in the eastern Grand Canyon has produced the first detailed reconstruction of tributary and hillslope response to local climate change, and suggests an out-of-phase relationship with the adjoining Colorado River, controlled by glaciation of its headwaters. The goals of this research are to reconstruct the catchment-basin response of two geomorphically different Colorado River tributaries ~300 km downstream from the sites of Anders et al [1]. OSL and U-series results are presented here.

Travertine Grotto, in western Grand Canyon, is a small steep drainage basin (~10 km^2, 170 m/km gradient). Fluvial sediments are characterized by inter-fingered travertine drapes within alluvium, with decreased clastic content near the top of terrace fills. Grand Wash is a large, low-gradient catchment (~4000 km^2, 17m/km gradient) that drains the Grand Wash Trough, the first extensional basin west of the Colorado Plateau. Fluvial sediments are inset into the Miocene basin fill with basal straths below the modern wash level.

Sampling: OSL samples were collected from terrace fills using light-proof metal tubes. Where possible, samples were collected from the base and top of terrace deposits to determine the timing of aggradation. At Travertine Grotto, samples for U-series analysis were also collected from laminated travertine drapes within the fluvial sediments.

Methods: Samples for OSL dating were processed at the University of Nebraska and analyzed using the quartz single-aliquot regenerative (SAR) technique [2] modified to include a 280°C bleach following each cycle [3]. Samples for TIMS U-series dating were analyzed by W. Sharp at the Berkeley Geochronology Center.

Results: The final OSL and U-series ages from Travertine Grotto and preliminary OSL ages from Grand Wash are summarized in Figure 1. In Travertine Grotto, the T3 terrace has the greatest sampling density, with OSL and U-series ages showing good correspondence, suggesting the OSL technique is working well for these fluvial sediments.

In Grand Wash, preliminary OSL ages range from 3-350 ka. The oldest terrace (T5) is producing an age of ~350 ± 40ka (~280 Gy equivalent dose), stretching the limits of SAR OSL dating. However, regenerative doses up to ~500 Gy do not show saturation, suggesting ages up to 600 ka could be obtained, assuming dose-rate calculations are accurate.

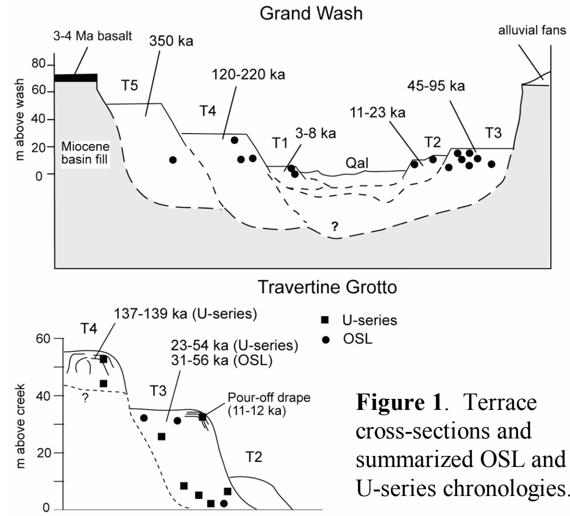


Figure 1. Terrace cross-sections and summarized OSL and U-series chronologies.

Conclusion/References: Geomorphic, stratigraphic and geochronologic investigations of Travertine Grotto and Grand Wash have produced detailed reconstructions of the Pleistocene-Holocene terrace chronologies. Correlations to local and regional climate change are still premature, but suggest fluvial aggradation during inter-glacial climates. OSL results are stratigraphically consistent and agree with U-series ages from the same deposits. Moreover, the 350 ka sample from T5 in Grand Wash is not near saturation and appears to be reliable, despite its old age.

[1] Anders, M.D., Pederson, J.L., Rittenour, T.M., Sharp, W.D., Gosse, J.C., Karlstrom, K.E., Crossey, R.C., Goble, R.J., Stockli, L., and Guang, Y. (2005), *Quaternary Science Reviews* 24, 2428-2448.

[2] Murray, A.S., Wintle, A.G. (2000), *Radiation Measurements* 32, 57-73.

[3] Murray, A.S, Wintle, AG (2003), *Radiation Measurements* 37, 377–381.