Thesis Abstracts

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Diana Chourio Camacho

Late Quaternary incision dynamics and valley bottom geometry within the Seine River catchment

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PSL University/MINES Paris/Centre de Géosciences, Fontainebleau, France

Degree: Ph.D.

Supervisors: Jean-Louis Grimaud, Hélène Tissoux, Paul Bessin, Mark Noble

Thanks to the use of paleodosimetric dating methods (ESR, OSL), this thesis contributes to better understand the chronology of the valley evolution and sediment transfer within the Seine River catchment and its major tributaries (Oise, Marne, Aube, Yonne, Loing and Eure rivers) during the Late Quaternary period. The valley bottom along the Seine catchment is variable in width, providing space for sediment accumulation during alluvial transfer. The alluvial deposits of the Seine River are mainly composed of quartz, which results from the alteration and erosion of the bedrock through which the river flows. This makes it possible to apply dating methods on quartz grains to estimate the phases of alluvial deposits following the incisions associated with major Quaternary climatic fluctuations. The aim of this thesis is first to propose a chronology of the valley bottom's infill and second to determine the residence timescale within the valleys based on the geometry at the bedrock alluvium interface.

For this, a total of 21 samples were collected from different sites within the Seine catchment in a fluvial environment, principally in valley bottoms, along their edges or in some fossil terraces. These samples were dated combining both the electron spin resonance (ESR) and optically stimulated luminescence (OSL) methods on optically bleached quartz grains provided by alluvial sediments. Seven samples were dated coupling both ESR and OSL methods, six using the ESR method and eight using the OSL method. Both methods are based on the same physical principle: the accumulation of electrons in trapping structures within the quartz lattice over time due to natural radiation.

Sample ages were determined as the ratio of total dose received since their deposition (equivalent dose D_e which is expressed in Gy) to the received dose calculated for one year (annual dose D_a, expressed in $\mu Gy\,a^{-1}$). The annual dose for all samples was determined considering the content of radioactive elements such as U, Th and daughters, and K in the field using a portable NaI γ-spectrometer and in the laboratory (High Purity Ge detector). The same D_a value was used for both ESR and OSL ages calculation. In contrast, the two methods differ in D_e determination. The D_e for ESR was calculated using the multiple aliquot additive (MAA) dose method, while for OSL the D_e was determined considering the single-aliquot-regenerative-dose (SAR) approach. ESR ages were determined by the multicentre approach using the Al, TiLi and TiH centres. A validation criterion of the dose response curves was performed regarding the comparison between the experimental points and the theoretical growth curve. A particular emphasis was given on the points with lower irradiation doses, with a special focus on allowing the curve to pass through the "natural" point.

The results of the ESR-OSL dating of sediments are predominantly associated with the glacial-interglacial Quaternary cycles. Along the valley bottom the returned ages recorded at least two Marine Isotopic Stages (MIS 6 and MIS 2). It is known that at the end of the Weichselian glaciation (MIS 2) erosion was less powerful than at the end of MIS 6. Therefore, it is possible that the deposits in the valley bottom from MIS 6 were not entirely removed during the Weichselian glaciation MIS 2, preserving deposits from MIS 6 in the valley bottom. Strath terrace deposits dated in this work provide additional constraints on the ages of the Seine valley formation and on incision rates since the Middle Pleistocene. Overall, the incision rates estimated from these terraces are in good agreement with the long-term incision rates known in the Paris Basin (50–60 $m\,Ma^{-1}$). Hence, at the large scale, the data indicate a rather stable configuration of the valleys since the Middle Pleistocene. Other aspects of this thesis potentially highlight some knickpoints (regressive erosion) observed above the chalk bedrock along the valley bottom (i.e., near the Poses dam or in the Bassée area). These knickpoints could originate from the same continuous base level fall, which would have occurred during limited periods of MIS 2 or MIS 6.

In conclusion, this study highlights that a combined approach involving (i) ESR-OSL measurements, (ii) valley bottom geometry restitution and (iii) sediment storage within the

valley bottom is highly valuable to further understand Late Quaternary sediment transfer within the Seine River catchment.

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Gwynlyn R. Buchanan

Infrared radiofluorescence dating: new insights into the (upper) dating limit, grain size and feldspar chemistry

July 2024

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Degree: Dr. rer. nat.
Supervisors: Prof. Dr. Sumiko Tsukamoto, Prof. Dr. Kathryn E. Fitzsimmons

Accurate luminescence dating of feldspar has long been hampered by the effect of athermal signal loss (anomalous fading) when using luminescence dating techniques that make use of recombination centres. Infrared radiofluorescence (IR-RF) dating is a luminescence dating technique that makes use of the principal trap and is therefore theorised to not suffer from fading to a significant extent. Extensive laboratory investigations have been done to better constrain and exploit the IR-RF signal and mechanisms but remarkably few have applied the technique to large sequences of natural sediments with known age control. In this dissertation, the utility and effectiveness of IR-RF dating were investigated and tested on coarse-, mid- and polymineral fine-grains of feldspar with a view to evaluating the upper dating limit of IR-RF as well as compared IR-RF with the recently developed novel infrared photoluminescence (IRPL) dating technique. Initially ten coarse-grained K-feldspar samples (∼25 to ∼900 ka) from the Luochuan loess-paleosol sequence were measured and compared with age control and it was found that a bleaching time of 1,500 s (between the natural and regenerated measurements) underestimated across all but the youngest sample while a longer bleach of 20,000 s resulted in good agreement with the age control up to 300 ka (5 samples) and underestimated for the older samples. Construction of the natural and laboratory dose response curves across the sequence revealed significantly different curve shapes for the shorter bleaching time and consistent curve shapes for the longer bleaching time, highlighting the importance of the longer bleach time. The potential of the IR-RF signal for dating was then tested on six polymineral fine-grained samples, and it was observed that the IR-RF signal did not describe the characteristic decreasing stretched exponential curve shape; these results were compared with Na- and K-feldspar mid-grain fractions of the same samples. The essentially flat curves were attributed to the dominance of Na-feldspar and quartz in the polymineral fine grains. Despite the flat IR-RF signals and poor dose recoveries, the age results for the polymineral fine-grains were consistent with age control up to 300 ka, the Na-feldspar mid-grains up to 350 ka and the K-feldspar mid-grains up to 200 ka. A comparison of two IR-RF signals (at room temperature, RF_{RT}; and at 70 °C, RF_{70}) and two IRPL signals (stimulated at 880 nm, $IRPL_{880}$; and at 955 nm, $IRPL_{955}$) on four coarse-grained coastal sediments (∼133 to 223 ka) from Sardinia showed good agreement with age control for all signals within 2σ. The IR-RF signal is an effective dating tool up to 300 ka for coarse- and polymineral fine-grains and its performance is comparable with IRPL dating.

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Neda Rahimzadeh

Towards extending the luminescence dating range of quartz: exploring the 375 °C quartz TL peak

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Degree: Dr. rer. nat.
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Optically stimulated luminescence (OSL) dating of quartz is widely used to establish an absolute chronology for Quaternary sedimentary deposits. However, its applicability is in general limited to the last ∼100–150 ka. Therefore, extending the range of quartz luminescence dating beyond this limitation is a key challenge. In the quest for extending this limit, other luminescence signals from quartz have been proposed, among which violet stimulated luminescence (VSL) is a promising signal. It is based on the use of violet stimulation (405 nm) to measure traps deeper than those accessible by blue light. The overall objective of this thesis is to develop and test the applicability of VSL dating to extend the quartz dating range. Attempts to establish an optimised single aliquot regenerative dose (SAR) protocol for VSL dating on four coarse-grained quartz samples from the coastal environment of Sardinia have not all been successful. It is found that the range of the applicability of the SAR VSL protocol is dependent on the natural dose size; using the SAR method for VSL dating remains challenging for samples with large natural doses (i.e., >250 Gy).

Subsequently, the multiple aliquot regenerative dose (MAR) protocol is, for the first time, tested on fine-grained quartz samples from a Chinese loess-palaeosol sequence in Luochuan with reference ages up to ∼1400 ka. The natural VSL dose response curve (DRC) saturates at about 900 Gy, which would potentially allow dating at the Luochuan section using VSL up to ∼300 ka. However, the application of the MAR protocol showed significant age underestimation for samples older than ∼100 ka. This MAR VSL age underestimation can clearly be attributed to the different shapes of natural and laboratory DRCs; the natural signal progressively deviates from the laboratory signal beyond ∼250 Gy. These observations are, however, contradicting the previous research in the same region, which showed that the MAR DRC

using coarse-grained quartz samples from the Luochuan section can reproduce the shape of the natural DRC. It can therefore be concluded that the grain size plays an important role in obtaining reliable ages. A direct comparison of fine- (4–11 µm) and coarse-grained (63–100 µm) quartz VSL data from nine samples from a loess section in southern Germany further confirm these observations. It is shown that there is a systematic tendency for the fine-grained VSL ages towards underestimation with increasing age. The fine-grained MAR DRC starts to deviate from the natural DRC at ∼300 Gy and therefore tends to underestimate the reference ages beyond ∼100 ka. In addition to the VSL signal, the physical characteristics and applicability of the multiple aliquot methods (MAR and multiple aliquot additive dose, MAAD) of the quartz isothermal thermoluminescence (ITL) signal measured at 330 °C (ITL_{330}) is systematically investigated by using nine fine-grained quartz samples from the Luochuan section. The natural ITL_{330} shows that the signal has a theoretical dating range up to ∼800 Gy, equivalent to ∼230 ka. The comparison of the natural and laboratory DRCs using MAR and MAAD protocols indicates that they start to diverge in shape beyond ∼200 Gy, setting an upper limit for reliable ITL_{330} dating of ∼70 ka. However, application of pulsed-irradiation (PI) for the MAAD protocol reveals that the shape of the natural DRC can mostly be reproduced with the PI-MAAD protocol and thus it can provide reliable ages up to natural saturation at ∼230 ka.

Based on the observations summarised in this doctoral thesis it can be concluded that the natural VSL and ITL_{330} signals have an extended growth, and the main limitation is the deviation between natural and laboratory generated DRCs beyond a certain dose, which caused a progressive age underestimation. Application of pulsed irradiation increases the reproduction of the extended VSL and ITL_{330} natural growth. While further investigations will be needed, it appears that this method can be a promising step forward in our attempts to extend the quartz luminescence dating age range.

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Victoria Schwarz

Hydroclimate Change Reconstructed from Lake-Margin Lunettes around Gariwerd in South-Eastern Australia

July 2024

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Degree: Masters
Supervisors: Prof. Dr. Kathryn Fitzsimmons, Dr. Tobias Lauer

Hydroclimate, defined as the interconnection of hydrology and climate, is highly important to assess environmental change. Especially in drought-prone regions, variability in hydroclimate can trigger major changes in landscape stability and affect ecosystems and human settlements. The highly variable hydroclimate with great variations in spatial and temporal landscape response in south-eastern Australia highlights the need of an improvement in the coverage of geochronologic and paleoenvironmental studies focussing on the reconstruction of hydroclimatic conditions. Lunettes, as transverse shoreline dunes at lakes, are valuable paleoenvironmental archives at the edge of Australia's dryland, as their sediment characteristics are altered through the conditions present during deposition and they are geomorphic proxies for the extent of the past dryland margins. In contrast, the lake bed is no suitable archive due to deflation. Periodic lake drying and lake bed deflation would result in clay pellet deposition whereas clean beach sand indicates full lake conditions. In this study, the history of lake filling and drying is investigated based on the lunettes for three former lakes (Lake Toolondo, Bryans Swamp, Nekeeya) around the mountain range Gariwerd/Grampians Ranges in western Victoria, Australia. This area is chosen due to its proximity to the semi-arid margin and the possibility to investigate whether an orographic effect on hydroclimate around the mountain range is preserved in the lunette's record. Toolondo is located west, Bryans Swamp in a southern valley and Nekeeya east of Gariwerd/Grampians Ranges. Optically stimulated luminescence (OSL) dating is used to constrain ages for sedimentation phases. Sediment characteristics, such as grain size and element composition, derived through laser diffractometry and portable X-ray fluorescence (pXRF), are used as proxies for lake conditions. This study enables the identification of the hydroclimatic history preserved in lunettes around Gariwerd/Grampians Ranges. At Toolondo drying lake conditions are preserved from ∼100–80 ka. A minor lake full phase with lunette deposition is recorded at ∼55 ka at Toolondo and Nekeeya. This is followed by major continuous to persisting sandy lunette deposition from ∼34–30 ka to 16 ka at all three lakes. Afterwards, minor full lake lunette deposition or partly reworking occurred at Toolondo and Bryans Swamp from ∼11–10 ka and at all three lakes from ∼7–5 ka and ∼2.4–1.7 ka. More recent activity is dated to ∼0.6 ka and <150 a at Toolondo and Nekeeya. The mostly continuous water availability at the lakes investigated highlights the importance of snow melt and vegetation response in mountainous regions during periods of generally higher aridity. Within this study, no evidence for an orographic effect of the mountain range Gariwerd/Grampians Ranges onto past lake hydrology could be found. Instead, latitudinal effects, the proximity to the mountain range and the catchment characteristics seem to have a greater effect on water availability within the studied lakes. The obtained results bring up the hypothesis of a "megalake" at Bryans Swamp through linkage with the adjacent Mahoney Swamp before 32 ka. This study improved the knowledge about spatial and temporal variability in hydroclimatic conditions and its landscape response and provides further evidence for more water availability during the extended Last Glacial Maximum (LGM) due to either decreased evaporation, increased rainfall or snow melt. The data can be used to guide future ap-

proaches to quantify climatic parameters in the past.

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Natalie Tanski

Dynamics of Climate and Tectonics on Surface Processes and Their Sedimentary Archives in the Colorado Plateau and Basin and Range, USA and the Calabrian Forearc, Sicily

August 2024

Utah State University, Logan, United States of America

Degree: Ph.D.

Supervisors: Tammy Rittenour, Joel Pederson

Landscapes change over time in response to movements of the Earth's crust and the effects of climate. This dissertation examines how these factors shape different landscapes, focusing on erosion of river canyons in elevated plateaus, how the transport history in quartz sand may be encoded in its properties, and how a paleo-delta has formed in response to sea-level change and fault displacement. I use dating techniques, field methods, and topographic analyses to offer insight into erosional patterns and rates in different landscapes.

Rivers can take a long time to adjust to changes in boundary conditions, even after those changes have ceased. I studied the Colorado River incision history in the tectonically stable central Colorado Plateau of Utah, to understand the timing, spatial variability, and controls on canyon carving. The incision history and topography of the region show remarkable variability in erosion across the region and through time, with significant rapid incision of ∼250 m in the last 350 ka. Results suggest this rapid erosion is a signal derived from baselevel fall by the Colorado River in the Grand Canyon region 5 million years ago. This study shows that even without major tectonic or climate change, landscapes can still maintain complex erosion patterns.

Optically stimulated luminescence sensitivity is a new technique used to study Earth's surface processes. However, the geologic processes that induce a luminescence phenomenon in quartz are still unknown. I investigate the geologic controls on the luminescence sensitivity of quartz sand using rocks and modern and paleo-river sediments in a small mountainous catchment in northern Utah, USA. The results indicate that the luminescence phenomena in quartz is enhanced with the time spent at the Earth's surface as the sand grain weathers, erodes, and is transported along hillslopes to river systems.

The Pagliara fan-delta in northeastern Sicily provides a unique opportunity to study how coastal sediments stack through time in response to climate and sea-level change and tectonic history. Dating of the delta using luminescence techniques, reveals that the delta formed 300–220 ka ago when accommodation space was generated by sea-level fall and subsidence from fault movement. After this time, river and shore processes began to excavate the delta, indicating a shift from sediment accumulation in the delta to tectonic uplift. Despite the change in tectonic stress revealed in the delta stratigraphy, the uplift and erosion rates of the region have remained relatively constant over the past 300 ka.

A PDF of this thesis can be downloaded from: https://digitalcommons.usu.edu/etd2023/250/

Hawke Woznick

Shedding Light on Past Ice-Free Intervals in Northwest Greenland: Luminescence Dating of the Base of the Camp Century Ice Core

August 2024

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Degree: Masters

Supervisor: Tammy Rittenour

The goal of this thesis is to provide greater resolution on the sub-glacial sediment ages and duration of ice-free intervals recorded in the Camp Century ice core, northwestern Greenland. Bulk sediment geochemistry and mineralogy were used to determine differences in sediment source and weathering, feldspar types, and inform sample selection for luminescence dating, which provides an age estimate of the last time sediment was exposed to sunlight.

The Camp Century core is separated into five subglacial sediment units. Samples were collected from each unit except unit 2, which is primarily composed of silty ice. Analysis of the bulk sediment geochemistry indicated the uppermost sediments were most depleted of soluble cations, indicating either sorting during transport or greater weathering. Statistical t-tests of the differences in the major elements in the sediment units above and below the silty ice lens (Unit 2) indicate that the upper sediments (Units 5, 4, and 3) are chemically different than the lower sub-glacial unit (Unit 1). Analysis of feldspars within the very fine sand fraction from each unit indicate they are dominated by K-feldspar, with an internal K content of 12.5 %, the value assumed for luminescence calculations. Age control on Camp Century subice sediment was obtained using post-infrared stimulated luminescence on the very fine-grained feldspar sand fraction. Luminescence results from the basal sediment unit (Unit 1) indicated that it was beyond the range of dating (>1.5 Ma). Preliminary luminescence results for the upper sedimentary units returned ages between 414 ka and 422 ka. These results confirm the initial age from the upper 10 cm of the core and indicate that Camp Century was last ice-free during the exceptionally long and warm Marine Isotope Stage 11 interglacial. An ice-free Camp Century within the last 400 ka greatly changes our understanding of the history and stability of the Greenland ice sheet. This research reveals that the Greenland ice sheet is more susceptible to melting, leading to global sea-level rise, than previously assumed.

A PDF of this thesis can be downloaded from: https://digitalcommons.usu.edu/etd2023/281/

Philip Liebrecht

Sedimentology of lake-margin lunettes in the Corangamite region, southeastern Australia

September 2024

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Degree: Masters
Supervisors: Prof. Dr. Kathryn Fitzsimmons, Dr. Jan-Hendrik May

Research on past climatic and hydrologic conditions is of high relevance when faced with the challenges of anthropogenic climate change. With water as an essential factor, variability in hydroclimate can affect landscapes as well as human settlements to a high degree. Within the already highly hydro-climatically variable Australian continent we investigate sedimentary deposits including lunettes, commonly found on the down-wind side of ephemeral lakes, as well as aeolian and fluvial deposits. Especially lunettes are valuable palaeoenvironmental archives, with their sediment sequences recording hydrologic conditions in their basins during their deposition. Samples were taken from three lakes in the Western Plains of the Newer Volcanics Province in Victoria: Lake Corangamite, Beeac and Murdeduke. The area is characterised by complex morphologies including multiple volcanic eruption centers as well as huge sedimentary deposits, which resulted in the hypothesis that a Megalake had previously existed in the Western Plains basin. This as well as the episodic salinity, increasingly becoming a problem with the arrival of European settlers and their pastoral agriculture, makes the area highly interesting. Using a combination of Optically Stimulated Luminescence (OSL) dating, remote sensing and sediment analyses a palaeolake extent, albeit smaller than previously hypothesized, as well as cascadic overflow points were identified. At Lake Beeac, a depositional phase at ∼42 ka was identified, followed by two deposits during lake drying conditions at ∼33 ka and ∼28 ka, respectively, at Lake Murdeduke. Immediately pre-LGM (Last Glacial Maximum), aeolian deposition occurred at Lake Corangamite. After a long inactivity, deposition resumed at Lake Murdeduke during lake full conditions ∼5 ka, whereas aeolian deposition occurred once more at Lake Corangamite around 3.6 ka, indicating variability in the late Holocene. With the arrival of European settlers and onset of pastoralism, reactivation occurred at the sampling sites of Lake Murdeduke, with four samples dated at ∼200 a.

A PDF of this thesis can be obtained by contacting the author: philip.liebrecht@gmail.com

Emma T. Krolczyk

Using Luminescence Dating to Investigate Geomorphic and Archaeologic Features at the Wiggins Fork Bison Jump Complex, Northwestern Wyoming

December 2024

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Degree: Masters
Supervisor: Tammy M. Rittenour

The terraces of the Wiggins Fork River in northwestern Wyoming host thousands of cairns that form an extensive network of drivelines and at least seven jump funnels. These anthropogenically placed features comprise the Wiggins Fork Bison Jump Complex, used prehistorically by Native Americans as a hunting method where bison were driven off cliffs for harvest. Previous radiocarbon analysis from bison bones preserved at the base of Jump #4 indicated a ∼200-year duration of use, though the spatial distribution and varying degrees of cairn degradation across the complex suggest an extended utilization period. This thesis explores the use of luminescence dating to determine the construction ages of cairns associated with Jump #4 and provide the deposition age of geomorphic features associated with the hunting complex.

The terraces of the Wiggins Fork were mapped and dated, and the lowest Pleistocene terrace resulted in a luminescence age of 16–23 ka, indicating deposition during the Pinedale glaciation and correlation with the lowest Pleistocene terrace of the Wind River. Luminescence dating of the overlying fine-grained alluvial deposit indicated deposition at ∼11 ka, coinciding with the Pleistocene to Holocene climate transition, and provided a maximum age for the archaeological features associated with the complex. Luminescence dating of cairns associated with the funnel of Jump #4 indicated that the jump was constructed ∼300–800 years ago. These placement ages primarily fell within error of the radiocarbon ages associated with the jump and suggest that the jump funnel was constructed during or prior to successful utilization. Cairn mapping and luminescence dating revealed that four gully-dissected parallel drivelines extending along the terrace tread approaching Jump #4 were constructed between ∼300 and 800 years ago. Results from each of the parallel driveline suggest that the features may have been reconstructed further inland to accommodate headward gully migration and reinforce the previously constructed drivelines. This represents a long-term investment in the landscape and adaptation to geomorphic change. The coinciding luminescence ages and radiocarbon demonstrate that cairns at this site can be dated, removing the need to find and disrupt bone deposits from the other jumps. These results have implications for ongoing archaeological investigations and efforts to protect this culturally and historically valuable site.

A PDF of this thesis can be downloaded from: https://digitalcommons.usu.edu/etd/