# Thesis Abstracts

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***Tamás Bartyik***

## Reconstruction of fluvial processes in the Maros River basin, with special respect to the applicability of OSL sensitivity

*June 2022*

Institute of Geography and Earth Sciences, University of Szeged, Hungary

*Degree: Ph.D.*
*Supervisor: Dr. György Sipos*

Recently, it has been shown that the luminescence properties of minerals, in particular quartz, can be used as an indicator of fluvial erosion and/or sediment origin for various fluvial processes. One of these properties is the so-called luminescence sensitivity of quartz grains, i.e. the intensity of the luminescence response per unit dose. Laboratory tests have shown that the magnitude of luminescence sensitivity can vary in response to light and heat exposure and radioactive radiation. Thus, in nature, high sensitivity has been associated with a high number of sediment cycles and low sensitivity with their absence. In addition, it has also been shown that the lithological background of quartz, i.e. the source area, can also be a crucial factor, so luminescence sensitivity can be used for the analysis of sediment provenance. Overall, however it is still questionable whether it is the inherited properties of source rocks (as primary factors) or the sedimentary history (as a secondary factor) that determine the luminescence sensitivity of sedimentary quartz. On the other hand, luminescence sensitivity studies have not yet been carried out on the sediments of the Carpathian Basin.

Although the reconstruction of the Late Pleistocene evolution of the lowland alluvial fan of the Maros River in Central Europe, using OSL dating has been done before, such studies have not been carried out in the middle and upper section of the river. The Retezat Mountains in the mountainous catchment of the river are one of the members of the Carpathians that were heavily glaciated during the Pleistocene glaciations. Changes in the glaciation and deglaciation phases in the area may have affected the ability of river to work downstream. Thus, sediment accumulation in the Hateg Basin in the foothills of the Retezat may be related to deglaciation. The terraces of the Middle Maros may also reflect these phases. In addition, a number of paleochannel patterns can be identified on the prominent alluvial fan of the lowland area of the Maros River. Their temporal and spatial displacements, water yields and channel types are indicators that the sediment discharge and sediment transport capacity of the river increased significantly from the Late Glacial to the Early Holocene and was higher than the present. However, at the regional level, the geomorphological processes in the lower catchment have not yet been compared with those in the upper catchment.

An own luminescence sensitivity measurement protocol was applied to 90 – 300 μm fluvial quartz grains in parallel with standard OSL age measurements to reconstruct geomorphological evolution.

In the thesis, was found the following correlations with luminescence sensitivity: The sensitivity of Alpine and Carpathian fluvial quartz in the lower section of the catchments show clear differences in terms of CW-OSL, TL 110 °C peak and LM-OSL techniques. Among the sensitivity parameters, the results of total LM-OSL and fast component ratio is the most applicable for the separation of sediments with different provenances. The sedimentary quartz grains of the Danube show a higher sensitivity with increasing age, while the Maros shows a lower sensitivity with increasing age. In the case of the Maros River, luminescence parameters are strongly influenced by sub-basin and river section scale factors. No general trend in the variation of the different sensitivity parameters is observed over the 565 rkm stretch studied. Along the Maros, the residual dose from quartz grains shows a clear downstream decrease, but the trend may be broken by tributaries and erosion.

In the terms of geomorphological reconstruction of Late Pleistocene and Holocene of Maros catchment: The MIS 3 stage in the Maros catchment was dominated by coarse-grained, gravel-sand sedimentation. A higher degree of fluvial incision in the middle catchment of the Maros was observed during the MIS 3-MIS 2 and the MIS 2-MIS 1 transition. Based on the data obtained, fluvial processes along the Middle Maros were mainly influenced by climatic conditions. There is no temporal relationship between the deglaciation phases in the Retezat Mountains and the water yield of the paleochannels of the lowland alluvial fan, but the sediment mobilised by the increase in precipitation may have influenced the channel pattern of the lowland section.

A PDF of this thesis can be downloaded from: http://doktori.bibl.u-szeged.hu/id/eprint/11145/

***Trine Freiesleben***

**Developing and testing models for rock surface dating using optically stimulated luminescence**

*July 2021*

Technical University of Denmark, Physics, Roskilde, Denmark

*Degree: Ph.D.*

*Supervisors: Kristina Jørkov Thomsen, Co-supervisor: Andrew Sean Murray*

Luminescence dating of rock surfaces is an emerging absolute chronological technique that has the potential to determine how long a rock surface has been exposed to daylight and/or how long it has been buried. The development of this technique into a robust dating method will give the opportunity to determine the ages of previously un-dateable stone structures/formations in both archaeology and geology, including megaliths, chambered burial mounds, cairns, cobble fans, ice-scoured bedrock, and many others. When a rock surface is exposed to light, the latent optically stimulated luminescence (OSL) signal is reset to different degrees depending on the distance from the surface and the duration of daylight exposure. Thus, by measuring the OSL signal as a function of depth into the rock surface, it is possible to determine how long the rock surface has been exposed to daylight, and how long it was subsequently buried, by modelling the measured luminescence-depth profile. The challenges involved in this procedure are addressed here, and in particular, the ability of a rock surface to record multiple sequential burial and exposure events is investigated experimentally. Existing models are examined and new, potentially more appropriate models introduced. These models are tested using both simulated and experimental data. Based on these tests it is concluded that exposure ages are very dependent on the exact model assumptions and that fitting parameters previously assumed to be constant with depth are in fact not.

It is shown that, although correct model assumptions improve the quality of exposure age estimates, significant discrepancies between observed and expected fitting parameter values remain and these discrepancies lead to inaccurate age estimation. This is particularly the case when post-IR signals from feldspar are used. The spectral dependency of luminescence signals is examined to better understand these problems. The demonstrated depth dependency of fitting parameters previously assumed to be constant with depth, also gives rise to discrepancies in parameter values. The surprising observation that, in rocks, the IR50 signal is apparently more easily bleached than the quartz fast-component OSL signal is explained in terms of light attenuation effects other than absorption (e.g. scattering and refraction) increasing the effective path length for shorter wavelengths, and so changing the shape of the light spectrum with penetration depth. This complicates parameter estimates in exposure dating even further.

Alternative approaches (rather than parameter estimation) for estimating how long a rock surface has been exposed to light are considered, based on modelling the shape and position of the measured luminescence-depth profile. It is concluded that the most accurate exposure age is derived by interpolating the depth of an unknown profile onto a curve of profile depths from known age profiles (the Exposure Response Curve, or ERC, approach). Generating ERCs by artificially illuminating surfaces at very high intensities to bracket the unknown profile, may provide calibration profiles of arbitrary 'age', determined by the total number of incident photons. Such an approach is very likely to give more accurate and precise light-exposure ages than using parameters calculated from first principles, or than using a single natural calibration profile (as is current practice).

The model dependency of rock surface burial dating is also investigated, and encouragingly it is concluded that the accuracy of burial dating is not significantly affected by the application of inappropriate models to determine the exposure history of a buried surface (and thus the degree of bleaching before burial).

Dating rock surfaces accurately requires that the environmental dose rate is modelled, because the dose rate is also depth dependent and influenced by the size of the rock itself. A simple analytical model designed with this is mind is presented and applied.

To investigate the accuracy and precision of rock surface dating, both rock surface and standard OSL dating are applied to two important archaeological sites in Central France. These two different applications determine: 1) the timing of the changeover from Neanderthal to anatomically modern humans, and 2) that Neanderthals were capable of making symbolic engravings on cave walls. In the first case, rock surface dating is successful, but in the other, the signal of interest recorded by the rock surfaces appear to have been erased by a prolonged exposure to daylight prior to sampling, or removed by significant erosion of the surface, and only the sediments retain the chronological information. These two application studies illustrate both the potential and some of the limitations of the method.

A PDF of this thesis and can be downloaded from Ancient TL.

***Elin Jirdén***

**OSL dating of the Mesolithic site Nilsvikdalen 7, Bjorøy, Norway.**

*June 2022*

Lund University, Lund, Sweden

*Degree: M.Sc.*

*Supervisors: Helena Alexanderson and Amber Hood*

Luminescence dating is a well-established dating method within geological and archaeological research. However, the use of luminescence dating, and more specifically optically stimulated luminescence (OSL), is currently underutilised in Norwegian archaeology. This study set about determining the suitability of this dating method as a viable option for excavations of Norwegian coastal Stone Age sites. This is done

by OSL dating six samples from three superimposed cultural layers at a settlement (Nilsvikdalen 7) at Bjorøy, SW Norway, which has previously been radiocarbon dated to the Late Mesolithic period, and subsequently evaluating the method suitability from the results.

The cultural layers all consist of varying degrees of humus-rich sand with charcoal, where OSL samples were taken from inside and outside an interpreted hut structure. Quartz OSL dating was carried out using the Single Aliquot Regenerative-dose (SAR) protocol for all six samples and yielded successful results. The samples displayed a strong quartz signal with excellent characteristics. The water content of the site yielded the highest uncertainties for the dose rate determination and was after thorough evaluation determined to ~63 – 114%. Dose rate was determined to ~2 – 4 Gy/ka. Different age models were applied, where the mean age was chosen for the final age determination. The bottom cultural layer was dated to the Late Mesolithic, with OSL ages of 8.07 ± 0.51 ka and 7.02 ± 0.43 ka inside the hut, as well as 6.60 ± 0.40 ka outside the hut boundary. The middle and upper layers were dated to Late Mesolithic – Early Neolithic, where the middle unit displayed an age of 6.25 ± 0.36 ka and the upper layer yielded ages of 5.56 ± 0.32 ka and 6.94 ± 0.36 ka (all dates inside the hut). Three of the samples overlap with the corresponding radiocarbon dates, whilst the other three do not statistically agree (values outside of ± 2 σ) with the radiocarbon dates. For the samples without statistical agreement, the OSL ages produced are younger than the corresponding radiocarbon dates.

For future OSL dating it is suggested to, if possible, take a control sample of recent or known age from a site area to reduce possible uncertainties in the luminescence age determination process. Given the successful dating of the Nilsvikdalen 7 site, this project demonstrates how OSL dating could provide a good solution for future dating of Norwegian coastal Stone Age sites.

***Raju Kumar***

## A new understanding of luminescence processes in feldspar using novel site-selective spectroscopic techniques

*March 2020*

Department of Physics, Technical University of Denmark, Risø Campus, Denmark

*Degree: Ph.D.*
*Supervisors: Dr. Mayank Jain and Dr. Myungho Kook*

Metastable states in solids are widely used for dosimetry and photonic applications. Feldspar, a ubiquitous naturally occurring aluminosilicate, consists of many defects and impurities; some of these transform into metastable states by capturing electrons or holes, when exposed to ionizing radiation. These metastable states can have lifetimes of millions of years rendering feldspar useful for luminescence geochronology. In this dating technique, the dose-dependent concentration of the metastable states (generated by ionizing radiation) is measured via optically stimulated luminescence (OSL) or infrared stimulated luminescence (IRSL) signals. These signals are generated by charge transfer across the metastable states, followed by electron-hole recombination resulting in the emission of light.

Despite many decades of research, the luminescence mechanisms and the associated defect system in feldspar are poorly understood; for example, the defect responsible for the main dosimetric trap (i.e. principal trap) and its physical characteristics are still unknown. This lack of knowledge may largely be attributed to the inherent physical processes involved in OSL and IRSL generation. The OSL/IRSL technique is not ideal for characterizing the principal trap (e.g. optical trap depth, electronic states, number of defects and their concentration, etc.) as it involves both electron and hole sites as well as the charge transport dynamics, making any interpretation of the electron-trapping state ambiguous. Therefore, it is desirable to use site-selective methods that can directly probe the principal trap without involving any hole sites in the emission process. The main purpose of this Ph.D. research is to advance our current understanding of the luminescence processes in feldspar and the associated defect system using site-selective multi-spectroscopic techniques.

This work shows that there are two principal traps in K-Na feldspar. These traps emit Stokes-shifted infrared photoluminescence (IRPL) bands centered at 1.41 eV (880 nm) and 1.30 eV (955 nm). The two trapping centers have similar electron capture cross-sections and excited-to-ground state relaxation lifetimes, but different trap depths and excited-state energies. These results suggest that the 1.41 eV and 1.30 eV emission centers consist of the same defect that resides in two different sites and, thus, experiences different crystal fields. Cathodoluminescence (CL) microscopy explores the question on the spatial variability of the two principal traps and their link to feldspar composition. CL investigations suggest that the two emission centers (i.e. the two traps) vary spatially even within a single-grain of feldspar and their relative emission peak intensity (1.30 eV vs. 1.41 eV) shows a correlation with the K-Na content. This work sheds new light on the long-standing issues of estimation of trap depth in feldspar, and whether there are single or multiple traps giving rise to the OSL/IRSL signals.

This Ph.D. research also establishes a link between the IRPL emission bands (1.41 eV and 1.30 eV) and the OSL/IRSL phenomenon. Tracking of changes in IRPL (i.e. trapped electron population) due to IRSL (i.e. electron and hole populations) shows that a) both the 1.41 eV and 1.30 eV centers participate in IRSL, and b) only a fraction of the principal trap population participates in the IRSL at a given measurement temperature. A comparison of thermal depletion of IRSL and IRPL signals suggests that the trapped electrons in the principal trap are quite stable up to about 400 °C. The decrease in IRSL because of preheating to 300-400 °C occurs due to the depletion of holes; the holes are used up during the TL measurement (i.e., preheating) prior to the IRSL measurement. Furthermore, it is observed that the electron trap-

ping probability in the principal trap is both a function of its electron capture cross-section and its distance to the nearest hole. This new understanding is anticipated to play a crucial role in the development of mathematical models of luminescence phenomena involving metastable states. Finally, the test of the potential of IRPL in sediment dating suggests that IRPL can be successfully adapted to a SAR protocol; it recovers accurate equivalent doses from 100 to 300 Gy (age range 20-128 ka) without a fading correction.

In terms of practical utility, a new measurement facility for detecting infrared photoluminescence (IRPL) at 1.41 eV (880 nm) and 1.30 eV (955 nm) for routine dosimetric measurements has been developed. Furthermore, a dose measurement protocol, i.e. coupled IRPL-IRSL SAR protocol, is developed to measure natural doses in feldspar using IRPL. This work establishes a fundamentally different dating technique based only on trapped electrons, compared to the existing OSL and IRSL dating techniques.

A PDF of this thesis can be downloaded from: https://orbit.dtu.dk/en/publications/a-new-understanding-of-luminescence-processes-in-feldspar-using-n and from Ancient TL.

***Kieran O'Gorman***

**Internal dose rates of single feldspar and composite mineral grains: Methodological developments and optical dating applications**

*August 2021*

University of Wollongong, Wollongong, Australia

*Degree: Ph.D.*

*Supervisors: Zenobia Jacobs, Bo Li, Dominique Tanner*

Optical dating of feldspar grains is playing a pivotal role in establishing timelines for hominin occupations in many parts of the world, including the Altai and Wallacea—two regions that are research hotspots for the study of human evolution, ancient dispersals and inter-group hominin interactions. A key challenge of optical dating of feldspar grains is determining the radioactivity within individual grains that are used for dating. Feldspar grains can contain up to ~ 14 wt% potassium (K) and considerable concentrations of rubidium (Rb), thorium (Th) and uranium (U), all of which have radioactive isotopes that give rise to an internal dose rate component. The internal dose rate can have a major impact on both the precision and accuracy of optical age estimates.

Feldspar grains are often composed of multiple mineral phases of variable compositions. Previous techniques used to determine K concentrations of feldspar grains are time-consuming, and either lack the spatial resolution to classify discrete mineral phases within grains or the coverage to obtain whole-of-grain average K concentrations. Samples from two sites (Ust'-Karakol-1 in the Altai and Leang Bulu Bettue in Wallacea), located in contrasting geological settings (plutonic versus volcanic terranes), are used to develop an approach where quantitative evaluation of minerals using energy-dispersive spectroscopy (QEM-EDS) is used to rapidly determine whole-of-grain average K concentrations of individual luminescent feldspar grains.

This approach is also applied to samples from two iconic archaeological sites: Denisova Cave in the Altai and Liang Bua in Wallacea. Individual luminescent grains from Denisova Cave are dominated by low-temperature feldspar varieties, which are characteristic of plutonic terranes; most grains are K-rich. Individual luminescent grains from Liang Bua are composite mineral grains composed of a range of feldspar varieties, quartz, clay minerals, heavy minerals and volcanic glass. These grains have a broad range of whole-of-grain average K concentrations—most are low-K. A novel approach, using QEM-EDS and laser ablation inductively coupled plasma mass spectrometry, is developed to investigate the K, Rb, Th and U concentrations of these grains, and determine single-grain and sample-average internal dose rates. Samples from different sedimentary contexts at the site have different internal dose rate distributions.

The potential of using infrared stimulated luminescence (IRSL) and post-infrared IRSL signal behaviours as proxies for K concentrations, as an alternative to directly measuring K concentrations, is investigated for one sample with a broad range of K concentrations. Signal intensity and fading rates are poor proxies, whereas thermal stability shows good potential for selecting the most K-rich grains with the most thermally stable IRSL signals.

Finally, optical dating of K-rich feldspar grains from 32 sediment samples is used to construct a better-resolved chronology for the sedimentary deposits of the South Chamber of Denisova Cave. The internal and external dose rates and equivalent dose distributions of samples from three sedimentary profiles are scrutinised. The resulting chronology is compared to those previously obtained for Main and East chambers. Together, the data provide further insights into the timing of occupation of this iconic site by Denisovans, Neanderthals and modern humans.

***Choudhurimayum Pankaj Sharma***

**Paleoclimatic Reconstruction from the Late Pleistocene-Holocene Sedimentary Archives of Ladakh Himalaya.**

*April 2022*

Wadia Institute of Himalayan Geology, Dehradun, India, and Banaras Hindu University, Varanasi, India

*Degree: Ph.D.*

*Supervisors: Dr. Pradeep Srivastava and Prof. Uma Kant Shukla*

The climate which is as old as the earth itself has been ever-changing and the current understanding of climate and its variation which is based on barely three-century-old instrumental data is insufficient to assess the wider pattern, major forcing, and its effects. This demands better exploration of geological archives of climate variability. At present

mountainous areas such as the Himalaya is evidently responding to climate change mainly in the form of widespread glacial retreat. These events are not unnatural since comparatively larger changes were known to occur in the recent geologic past. However, with the rise in the population where the global 15% is dependent on the freshwater supply from Himalayan Glaciers and rivers, a slight change becomes crucial.

The Himalaya has been acting as a barrier to the Indian Summer Monsoon (ISM) rainfall where the area north of its highest peak remains a rain shadow. It is influenced by the three climatic systems Vis ISM, Westerlies, and the East Asian Summer Monsoon (EASM). Ladakh in its western part is one of such areas influenced partly by westerlies and partly by the ISM. Recently, Ladakh is known to be highly susceptible to hydroclimatic hazards and subjected to occasional catastrophic hydrological events, and is known to endanger lives and properties of people residing there. Detailed investigation of geological archives of climate is imperative to expand our knowledge of climatic variability and extreme events that rarely occur on the human timescale. Ladakh is known to be affected almost annually by debris flows ranging from minor to catastrophic scale events. Though triggered by abnormal climatic conditions the long-term causative factor has been its topography. The present thesis deals with past climate reconstruction, understanding flood history, and past extreme hydrological forces that directly impact the infrastructures and lives of inhabitants of Ladakh.

To reconstruct the past climate, a chronologically well-constrained sedimentary archive from Upshi (Ladakh) was studied using a multi-proxy approach i.e. (palynological, geochemical-stable isotopic analysis, and environmental magnetism). Several slack water deposits (SWDs) preserved along the Indus River at Ladakh were explored to reconstruct past floods. SWDs are stacks of sand-silt couplets deposited rapidly during large flooding events in areas where local geomorphic conditions cause a sharp reduction of flow velocity. Each couplet represents a flood and here the age is constrained using Optically Stimulated Luminescence (OSL) for sand and AMS 14C for charcoal specks from hearths. Lastly, in an attempt to understand the role of debris flows in landscape evolution through time and space, past events were investigated using sedimentary facies analysis and luminescence chronology. All ages fall in the Holocene Epoch. Three independent methods namely Weights of Evidence (WOE), index of connectivity (IC), and Flow-R model were used to examine the vulnerability of the region to debris flow hazards.

So based on these studies the last three millennia is known to witness three major climatic oscillation- (1) warm from ~ 2.7 to 1.8 ka, (2) cold from ~ 1.8 to 1.1 ka, and (3) warm from ~ 1.1 to present and the record is comparable to the climatic history of the Ganga and its foreland. After the last glacial maximum, three phases of increased extreme flood recurrence happened – from ~ 14 to 11, ~ 10 to 8, and ~ 7 to 4 ka with increased penetration of ISM. The provenance study suggests Zanskar River is highly erosive during floods. The presence of hearths also indicates ancient human activity and the timeframes were established using the 14C ages opening up the question of past Human existence in this region for further studies. The warm climatic phases were found to be influenced by planetary warming and solar insolation in the last three millennia. The high flooding phases were also found to be connected with the dynamics of the arctic region. The study of debris flow indicates they were an important agent of denudation and aggradations and such events will continue to occur regardless of human activities. The susceptibility and risk analysis suggest presently Phayang, Shakti and Kharoo are conductive for frequent gully centric flows whereas the rest is likely to get buffered. However, this might lead to higher magnitude but lesser frequency mass flow events.

***Nupur Tiwari***

## Technology, chronology and landscape archaeology of microlithic occurrences in the central Narmada Basin, Madhya Pradesh, India

*May 2022*

Indian Institute of Science Education and Research, Mohali (IISER), Punjab, India

*Degree: Ph.D.*
*Supervisor: Dr. Parth R. Chauhan*

The research carried out for this PhD thesis aimed to survey open-air microlithic sites in Sehore and Hoshangabad Districts of the central Narmada Basin or river valley in Madhya Pradesh, India. Geographically, the surveys were targeted along the Vindhyan Hills to the north of the basin, along the Gondwanas or Satpuras to the south of the basin and the intermediate Narmada floodplain zone in the centre, thus dividing the study area into three distinct zones, i.e. northern, central and southern. The study area selected for this study is located in the central region of the Indian Subcontinent. This region must have served as a corridor for various faunal species and hominins (abundant vertebrate and invertebrate fossils and the only-known archaic hominin fossil, a partial cranium, was discovered in this region). The goal of this research was threefold: (1) to understand the geoarchaeological and spatial contexts of the microlithic record and associated attributes in the central Narmada Basin, (2) to establish a preliminary geochronological framework of microliths in this region and spatially document the evidence to reconstruct the landscape adaptations by hominins in the north, central and south of the Narmada River in this part of the basin and (3) to address specific characters of the regional microlithic typology, technology and chronology in the study area and broad comparisons with other regions of India.

Luminescence dating was applied at key sites to understand the temporal context of the microlithic record in the study area. This provided a broad antiquity to the distribution of microliths in the valley, contributing to more robust interpretations of the region's occupational history. There are no

lengthy stratigraphic sections bearing microliths *in situ*, except for a few sloping sedimentary horizons that were eroding. These sedimentary horizons regularly yielded microliths and were least disturbed; few of these sites were selected for OSL dating.

The scarcity of dateable microlithic sites was observed during the explorations and surveys. Most of the sites appeared in the pediment zone of Vindhyan and Gondwana foothills. The context of all these sites and occurrences are varied, which points towards a significant and intensive use of the landscape and highly mobile groups of hunter-gatherers. The immense spread of microliths around this region and their absence in some pockets is now better understood through intensive surveys. Sites for OSL sampling were selected after exploring all accessible regions with thick sediment accumulation and the appearance of associated microliths eroding out. The selected sites were visited multiple times before deciding upon specific locations for sample collection. Hence, the least disturbed sites with microlithic occurrences were selected to understand the nature and timing of the burial of these microliths as well as the general age of their sedimentary contexts.

Specific criteria were fixed before sampling was carried out, including the assemblage size and artefact condition. Four sites from the northern region, i.e. Pilikarar-I, Pilikarar-II, Naganpur-I and Chikli, and two sites from the southern region, i.e. Morpani and Parccha were selected.

Infra-red ($870 \pm 40$ nm) stimulated luminescence (IRSL) was measured using the combination of Schott BG 39 and Corning 7-59 (320 – 460 nm). Optically stimulated luminescence (OSL) from quartz was measured using a 7.5 mm Hoya U-340 ($330 \pm 35$ nm) after blue light stimulation ($470 \pm 20$ nm). Single aliquot regenerative dose (SAR) procedure was used to estimate the equivalent dose using IRSL as suggested by Murray and Wintle (2003). Any sensitivity changes that occurred during the multiple heating, stimulation and irradiation in the sample may be corrected by a constant subsequent test dose luminescence signals. Preheat temperature for polymineral fine grains and coarse grain quartz grains were 250 °C and 240 °C, respectively. Each aliquot was subjected to a strict set of criteria before being accepted, and those criteria are 10% of test dose error, 10% of recycling dose and 5% recuperation dose. These fine grains are polymineral in nature, and only feldspar grains emit IRSL. IRSL of irradiated feldspar exhibit fading with time, and hence fading rate of IRSL for each sample was estimated as per the method adopted by Auclair et al. (2003). All the luminescence measurements were carried out in Risoe TL/OSL Reader Model DA-20 (Bøtter-Jensen, 2003). Luminescence ages were calculated using equivalent dose divided by dose rate, and the fading corrected ages were obtained using the calculated fading rates following the procedure established by Huntley and Lamothe (2001). Dates obtained through fine-grained IRSL confirm microliths' last burial age between Late Pleistocene to Late Holocene (~ 50 ka – 2 ka).

A PDF of this thesis can be requested from: nupurti-wari05@gmail.com