Thesis Abstracts

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Pavlos G. Konstantinidis

Discrimination of different recombination pathways of luminescence in thermoluminescence detectors: optimization over thermal stimulation and detector material

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Aristotle University of Thessaloniki, Physics Department, Thessaloniki, Greece

Degree: Ph.D.
Supervisors: Prof. George Kitis, Prof. Alexanda Ioannidou, Dr. George S. Polymeris

The primary objective of the present doctoral dissertation is to investigate the underlying mechanisms behind the localized and the de-localized recombination pathways during luminescence phenomena, as well as the semi-localized theory. The study begins with an experiment aimed at identifying two main overlapping thermoluminescence (TL) peaks in BeO Radkor, each following different recombination pathways. Thus, a refined protocol is developed to analyse the pathways, using various experimental techniques and heating treatments to distinguish between the two mechanisms.

However, to create the perfect protocol, in addition to BeO Radkor, two more standard dosimetric materials were also used, namely MgB_4O_7:Dy,Na and LiB_4O_7:Cu,In, as it is known from the literature that the first follows the localized pathway, while the second follows the de-localized pathway. The first attempt to create the desired protocol led to a new experimental procedure, which includes techniques like Initial Rise, Peak Shape Methods, and Isothermal Decay, utilizing the Lambert W function. Using this new approach, the activation energies of all the materials were calculated.

To improve the protocol, some modifications were made, including pre-heating treatments of the samples. The second attempt was partially successful, as in the cases of BeO Radkor and MgB_4O_7:Dy,Na, where signs of the transition between the two different recombination pathways were observed. Ultimately, a last modification was made, incorporating both previous protocols and with the help of the final protocol and the use of equations involving the Lambert W function, the desired outcome was achieved: the transition from the localized to the de-localized pathway in the case of BeO Radkor was observed, strengthening the semi-localized theory. This optimized protocol was also applied to MgB_4O_7:Dy,Na, in which some changes were indeed observed, meaning that a more intense pre-heating treatment could also lead to the transition between the two mechanisms.

The outcome of the dissertation affirms that, with specific thermal treatments and a unique protocol, the semi-localized theory is substantiated, demonstrating the feasibility of transitioning between the two recombination mechanisms.

A PDF of this thesis can be obtained by contacting the author: pavkonst@physics.auth.gr

Anna-Lena Geis

The Chronology of the Riedstadt-Erfelden Drill Core: Application and Comparison of Multi-Method Luminescence Dating

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Justus-Liebig-University Giessen, Department of Geography, Giessen, Germany

Degree: M.Sc.
Supervisors: Prof. Dr. Markus Fuchs, Dr. Mariana Sontag-González

The Upper Rhine Graben is a rift system that contains one of the most continuous sequences of unconsolidated Cenozoic sediments deposited by the river Rhine. Furthermore, its position between the northern European inland and alpine glaciation during the Pleistocene makes it a valuable archive for understanding the interactions of tectonic and climatic control on sedimentation and erosion processes. Thus, numerous drilling projects have been carried out in recent decades. In 2020/21, the Hessian State Agency for Nature Conservation, Environment and Geology (HLNUG) carried out a new continental drilling project near Riedstadt-Erfelden in Hesse, Germany, to obtain further information on the development of the northern Upper Rhine Graben infillings.

This thesis presents new chronological information on the upper section of the core derived from combined luminescence dating approaches. Previously published optically stimulated luminescence (OSL) and infrared radiofluorescence (IR-RF) ages of this core are complemented by recalculated OSL ages due to a new laboratory source calibration and by new measurements using infrared-stimulated luminescence (IRSL), post-infrared-IRSL (pIRIR), and infrared photoluminescence (IRPL). The latter is a novel approach that utilises a potentially non-destructive and non-fading signal from K-feldspar. For the first time, the multiple elevated

temperature (MET)-pIRIR-IRPL single aliquot regenerative dose (SAR) protocol was applied to fluvial samples covering a large age span. Also, a fading test was conducted, and the effect of a varying test dose size was investigated on the signals derived from the protocol.

IRPL ages are in agreement with Middle Pleistocene luminescence ages of previous studies and biostratigraphic and palaeomagnetic data, while showing negligible fading and less sensitivity to a varying test dose size than pIRIR signals. This could be a major advantage of the method. However, IRPL ages overestimate Late Pleistocene quartz OSL ages, an observation that should be investigated further in future studies. Differences in ages between IRPL and IRRF, although both signals are thought to arise from the same dosimetric trap, could be due to the required differences in sensitivity correction methods. The $pIRIR_{225}$ and $pIRIR_{290}$ ages generally overestimate OSL and IRPL ages, while fading correction of $IRSL_{50}$ ages was not successful, as they still underestimate quartz ages, emphasising the advantages of utilising a potentially non-fading K-feldspar signal. Combined ages indicate a deposition of the Mannheim Formation during the Elsterian-Holsteinian (MIS 11–12) to Weichselian (MIS 2) and a Cromerian (MIS 13–21) age of the Ludwigshafen Formation.

A PDF of this thesis can be obtained by contacting the author: anna-lena.geis@uni-giessen.de.

Aimin Zhang

Quantifying pedoturbation and reconstructing pedogenesis in black soils using single-grain luminescence techniques

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Chinese Academy of Sciences, Nanjing Institute of Geography and Limnology, Nanjing, China

Degree: Ph.D.
Supervisor: Hao Long

Black soils are vital global "granaries" and terrestrial 'carbon sinks". Studying their age and evolution helps predict future trends and guide conservation efforts. Traditional soil age determination relies on radiocarbon (^{14}C) dating of soil organic matter, but soil's open-system nature leads to mixed-age results. This study approaches the issue from the perspective of soil mineral particles, utilizing single-grain (SG) luminescence dating to characterize the mixing features of black soils and, on this basis, reconstructing its formation process in combination with the deposition history of its parent material.

This study focuses on a black soil profile (GN1) with multiple krotovina (filled animal burrows) in a typical black soil region of Northeast China, as well as four black soil profiles (LS1, SH1, HL5, BA1 from south to north) developed on loess parent material under stable geomorphic conditions across a latitudinal gradient. For each profile, samples for soil property analysis, luminescence dating, and environmental dose rate determination were collected. Basic soil properties — including particle-size distribution, soil organic carbon content, and pH — were measured to characterize the physicochemical characteristics of the profiles. For luminescence dating, quartz and potassium feldspar (K-feldspar) grains were extracted. Both minerals underwent pretest evaluations (e.g., bleaching tests, preheat plateau tests and dose recovery tests) to assess their luminescence characteristics and ensure measurement reliability. Considering testing efficiency, K-feldspar was ultimately selected as the primary material for SG equivalent dose (D_e) determination using the $pIRIR_{225}$ signal.

After comprehensively evaluating the effects of instrumental reproducibility, grain-to-grain variations in luminescence properties, heterogeneous bleaching, and micro-dose rate variations on D_e distributions, the pedoturbation patterns were interpreted. Three indicators—the proportion of zero-dose grains (P_0), overdispersion (OD) of D_e distributions, and the k/p_{max} value derived from the Finite Mixture Model—were used to assess modern downward pedoturbation intensity, overall pedoturbation intensity, and pedoturbation structure, respectively.

To validate the effectiveness of luminescence indicators in characterizing soil mixing, GN1 was analysed by comparing luminescence samples from inside and outside krotovinas. Additionally, regional variations in pedoturbation characteristics were investigated across the four latitudinally distributed black soil profiles. Finally, the formation history of the black soils was reconstructed based on a comprehensive understanding of their soil mixing characteristics. The main findings are as follows:

1. The OD values of single-grain K-feldspar D_e distributions from the five black soil profiles ranged from 21 % to 163 %. Dose-rate analyses and controlled experiments demonstrate that instrumental reproducibility and inter-grain luminescence variations collectively contribute 9–18 % to the OD values, while β-micro-dose-rate heterogeneity accounts for 10–23 %. Heterogeneous bleaching exerts negligible influence. Soil mixing was identified as the dominant factor controlling the dispersion of D_e distributions in the upper horizons of all profiles.

2. The krotovina formation histories of the GN1 profile were reconstructed by comparing intra- and extra-krotovina SG age distributions with depositional contexts. The results indicate that the two black krotovinas (at 80 cm and 160 cm), whose filling materials both mainly originated from the upper soil horizon, were formed during a coeval rapid filling event ≤ 2.7 ka. In contrast, the yellow krotovina at 70 cm was filled with material derived from the lower section of the profile and formed after the initiation of black soil formation.

3. All loess-derived black soil profiles, except the northernmost BA1, contain detectable zero-dose grains.

Within the active mixing zone (defined by maximum zero-dose grain penetration), each profile exhibits coherent decreasing trends in P_0, OD, and $k/p_{\max}$ values with depth, demonstrating widespread, depth-dependent weakening of pedoturbation intensity. Spatially, the thickness of the active mixing zone decreases latitudinally from 100 cm (LS1, southernmost) to 35 cm (BA1, northernmost), accompanied by a sharp decline in surface P_0 values from 46–36 % to 3–0 %. These findings reveal a significant northward decrease in soil mixing intensity that correlates well with documented latitudinal patterns of soil faunal activity intensity across Northeast China's black soil region.

4. The deposition age of loess beneath the mollic epipedon (SOC > 6 g kg^{-1}) in profiles LS1, SH1, HL5, and BA1 constrains their black soil ages to no more than 28 ka, 21 ka, 18 ka, and 20 ka, respectively. SH1, HL5, and BA1 retain original depositional signals of the loess parent material within the mollic epipedon, indicating dust accretion during black soil formation, whereas LS1 lacks such signals due to intensive pedoturbation. However, numerical simulations and luminescence profile comparisons under stable versus accreting surface scenarios confirm concurrent dust accretion in LS1 as well. A pronounced mixing intensification marks the onset of black soil formation in LS1 at $\sim$16 ka.

A PDF of this thesis can be obtained by contacting the author: zhangaimin21@mails.ucas.ac.cn