1. PHD PROJECT DESCRIPTION (4000 characters max., including the aims and work plan, all in English)

Project title:

Thermally modulated optically stimulated luminescence (TM-OSL) in dating sediments of volcanic origin.

1.1. Project goals

The overarching aim of the project is to find a new approach for OSL dating of sediments which contain quartz of volcanic origin. The way this aim is going to be achieved is the application of thermally modulated optical stimulation method for the selective detection of the most effectively bleached OSL components in volcanic quartz and systematic investigation of traps responsible for this signal for the establishing its thermal stability.

1.2. Outline

Quartz is the mineral most often used for age estimation in sediment OSL dating [1-2]. The OSL signal of quartz consists of individual components with different bleaching and saturation characteristics [3-7]. The so-called fast OSL component is the best recognized OSL component in quartz. It is also the most desirable OSL signal in the dating practice, because it is proved that it is most effectively bleached by sun light during the mineral grains transport before the deposition. The complete bleaching of the OSL signal prior to sediment layer creation is the main assumption of OSL dating. It happens that quartz grains separated from sediment do not show the fast component at all, as for example, in the known case of sediment deposited by the AD 869 Jogan tsunami on the Sendai Plain, north-eastern Japan [8]. Similar problems arose in projects recently implemented in Africa by a few archaeological groups in the international cooperation [9-10].

The East African rift is known for having a good record of lower Palaeolithic periods. A lot of valuable archives of early hominid were found in this area. It is also important in the debate of the “Out of Africa” hypothesis, or for the study of the transition from Middle to Later Stone Age (MSA/LSA) cultures. The projects mentioned above focus on the end of the transition from LSA to Neolithic cultures (i.e. from hunther-gatherers to food producers) in Ethiopia. The sediment samples collected in the frame of these projects for OSL dating contain the quartz of volcanic origin and reliable dating results could not be obtained when using the standard methods.

The signal of quartz from volcanic sediments is often dominated by a medium component, which is considered to be thermally unstable and unsuitable for dating. These poor properties have been known for long [11-13], but up to now, traps being the source of this signal are not identified. Recently, some tests were carried out in dating laboratory at NCU for a few examples of the African samples as well as for the Jogan tsunami samples from Japan. The results proved that the OSL of quartz grains extracted from both sediments does not contain the fast component. The observed medium component, however, turned out to be a complex one. This finding was possible thanks to the new optical stimulation technique, called thermally modulated OSL, which has been

introduced in the local laboratory [14]. It allows for better separation of the individual components of OSL signal TM-OSL measurement rely on a continuous optical during a linear heating of the sample. The adequate selection of parameters that affect the TM-OSL process (the stimulation energy, the photon flux density and the heating rate) enables the much better separation of individual OSL components than the methods used so far [15]. The complexity of medium component in volcanic quartz indicates that it origins from several traps. This gives a chance to separate a thermally stable part of this signal. It can be achieved by the specially optimized TM-OSL stimulation after the identification of the source trap.

Summing up, the works planned in the project consists in the intensive investigations of the OSL medium component and developing the TM-OSL measurement which allows to detect solely the stable part of the dominating OSL signal in the volcanic quartz. The final achievement of the project, if the previous steps succeed, will be a new dating protocol dedicated to sediments of volcanic origin. The new protocol will be tested using the problematic African sediment samples.

1.3. Work plan

Task 1 – TM-OSL measurements of selected samples of volcanic quartz aimed to establishing the optimal experimental parameters for effective separation of the medium OSL components.

Task 2 – Estimating the parameters of traps responsible for the medium components.

Task 3 – Testing the TM-OSL signal of volcanic quartz from various locations for checking the generality of the previously obtained data.

Task 4 – Measurements of the dose response curves of TM-OSL medium components to determine the time range of dating with use of this signal.

Task 5 – Developing the single aliquot regeneration dose protocol using the TM-OSL medium component.

Task 6 – Testing the new protocol using a set of African sediment samples.

1.4. Literature

[1] M.J. Aitken, Introduction to optical dating: the dating of Quaternary sediments by the use of photon-stimulated luminescence, Oxford University Press, Oxford, UK, 1998.
[2] A.G. Wintle, Fifty years of luminescence dating, Archaeometry 50 (2) (2008) 276-312.
[3] J.S. Singarayer et al., Assessing the completeness of optical resetting of quartz OSL in the natural environment. Radiat. Meas. 40 (1) (2005) 13-25.
[4] M. Jain, A.S. Murray, L. Bøtter-Jensen, Characterisation of blue-light stimulated luminescence components in different quartz samples: implications for dose measurement, Radiat. Meas. 37 (4-5) (2003) 441-449.
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[10] Brandt, S.A. et al., A new MIS 3 radiocarbon chronology for Mochena Borago Rockshelter, SW Ethiopia: Implications for the interpretation of Late Pleistocene chronostratigraphy and human behavior, Journal of Archaeological Science: Reports 11 (2017) 352-369.
[11] Choi, J.H., Duller, G.A.T., Wintle, A.G., Cheong, C.S. (2006). Luminescence characteristics of quartz from the Southern Kenyan Rift Valley: Dose estimation using LM-OSL SAR. Radiation Measurements, 41(7-8), 847-854.
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[13] Tsukamoto, S. et al., Luminescence property of volcanic quartz and the use of red isothermal TL for dating tephras. Radiation Measurements 42 (2007), 190-197.
[14] Chruścińska A., Kijek N., Thermally modulated optically stimulated luminescence (TM–OSL) as a tool of trap parameter analysis, J. Lumin. 174 (2016) 42-48.
[15] Chruścińska A., Szramowski A., Thermally modulated optically stimulated luminescence (TM-OSL) of quartz, J. Lumin. 195 (2018) 435-440.

1.5. Required initial knowledge and skills of the PhD candidate

The candidate is expected to have an experience with the measurements of stimulation luminescence of minerals and the sample preparation required for such experiments. The ability to use software commonly used for OSL and TL data acquisition and analysis is also very highly valuable as well as the good knowledge of Matlab.

1.6. Expected development of the PhD candidate's knowledge and skills

The PhD student will develop the knowledge about luminescence dating and will use it to investigate sediments which are among others crucial for establishing the chronology of human occupations and migrations at Ethiopia during Middle to Later Stone Age (280 000 - 20 000 years BP). The Candidate will have opportunity to evolve the luminescence dating techniques adequate for sediments of volcanic origin which up to now are problematic because of their luminescence properties. To accomplish this, the OSL characteristic of quartz separated from these sediments will be investigated with application of several new techniques developed in the Luminescence Dating Laboratory at NCU. The proper use of these methods requires a deep understanding of stimulated luminescence processes which will be another candidate skill developed during the preparation of the PhD thesis.