Verification of fundamental rules of luminescence dating – the dose-rate effect and alternative models of radiative excitation.

(description for the general public)

To study the past we can rely on those properties of matter that are permanent or change in an easily predictable way. Ionizing radiation has been present on the Earth for millions of years. It consists of high-energy photons, electrons, or heavy particles. It is constantly present in the natural environment, mainly because of the commonly occurring radioisotopes and cosmic rays.

A few decades ago, it was discovered that in nature there are minerals that can "remember" the dose of absorbed radiation. This information can be stored for thousands or even millions of years. This natural clock measures the time elapsed since sediments were last exposed to sufficient heat or sunlight. The accumulated dose can be read in laboratory. This way one may calculate the age of the mineral using the simple formula:

$$\mathrm{Age\ [a]} = \frac{\mathrm{paleodose\ [Gy]}}{\mathrm{dose\_rate\ [Gy \cdot a^{-1}]}} \tag{1}$$

Dose rate is derived from either direct measurement or radionuclide concentrations. Paleodose (the natural dose) can be measured in laboratory using thermoluminescence (TL) or optically stimulated luminescence (OSL) phenomena. The dose is estimated by comparing the TL or OSL readout from a natural mineral to laboratory growth TL/OSL curve.

The basic problem of this method relates to different conditions of excitation. The natural dose was delivered at very small dose rate during thousands or millions years. The laboratory excitation is much faster. In some cases the laboratory dose rate is greater by 10 orders of magnitude. There are some theoretical arguments that these two types of excitation are not the same. We call it dose-rate effect. Nevertheless, the experimental evidence is very weak. There is no clear evidence for or against it.

The dearth of experimental investigation is both unexpected and astonishing considering the importance of the problem for the accuracy of luminescence dating applications. Most likely this is the most important problem in luminescence dating of geological and archeological objects.

The aim of the project consists of three parts:

- **Systematic experimental test (verification) of the dose-rate TL and OSL response** for beta and gamma irradiation in the range of 6 orders of dose-rate magnitude which is planned for at least two years of observation. Several natural and laboratory grown materials will be tested with more than one thousand samples.
- **Investigation and theoretical analysis of TL and OSL spectral properties on the dose rate.** Identification of localized and delocalized recombination routes in some materials is expected.
- **Development of new models of radiative excitation** taking into account spatial correlation between generated hole-electron pairs and diffusion of charge carriers.

The expected most important result of the project will be confirmation (or not) of the principle of independence of TL and OSL measurements from the dose rate of excitation. The result is **crucial for luminescence dating.** In the case of confirmed dose-rate dependence for some materials, most likely it will be possible to calculate relevant **correction factors** for determining the absorbed dose. This, in turn should make the luminescence dating more reliable.