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OPTICALLY STIMULATED LUMINESCENCE OF QUARTZ FOR PROVENANCE ANALYSIS

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Introduction: Quartz is one of the most common minerals forming continental crust rocks and is abundant in siliciclastic sediments, especially silt (4-62 μm) and sand (62-2000 μm). Quartz sediment grains are also present in construction products, such as ceramics and bricks. Retrospective dosimetry using optically stimulated luminescence (OSL) of quartz is well known and successfully applied for dating geological and archaeological materials. However, quartz OSL is also useful to track the origin or "provenance" of quartz sediment grains. Thus, the provenance analysis of quartz is helpful to solve several problems in Earth and Archaeological Sciences and has excellent potential for application in forensic issues. The sensitivity (light emitted per unit mass per unit dose) of the fast OSL component is the main characteristic used for the provenance analysis of quartz. This is supported by the relationship between OSL sensitivity and the irradiation and light exposure history of quartz grains on Earth Surface. In this work, we will show the range of OSL sensitivity observed in quartz from different geological settings, results of experiments designed to understand the OSL sensitization in the Earth surface, and discuss potential controls leading to high variation in quartz OSL sensitivity in the single-grain scale.

Material and method: We used a suite of rock and sediment samples from different geological settings in South America to characterize the natural range of quartz OSL sensitivity. Sediment samples were treated to concentrate quartz grains in the 180-250 μm grain size. This included wet sieving to isolate the target grain size fraction, treatments with oxygen peroxide (H_2O_2), hydrochloric acid (HCl), and hydrofluoric acid (HF) to respectively eliminate organic compounds, carbonates and other silicates (mainly feldspar), and heavy liquid separation using metatungstate solutions at densities of 2,75 and 2,62 g/cm^3. Rock samples were measured using slices with around 1 mm thickness. Luminescence measurements were carried out in Risø TL/OSL-DA-20 readers equipped with blue and infrared LEDs for stimulation, Hoya U-340 filters for light detection in the ultraviolet band, and a built-in Sr^{90}/Y^{90} source for beta irradiation. One reader is also equipped with an EMCCD camera, which allowed acquiring spatially-resolved luminescence data for rock slices and sediment single grains. The OSL sensitivity was measured using signals regenerated by beta irradiation after bleachingnatural signals using blue LEDs.

Results: The OSL sensitivity of quartz sediment grains varies by five orders of magnitude (10^{-1}-10^4 cts mg^{-1} Gy^{-1}). Quartz with high sensitivity (>10^2 cts mg^{-1} Gy^{-1}) was only observed in sediments. This large range of variation is related to the sensitization of the fast OSL component in sediment samples that experienced successive events of solar exposure (bleaching) and burial irradiation. Thus, the OSL sensitivity correlates with the lifetime of quartz as a sediment grain. We observe significant variation in OSL sensitivity between and within quartz grains of the same sample, suggesting a heterogeneous behaviour of the sensitization process. Laboratory irradiation-illumination cycles were able to increase quartz OSL sensitivity, but only with a limited sensitization that can be described by a saturating exponential behavior. The degree of sensitization is possibly dependent of the irradiation dose. In this case, the sensitization in nature will depend on the transient burial time of quartz sediment grain in sediment layers during their lifetime in surface systems.

Conclusions: The variation of quartz OSL sensitivity spanning five orders of magnitude allows the discrimination of quartz grains with different irradiation-bleaching histories. Although, the sensitization process is not fully understood in terms of the effect of irradiation-illumination cycles on quartz luminescence processes, the OSL sensitivity can discriminate sediments from different settings, supporting its use in sediment provenance analysis.