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The Problem of using Quartz as a radiation dosimeter: fundamentals of dose dependence

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Quartz is widely used as a radiation dosimeter in Quaternary geomorphological and archaeological dating applications through Optically Stimulated Luminescence (over 1,200 journal publications since 2000). However, obtaining an accurate equivalent radiation dose (D_E) can be challenging, especially where the luminescence intensity of the quartz is dim. The causes of variation in luminescence intensity between quartz grains of different provenances, transport and thermal histories is unknown, however it has been suggested that it relates to either the dosimetric history of the grain, or mechanical processes which occur in transit.

Investigation of the fundamental properties of the luminescence of quartz, enables investigation of dose dependent changes in luminescence intensity. A series of dose dependence experiments were conducted using spectroscopic ionoluminescence, which comprises the excitation of quartz with protons accelerated at 0.95 MeV. The energy delivered to the sample throughout ion implantation is similar to that received during gamma irradiation, and thus approximates sample radiation dosing.

A natural macro-crystal of α-quartz was investigated parallel and perpendicular to c, to observe any orientation dependent effects, as well as a calibration quartz from the Risø National Laboratory, Denmark, and a Scottish geomorphological sample, prepared using standard laboratory procedures. The calibration quartz sample has excellent luminescence intensity and is suited to analysis using the single-aliquot regenerative dose (SAR) standard OSL protocol, the Scottish sample alternatively has very dim luminescence and exhibits variable behaviour when analysed with SAR.

Despite the differences between the luminescence behaviour of the samples, all three responded to the dose dependence experiments in a similar manner. The UV/blue emission was observed to deplete with increasing dose, whereas the red emission, not normally analysed within OSL, exhibited increased luminescence intensity. The data provide insights into mechanisms that control the sensitivity of quartz to OSL. Irradiation modifies the way that energy is distributed between the various recombination pathways, notably favouring the red over the UV/blue. Quartz that has experienced substantial irradiation over geological time, such as Scottish quartz derived from the granite mountains of the Grampians, will luminesce relatively dimly in the UV/blue. The total irradiation budget of the quartz from formation to deposition to sampling is therefore encoded in its luminescence response.