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Review

Optically stimulated luminescence signals from quartz: A review

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HIGHLIGHTS

- Review of OSL signals in quartz.
- New developments in measurement techniques.
- New findings concerning the trap structure.

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ABSTRACT

Optically stimulated luminescence (OSL) was first observed from natural quartz 30 years ago. Since it increases with exposure to radiation, OSL has been developed as a dating tool for sediments. Most commonly, the OSL signal is observed using optical filters that pass wavelengths centred on 340 nm during optical stimulation at 470 nm. Experimental evidence behind the choice of measurement conditions for dating is presented, for example, information on the emission spectra. Different methods of optical stimulation are reviewed, including non-linear application of stimulation power; these are related to isolation of the fast OSL component that is most appropriate for dating sediments. Practical methods for fast OSL component separation are mentioned. Information on the stimulation process has been obtained by varying the wavelength during measurement and by varying the stimulation temperature. On the other hand, information on the recombination process is provided by observing the OSL emitted when the stimulation source is pulsed; this has practical applications when feldspar contamination is expected. Although laboratory experiments imply more than adequate thermal stability of the fast OSL signal for dating back to a million years, ages determined in the laboratory using the single aliquot regenerative dose procedure do not agree with independent ages. To address this problem, luminescence signals derived from the same electron trap, as well as those resulting from stimulation in the infrared (875 nm) and in the violet (405 nm), have been investigated as potential dating tools.

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1. Overview

Over the past 30 years, a particular optically stimulated luminescence signal (termed the fast component) has been measured from sedimentary quartz grains and used to obtain depositional ages for the sediments. Alongside such applications, laboratory experiments have been carried out in order to establish a basis for the measurement protocols used for age determination. The first part of this review paper (sections 2–10) covers experimental work carried out primarily since 2003 when a book was published (Bøtter-Jensen et al., 2003) on Optically Stimulated Luminescence Dosimetry which had extensive sections on quartz. Also, in the last 15 years, models of OSL production in quartz have been developed, based on the numerical model of Bailey (2001), that enable prediction of experimental results and also prediction of the stability of the fast OSL signal over long periods of time, as is needed for dating.

Experimental work on methods of measurement of the OSL signals is presented in section 4 and a summary is presented in terms of what is most useful for dating procedures. In section 5, spectral measurements are reported, not just for OSL but also for associated methods of luminescence production. Although the spectra are well characterised, there is still a lack of information about the nature of the defects in natural quartz and this is mentioned in the summary of section 5. Sections 6 and 7 provide an overview of processes related to OSL production, and the conditions under which the signal may be measured in the single aliquot regenerative dose (SAR) protocol widely used to obtain ages for sediments.

However, applications to independently dated sedimentary deposits from the last 200,000 years (200 ka) have yielded underestimated OSL ages for sediments over 50 ka. This is discussed in section 8, where dose response curves for the fast component of the OSL signal are discussed. This has led to investigations of new methods of stimulating OSL which are discussed in section 9. In sections 10 and 11, the latest developments concerning other signals derived from trapped electrons are reviewed individually.

The intention of this paper is to provide an overview for doctoral students embarking on a research project on OSL of quartz, particularly when their aim is to use OSL signals to provide a chronology. The aim is to summarize what is known, and what is not known, about the OSL signals found in sedimentary quartz, with some additional information from synthetic materials. Where experimental results have been discussed within a modelling framework this has been included in this review.

2. Introduction

When quartz grains are exposed to light following absorption of a radiation dose, an optically stimulated luminescence (OSL) signal is observed. The larger the dose, the greater is the OSL signal and this property enables quartz to be used as a dosimeter (Bøtter-Jensen et al., 2003; Preusser et al., 2009). The effective radiation dose received by quartz grains in the environment can be obtained by comparing the natural OSL signal with the OSL measured after the delivery of a dose from a calibrated, usually beta emitting, laboratory source. The signal decays rapidly when exposed to direct sunlight and increases again through absorption of environmental radiation once the quartz grains have been incorporated in a sedimentary deposit. A measurement procedure has been developed in which the effective dose received by the grains in nature, termed the equivalent dose, can be obtained for a single aliquot of quartz grains (Murray and Wintle, 2000) consisting a few hundred to a few thousand grains (Heer et al., 2012) or even for a single grain of a diameter of 100–200 μm (Jacobs and Roberts, 2007; Duller, 2008). The equivalent dose is divided by the separately measured environmental dose rate to obtain an age; in the case of sediment, this is the time since the quartz grains were last exposed to sunlight. The acquired OSL can also be erased by heating the quartz grains, e.g. during firing of ceramics, however in this review we will not consider heating as a zeroing mechanism.

The OSL signal used for dating is usually obtained under conditions of constant power density of the stimulating light source, usually at blue or green wavelengths, most frequently of the order