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Thermoluminescence signal in K-feldspar grains: Revisited

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HIGHLIGHTS

- We investigate the post-IR isothermal TL (ITL) signal for sedimentary feldspar.
- This signal is potentially stable enough for feldspar luminescence dating applications.
- The dose response range of this signal is wider than that of post-IR IRSL signal.
- Its higher residual precludes its application to young samples.
- IR bleaching and heating treatments affect the decaying rate of post-IR ITL signal.

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ABSTRACT

Recent work has shown that infrared stimulated luminescence (IRSL) signals in sedimentary coarse-grain K-feldspars are derived mainly from high temperature thermoluminescence (TL) peaks around 400 °C, and the fading components of the IRSL signal can be preferentially removed by prior IR stimulation at relatively low temperature. Considering the complexity of TL signal for very old samples, we may choose non-fading components from K-feldspar TL signals using the combination of optical and thermal activation methods. This paper examines a protocol of post-IR isothermal TL (i.e. pIRITL) signal for sedimentary coarse-grain K-feldspars, which results from isothermal TL measurements following elevated temperature IR bleaching. We show that a sum of two exponential decay functions can fit well to the pIRITL decay curves, and both the holding temperature for isothermal TL measurements and the prior elevated temperature IR bleaching can affect greatly the fast components of pIRITL signal. The dose response ranges of pIRITL signal are wider than those of post-IR IRSL signals, but the relative high residual pIRITL signal means that it is not appropriate for dating young samples. It is expected that one isothermal TL signal for K-feldspar measured at ~400 °C following IR bleaching at 290 °C (i.e. $pIRITL_{400}$) is useful for dating very old samples.

1. Introduction

The infrared stimulated luminescence (IRSL) signal from sedimentary feldspar has been used for optical dating of sediment for the last two decades (Hütt et al., 1988). IRSL dating results of sedimentary feldspar is younger than expected values due to anomalous fading (Huntley and Lamothe 2001; Huntley and Lian, 2006; Lamothe and Auclair, 1999), athermal decays of luminescence signal during storage at ambient temperature after irradiation (Wintle, 1973). The blue component of feldspar IRSL signal always shows dose under-estimation because of fading.

Recent studies suggested that there existed apparent stable luminescence signals from feldspar derived from both thermal-stimulated red emissions (Fattahi and Stokes, 2003) and elevated temperature IRSL (or post-IR IRSL) blue emissions (Thomsen et al., 2008, 2011). Based on post-IR IRSL signals, a dating method has been developed (Buylaert et al., 2009; Thiel et al., 2011; Thomsen et al., 2008, 2011). The apparent stable IRSL signals are supposed to arise from the spatially distant trapped electron–hole recombination, according to the physical model based on a single dosimetric trap for feldspar luminescence (Jain and Ankjærgaard, 2011). The spatially close trapped electron–hole pairs are more easily recombined under IR stimulation through tunneling process (Jain and Ankjærgaard, 2011).

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Alternatively, it is well known that TL can also be used for dating old samples where burial doses are much greater than any residual doses, although TL is not as sensitive to daylight as the OSL signal in both quartz and feldspar. In cases where the dose saturation levels of the net TL signals are very high (> 600 Gy), these TL signals can be used for dating beyond the OSL age range.

It has been suggested that IRSL signals in sedimentary coarse-grain K-feldspars stimulated at 50 °C and at higher temperature (e.g. the pIRIR signal) are derived mainly from one or two thermally-stable deep TL peaks around 400 °C (Murray et al., 2009), although it is proposed that the lower fading rate of pIRIR signal is associated with a TL trap at higher temperature (Thomsen et al., 2011). It has also been suggested that the fading component of the IRSL signal is preferentially removed by IR stimulation at low temperature (Thomsen et al., 2008; Jain and Ankjærgaard, 2011). If this is true, then other luminescence signals (e.g. TL) remaining after prior IR stimulation may also show lower fading rates. In this paper we use isothermal TL (i.e. ITL) measurement of signals from around 400 °C to test this hypothesis.

2. Experimental details

All luminescence measurements were carried out on an automatic Risø TL- DA-12 reader equipped with 875 nm (FWHM=40 nm) LED array delivering ~100 mW cm^{-2}, and a calibrated $^{90}Sr/^{90}Y$ beta source delivering 0.0908 Gy/s to quartz. The IRSL and isothermal TL signals were detected using a photomultiplier tube mounted by a blue filter package containing Schott BG-39 and Corning 7–59 filters, which allows for a transmission centered in blue (320–480 nm). The heating rate was 5 °C/s and the maximum temperature for TL was 700 °C, and the power level was software controlled and set at 90% for IRSL measurements.

Three samples studied in this paper are all coarse-grained K-feldspar extracted from sediments using heavy liquids method (Thomsen et al., 2011). Two of them (NLL-10225 and NLL-062213) were collected at the base of the Vale de Freixo Pliocene succession, in central Portugal. Based on the age control of the isotopic Sr dating of shells (Silva et al., 2010), NLL-062213 has an expected infinite age of ~3.6 Ma and thus is expected to have an equivalent dose of ~10 kGy (Thomsen et al., 2011). There is no published age control for NLL-102225, but it is also a very old sample according to the independent quartz luminescence ages control and the equivalent dose is expected to be greater than 350 Gy. The corresponding modern sample is NLL-102232.

3. TL glow-curves and SOL2 bleaching

To illustrate the behavior of our samples, Fig. 1(a) presents the

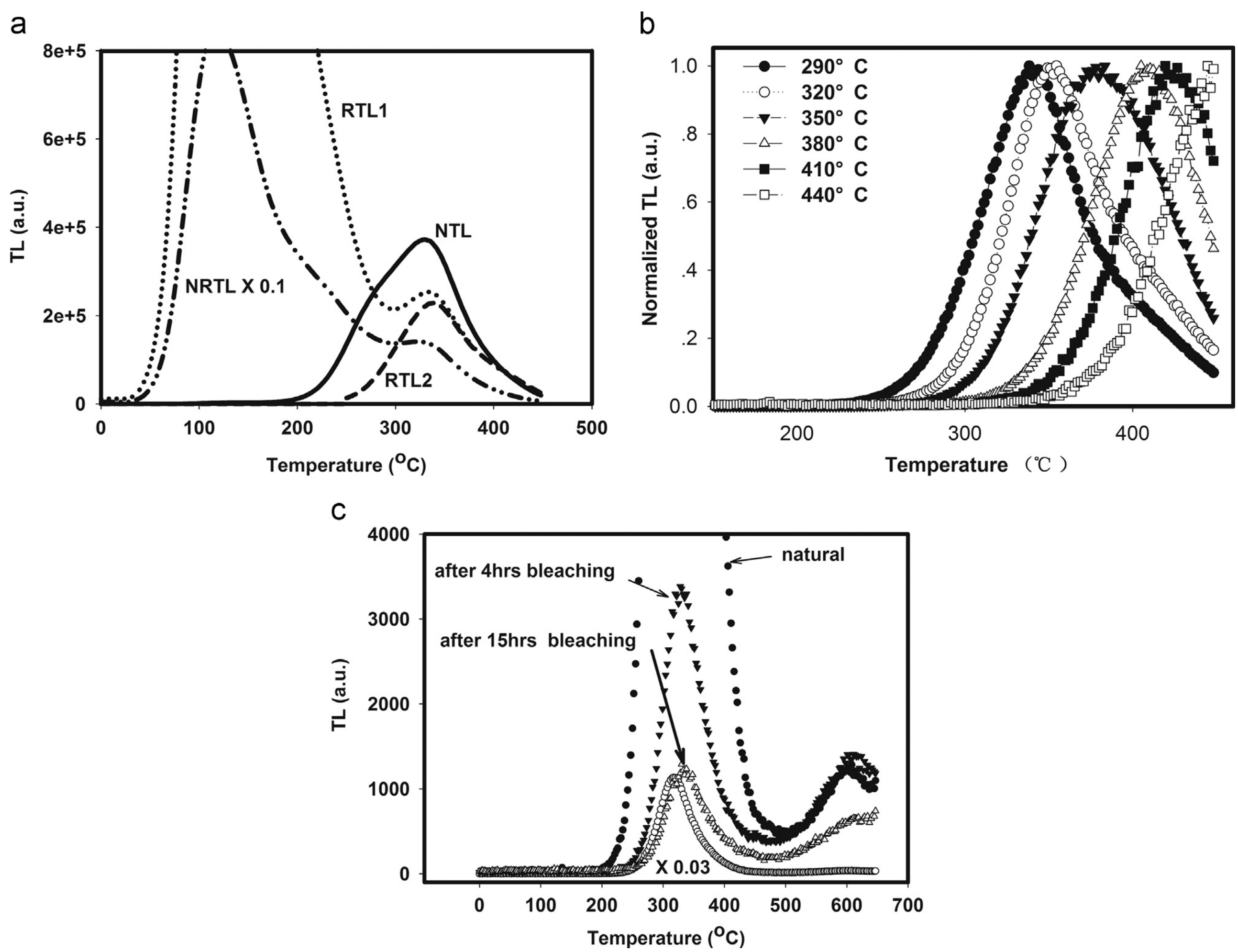

Fig. 1. (a) TL curves from sample NLL-102225. NTL: natural TL without preheating; RTL1: 600 Gy regenerative TL without preheating; RTL2: 600 Gy regenerative TL with preheating for 60 s at 250 °C; NRTL: 600 Gy irradiated natural TL without preheating, multiplied by 0.1. (b) Normalized TL curves from sample NLL-102225: natural with cut-preheating in temperatures ranging from 290 °C to 440 °C. (c) TL curves from sample NLL-102225: a natural aliquot and two natural aliquots experienced SOL2 simulator bleaching in the periods indicated, one natural TL readout multiplied by 0.03 for comparison.