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TL dating of feldspars using their far-red emission to deal with anomalous fading

Raphaël Visocekas*, Gilles Guérin

Laboratoire de Géochronologie, Département des sciences de la Terre, Université de Paris-Sud Orsay, 91405, Orsay Cedex, France

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Abstract

New studies of thermoluminescence (TL) dating of feldspars involving their far-red emission are proposed. The intense TL of feldspars is affected by the pervasive effect of anomalous fading, a strong deterrent to their use for TL dating. With volcanic feldspars, the natural TL can fade completely. With other feldspars, such as found in sediments, anomalous fading may turn out to be weaker and correct TL dates could be obtained. This effect of fading may be dealt with methods based on the little studied far-red emission, a band centred around 710 nm present in the TL of all feldspars. Apparently this emission does not fade during geological storage, or at least much less than the visible and UV ('blue') emissions used by conventional TL, OSL or IRSL readers. This emission has enabled dating by TL and has been expanded to IRSL. These TL experiments are resumed with improved methods for filtering, collection of data and protocols. Firstly, the stability of TL in some sediments is tested by the B_{ir} protocol. B_{ir} is the ratio of the conventional 'blue' emission to the far-red emission measured simultaneously in the course of a TL measurement by use of filters on a carousel. Comparison of the values of B_{ir} between prompt TL and the natural TL provides a sensitive gauge of the stability of conventional TL, which is verified notably with some sediments dated by Preusser [IRSL dating of K-rich feldspars using the SAR protocol: comparison with independent age control. Ancient TL 21, 17–23.]. Secondly, two volcanic plagioclases of known age from Olby and Royat are considered. In their natural TL, the conventional 'blue' emission has drastically faded away but not the far-red one. Additive TL using this far-red emission leads to a satisfactory evaluation of the natural dose of these samples, hereby confirming the stability of this far-red emission during geological storage.
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1. Introduction

1.1. Anomalous fading

Thermoluminescence (TL) dating of feldspars cannot be dealt with without mention of the anomalous fading effect. This is a widespread effect and a major hindrance for accurate dating of feldspars (see e.g. Aitken, 1985). With volcanic feldspars it results in the loss of most, if not all, their natural TL. With other feldspars which displayed some natural TL and were eventually well dated (Hütt et al., 1993; Preusser, 2003, etc.) it cast an a priori suspicion of partial fading which had to be withdrawn. Different ways have been investigated to circumvent this obstacle. As anomalous fading follows a logarithmic law of decrease, some scientists used this law to compensate for the small fading losses in some sedimentary feldspars (Huntley and Lamothe, 2001). Since the TL of plagioclases at higher temperatures has been shown not to fade, correct dates could be obtained using the TL above 600 °C termed the high temperature TL ('HTTL'), (Guérin, 1983; Guérin and Valladas, 1980). This method is currently used again with improved methods (Guérin, this conference).

1.2. The far-red emission in feldspars

Other methods of circumventing anomalous fading had been proposed based on the far-red emission in the TL of feldspars. This far-red emission is spectrally well characterized, consisting in a narrow Gaussian peak with a maximum around 710 nm and a width of 120 nm or so (Bos et al., 1994). This emission is attributed to the impurity Fe^{3+}. It is

* Corresponding author. Tel.: +33 1 45 81 55 41.
E-mail address: visocek@paris7.jussieu.fr (R. Visocekas).

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detected throughout all the TL glow curve, starting at lower temperatures in the tunnel afterglow before higher temperature TL is detected (Visocekas, 1993). It is commonly observed among all feldspars more evenly than the conventional emission. Conventional TL equipment is unsuitable for observation of this emission as their spectral sensitivity does not reach up to 750 nm. However, it may be easily measured in cathodoluminescence (CL) at RT with the appropriate equipment, without the problem of thermal background emission (Visocekas et al., 1994; Blanc, 2000).

1.3. Stability of the far-red emission

The outstanding feature of this feldspar far-red emission is its stability during storage. This is dramatically visible for most feldspars when prompt TL and TL after some storage are measured in parallel in the 'blue' and the far-red bands. After storage of some months, even only days, the intensities of 'blue' emissions are much more reduced than the far-red ones (Zink et al., 1995; Visocekas, 2000). A typical example is the natural TL of volcanic feldspars: where for most of the time, the 'blue' TL has completely faded away while the far-red emission remains with an intensity corresponding to the natural dose (Zink and Visocekas, 1997). Recent studies discussed this far-red emission stability using TL (Fattahi and Stokes, 2003c) and IRSL (Fattahi and Stokes, 2004) with detection of emissions extended into the red domain. The ratio B_{ir} of the intensities of 'blue' to far-red at a given TL temperature is by nature independent of the weight of the sample, and of the long term stability of the PMT. It was also observed not to depend on the dose used (Visocekas, 1993): B_{ir} depends only on the storage time, which makes it a remarkably easy and accurate test of evaluation of anomalous fading compared with conventional methods of testing (Visocekas, 1993, 2000).

1.4. Applications to TL dating of feldspars

Ever since it was first proposed, the TL signals of feldspars have scarcely been used for dating, apart from the studies of Fattahi and Stokes (2003a,b, 2004) (Stokes and Fattahi, 2003) who extended the methods of investigation from red TL to IRSL. The advantage of IRSL is to reduce the effects of unwanted thermal emission, which prevents us from precise observation of red TL above 280 °C (see Fig. 7). However an extra difficulty for IRSL is to detect anti-Stokes emission in the range 600–750 nm under stimulation at a neighbouring wavelength of some 833 nm (Fattahi and Stokes, 2003a).

2. Using the far-red emission for fading tests and irradiation

2.1. Experimental details

In principle, the equipment and experimental protocol are the same as reported previously (Visocekas, 1993, 2000; Visocekas et al., 1994; Zink et al., 1995; Zink and Visocekas, 1997). However quite a few improvements are added now to the method. According to the laws of luminescence, the emission spectra do not differ notably from the spectra obtained by CL at RT. Dozens of new CL spectra were obtained from 200 to 1100 nm (Blanc, 2000), samples of which are shown in Fig. 1: volcanic sanidines (Laacher See, Rocca Monfina), anorthoclase (Anakia), alkali feldspar from sediments (Norinkylä).

The striking feature is the common far-red narrow emission peak around 710 nm (normalized to the peak intensity in Fig. 1). In the rest of the spectrum, which is mostly the 'blue' emission observed with conventional TL or OSL equipment, the intensities and spectral distributions are much more scattered. The same features appear with all the other CL spectra observed.

For subsequent measurements, the TL detection is organized so as to detect simultaneously these two wide bands, far-red from 630 to 750 nm and 'blue' from 400 to 570 nm. The band from 570 to 630 nm is omitted as stable and fading emissions are mixed up in that region. These detection regions are achieved by the following combination of a PMT and filters (see Fig. 2).

The PMT 31034 has a photocathode with a sensitivity extending into the infrared, a range which has to be limited to avoid overwhelming background thermal emission in TL. This is achieved with fixed 'cold' filters, a combination of Balzers Calflex C and Corion LS 750 filters, cutting off above 750 nm. Unfortunately, they cut off detection below 400 nm as well. In addition, four filters are mounted on a carousel (BG 42, OG 570, RG 630 from Schott and a transparent quartz). As the carousel rotates during heating the spectral ranges detected through these filters are as shown in Figs. 3–6: firstly, BG 42 emulates the 'blue' collected with a conventional PMT plus filter system. Then, the transmission through OG 570 gives

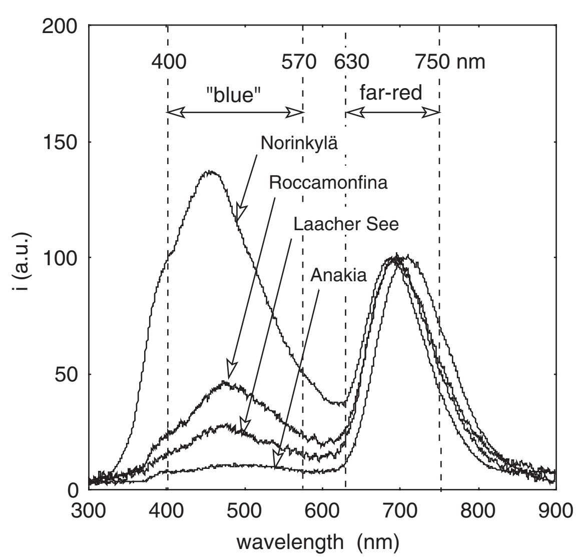

Fig. 1. Cathodoluminescence spectra of four different alkali feldspars. Volcanic sanidines: Laacher See (G), Rocca Monfina (It); anorthoclase: Anakia (Aust.); alkali feldspar from sediments: Norinkylä (Fin.). 'Blue' and far-red are the two spectral ranges delimited by the optical filters. Intensities are reduced to the same level at the maximum far-red wavelength of 700 nm.

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