Available online at www.sciencedirect.com
ScienceDirect
Quaternary Geochronology 2 (2007) 216–221
QUATERNARY GEOCHRONOLOGY
www.elsevier.com/locate/quageo

Research paper

A test case for anomalous fading correction in IRSL dating

Jakob Wallinga[a,*], Adrie J.J. Bos[b], Pieter Dorenbos[b], Andrew S. Murray[c], Jeroen Schokker[d]

[a]*Netherlands Centre for Luminescence dating, Faculty of Applied Sciences, Delft University of Technology, Mekelweg 15, NL-2629 JB, Delft, The Netherlands*
[b]*Faculty of Applied Sciences, Delft University of Technology, Mekelweg 15, NL-2629 JB, Delft, The Netherlands*
[c]*Nordic Laboratory for Luminescence Dating, Risø National Laboratory, Department of Earth Sciences, Aarhus University, DK-4000 Roskilde, Denmark*
[d]*TNO Built Environment and Geosciences—Geological Survey of the Netherlands, PO Box 80015, NL-3508 TA Utrecht, The Netherlands*

Received 12 April 2006; accepted 1 May 2006
Available online 12 July 2006

Abstract

Infrared-stimulated luminescence (IRSL) dating of feldspars has the potential to date deposits beyond the age range of quartz optical (OSL) dating. Successful application of feldspar IRSL dating is, however, often precluded due to anomalous-fading, the tunnelling of electrons from one defect site to another. In this paper we test procedures proposed for anomalous-fading correction by comparing feldspar IRSL and quartz OSL dating results on a suite of samples from continental deposits from the southeastern Netherlands. We find that even after anomalous-fading correction IRSL ages underestimate the burial age of the deposits and argue that this may be a consequence of a dependency of anomalous fading rate on the dose rate and on the absorbed dose.

Keywords: Luminesence dating; IRSL; Feldspar; Quartz; Anomalous fading

1. Introduction

Luminescence-based dating methods are the only means available to provide burial ages of sediments deposited during the full length of the last glacial cycle. The most commonly used method is optical dating using the quartz optically stimulated luminescence (OSL) signal. Depending on the environmental dose rate and saturation behaviour, this usually limits successful application to the last 100 to 150 ka. Extending the age range for which optical dating can be used reliably is one of the main challenges faced by the luminescence-dating community.

The infrared-stimulated luminescence (IRSL) signal of feldspar saturates at higher doses than the quartz OSL signal and can in principle be used to date deposits that are much older. Unfortunately, the feldspar IRSL signal is often affected by anomalous fading, which is the name given to the detrapping of charge on a time scale where the charge is expected to be thermally stable (see e.g., Wintle, 1973; Aitken, 1985). Due to anomalous fading the IRSL signal decays with time, this leads to an underestimation of the burial age of a sample.

Correcting IRSL ages for anomalous fading is difficult due to the considerable extrapolation needed to relate the decay of the luminescence signal observed on the laboratory timescale to that occurring in geological time. For this reason, Aitken (1985, Appendix A6) argued against making a quantitative correction. Nevertheless, correction procedures have received renewed attention in the last few years (Huntley and Lamothe, 2001; Auclair et al., 2003; Lamothe et al., 2003), although it is acknowledged that the equations used do not hold for geological time (Huntley and Lamothe, 2001). Attempts to develop an anomalous-fading correction have become feasible thanks to the development of single-aliquot procedures applicable to feldspar (Wallinga et al., 2000a), these allow more precise measurements of the fading decay of the IRSL signal with time (Auclair et al., 2003). Anomalous-fading corrections have been used in a number of studies, including Ollerhead et al. (2001) and Balescu et al. (2003).

In this paper we show that anomalous-fading corrections do not eliminate IRSL age underestimation for a terrestrial

*Corresponding author. Tel.: +31(0)152781056.
E-mail address: J.Wallinga@tudelft.nl (J. Wallinga).

1871-1014/$ - see front matter
doi:10.1016/j.quageo.2006.05.014

sequence spanning several glacial–interglacial cycles in the Netherlands and we discuss the reasons for this.

2. Materials and methods

2.1. Site, samples and preparation

Samples for this study are taken from the Boxtel core from the southeastern Netherlands (for location and geological context see Schokker et al., 2005). From lithostratigraphy, biostratigraphy and quartz optical dating it is known the record spans at least 400 ka (Schokker et al., 2005); the quartz OSL ages are presented in Fig. 1 and in Table 1. Thanks to the extremely low dose rate, quartz optical dating could be used further back in time than usual. Schokker et al. (2005) regarded quartz ages valid up to a depth of 17.56 m (lowermost sample 20-1; 483 ± 41 ka), with the exception of two outliers (samples 17-1 and 18-1). To avoid bias by these outliers, we only use the quartz OSL dating results from the upper 13.1 metres of the core (sample 1-1 to 14-1) as age control. This section was chosen because: (1) the quartz OSL age obtained on Eemien (OIS5e) deposits (114 ± 11 ka) is in agreement with the expected age; (2) quartz OSL ages are internally consistent; (3) quartz OSL equivalent doses are not greater than 200 Gy; OSL dose response curves indicate that the signal is not at saturation for these doses (Fig. 10 in Schokker et al., 2005). In other studies quartz optical ages obtained in this dose range have been shown to agree with independent age control (reviewed by Murray and Olley, 2002). We therefore suggest that the quartz OSL ages obtained on samples 1-1 to 14-1 are robust and provide age control for comparison with our feldspar data.

Samples from the Boxtel core were treated with HCl and H_2O_2 to remove carbonates and organics. After sieving, the 180–250 μm fraction was density separated to obtain the potassium-rich feldspar fraction (< 2.58 g/cm^3). The heavy fraction was treated with concentrated HF to obtain a pure quartz sample and etch the outer skin of the quartz. The feldspar extracts were not HF treated.

2.2. Luminescence measurements

Risø TL/OSL DA15 machines equipped with internal 1.48 GBq ^{90}Sr/^{90}Y beta sources were used for luminescence measurements (Bøtter-Jensen et al., 2000). The dose rate of these readers is between 0.029 and 0.151 Gy/s, depending on the spacing between source and sample. IR diodes providing 130 mW/cm^2 at 880 nm were used for stimulation; a detection window around 410 nm was used through a combination of Schott BG3 (2 × 3 mm), BG39 (2 mm) and GG400 (3 mm) filters.

The IRSL single-aliquot regenerative-dose (SAR) procedure for feldspar as proposed by Wallinga et al. (2000a) was modified in two aspects (Table 2): (1) an identical heat treatment was used for regeneration and test doses to improve the sensitivity correction (following Huot and Lamothe, 2003; Blair et al. 2005). (2) a high-temperature IR bleach was included at the end of each SAR cycle to minimise recuperation effects (following a similar approach suggested for quartz by Murray and Wintle, 2003). We thoroughly tested the modified SAR to ensure that it satisfactorily corrected for sensitivity changes and to check

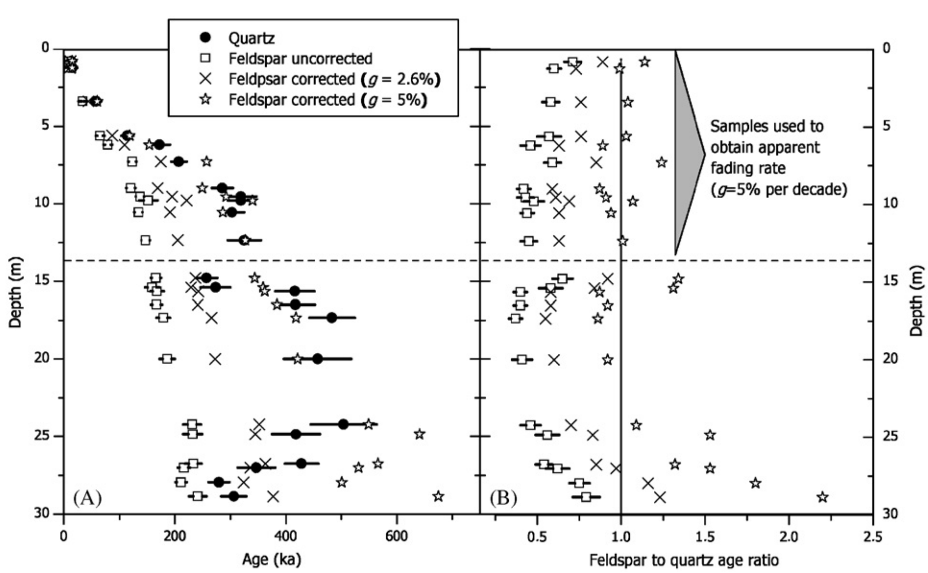

Fig. 1. (A) Optical dating results for the quartz (closed circles) and feldspar (open squares) fraction. Feldspar results after anomalous-fading correction are also shown, using the measured fading rate for correction ($g = 2.6\%$ per decade; crosses) and using a fading rate that brings quartz and feldspar ages in agreement ($g = 5\%$ per decade, open stars). The horizontal hatched line at 13.1 m depth represents the lower boundary used to derive the 'apparent' anomalous-fading rate of 5% per decade. (B) Ratio of quartz and feldspar optical ages before and after anomalous-fading correction (symbols identical to Fig. 1A).