Quaternary Geochronology 6 (2011) 468–479

Contents lists available at ScienceDirect

Quaternary Geochronology

journal homepage: www.elsevier.com/locate/quageo

Research Paper

Luminescence dating of K-feldspar from sediments: A protocol without anomalous fading correction

Bo Li*, Sheng-Hua Li

Department of Earth Sciences, The University of Hong Kong, Pokfulam Road, Hong Kong, China

ARTICLE INFO

Article history:
Received 9 October 2010
Received in revised form
9 May 2011
Accepted 16 May 2011
Available online 7 June 2011

Keywords:
Feldspar
Luminescence
IRSL
Post-IR
Anomalous fading
Sediment

ABSTRACT

A protocol for optical dating of potassium-rich feldspar (K-feldspar) is proposed. It utilizes the infrared stimulated luminescence (IRSL) signal measured by progressively increasing the stimulation temperature from 50 to 250 °C in step of 50 °C, so-called multi-elevated-temperature post-IR IRSL (MET-pIRIR) measurements. Negligible anomalous fading was observed for the MET-pIRIR signals obtained at 200 and 250 °C. This was supported by equivalent dose (D_e) measurements using the IRSL and MET-pIRIR signals. The D_e values increase progressively from 50 °C to 200 °C, but similar D_e values were obtained for the MET-pIRIR signal at 200 and 250 °C. Measurement of modern samples and bleached samples indicates that the MET-pIRIR signals have small residual doses less than 5 Gy equivalent to about 1–2 ka. We have tested the protocol using various sedimentary samples with different ages from different regions of China. The MET-pIR IRSL ages obtained at 200 and 250 °C are consistent with independent and/or quartz OSL ages.

1. Introduction

Dating of sedimentary deposits can be achieved using optically stimulated luminescence (OSL) signal from quartz and feldspar grains from sediments (Aitken, 1998). The luminescence signals of quartz or feldspar are used to measure the dose received by the grains in their sedimentary environment since deposition. The age is obtained by dividing the absorbed dose or equivalent dose (D_e) (in Gy) by the dose rate (in Gy/ka) which is derived from the decay of radionuclides in the sediments, and a contribution from cosmic rays (Aitken, 1985). In the last decade, with the development of single-aliquot-regenerative-dose (SAR) protocol (Murray and Wintle, 2000), quartz OSL dating has been widely applied to dating Quaternary sediments (Murray and Olley, 2002; Wintle and Murray, 2006; Wintle, 2008). However, dating of old deposits is limited by the saturation of the quartz OSL signal with increasing dose (Wintle and Murray, 2006).

The infrared stimulated luminescence (IRSL) from sedimentary feldspar has been used for optical dating of sediment for the last two decades since the first report of optical stimulation spectra of feldspar by Hütt et al. (1988). The IRSL signal from feldspars is particularly useful for dating as it has several advantages over the OSL signal of quartz. Firstly, the IRSL signal from sand-sized K-feldspar grains saturate at higher doses than the quartz OSL signal; thus it has the potential for extending the datable range for sedimentary deposits. Secondly, when using appropriate filters to reject the stimulation light in each case, the IRSL signals are often much brighter than the quartz OSL signal; this enables high precision luminescence measurements to be made. This leads to a high reproducibility for natural dose measurements (Li et al., 2007b). The high contribution of the internal dose rate from ^{40}K and ^{87}Rb will also result in higher equivalent doses for young samples; thus it has a greater potential for the younger age limit (Li et al., 2007b).

Despite of various advantages over quartz OSL dating, the application of IRSL dating of K-feldspars has long been limited due to anomalous fading, an athermal process of decay of luminescence signals during storage at ambient temperature after irradiation, as first noted for the thermoluminescence (TL) signals from feldspars by Wintle (1973). Later, the IRSL signals have also been shown to anomalously decrease with storage at room temperature at which the signals are supposed to be thermally stable (Spooner, 1992, 1994; Huntley and Lamothe, 2001; Huntley and Lian, 2006). The anomalous fading of the luminescence signal has been suggested as the main reason for the age shortfall in IRSL dating of feldspar (Lamothe and Auclair, 1999; Huntley and Lamothe, 2001; Huntley and Lian, 2006; Li et al., 2007a).

Given the great potential of extending the age range of luminescence dating using feldspar, attempts have been made to correct

* Corresponding author.
E-mail address: boli@hku.hk (B. Li).

1871-1014/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.quageo.2011.05.001

for or to avoid the anomalous fading effect (Sanderson and Clark, 1994; Lamothe and Auclair, 1999; Huntley and Lamothe, 2001; Zhao and Li, 2002; Lamothe et al., 2003; Tsukamoto et al., 2006; Li et al., 2008). Huntley and Lamothe (2001) proposed a method to correct for the anomalous fading using K-feldspar, based on the measurement of the fading rate (g-value) in terms of percentage loss per decade (Aitken, 1985). However, this method can only be applied to young samples with linear dose response curves. For older samples, such method becomes unreliable as a result of dose-dependent changes in anomalous fading rate (Kars et al., 2008; Li and Li, 2008).

Recent studies suggested that the initial part of the IRSL signal has a higher anomalous fading rate when compared to the later part (Thomsen et al., 2008; Li, 2010). This observation has led to the development of post-IR IRSL (pIRIR) dating methods, in which an IRSL bleaching at low-temperature ($\sim$50 °C) is applied before a high-temperature (>200 °C) IRSL measurement to reduce the fading rate of feldspar (Thomsen et al., 2008, 2010; Buylaert et al., 2009; Thiel et al., 2010). However, detectable anomalous fading is still present in the pIRIR (225 °C) signals (Buylaert et al., 2009) and fading correction has not been avoided although the magnitude of age correction is reduced. More recently, Thiel et al. (2010) and Thomsen et al. (2010) both show evidence for the natural pIRIR (290 °C) signal being in saturation on a laboratory dose response curve, indicating that the signals may be stable, but they both report non-zero laboratory fading rates (1.1 $\pm$ 0.3%/decade and 1.3 $\pm$ 0.4%/decade, respectively).

Given the ambiguity of the one-step pIRIR signal stability and the strong model dependence of the fading correction procedure, especially for old samples (Li and Li, 2008), searching for non-fading signal from feldspar is necessary. In this paper, we propose a dating method for K-feldspars that utilizes the IRSL and multi-elevated-temperatures post-IR IRSL ((MET-pIRIR) signals. We show that using this protocol yields reliable ages and avoids anomalous fading corrections.

2. Samples and analytical facilities

Eleven aeolian sedimentary samples from three different deserts from Northern China, namely the Mu Us, Hulun Buir and Hunshandake, and two loess samples from the Chinese Loess Plateau were used in this study. Fig. 1 shows the location of the sampling sites. Table 1 shows a list of all samples used in this study. Samples WG1, WG2 and WG3 from Wan Gong (WG) and HLD3 from He Er Hong De (HLD) were taken from the Hulun Buir Desert. Samples SGDL10, SGDL11 and SY3 were taken from San Gen Da Lai (SGDL) and San Yi (SY) sites from the Hunshandake Desert (Li et al., 2002; Li and Sun, 2006). These samples have quartz OSL ages in the range of 0–13 ka. Sample FJGW1 was taken from the Fanjiagouwan site on the bank of the Sala Us River at the south edge of the Mu Us Desert. An IRSL Isochron age of 54 $\pm$ 7 ka was derived for this sample, a similar age of 55.7 $\pm$ 1.0 ka was also obtained based on quartz OSL measurements (Fan et al., 2011). Samples Sm3, Sm5, Sm0404 and Sm8 were taken from the Shimao section in the transition zone between the Mu Us Desert and the Loess plateau (Li et al., submitted for publication). The isochron ages obtained using the K-feldspar grains in different grain sizes for samples Sm3, Sm0404 and Sm5 were 41 $\pm$ 6, 92 $\pm$ 20 and 121 $\pm$ 26 ka, respectively, which are consistent with the model ages based on stratigraphical correlation (Sun et al., 1999; Li et al., 2008). The age of Sm8 ($\sim$0.5 Ma) was estimated by correlation between stratigraphy and marine oxygen isotopic stages (OIS 12) (Li and Li, 2008; Li et al., submitted for publication). Previous study on the equivalent dose of the samples from the section suggested that the IRSL signal for sample Sm8 has reached an equilibrium state, i.e. the IRSL traps were in equilibrium between electron filling and escaping (or fading) (Li and Li, 2008; Li et al., submitted for publication). This is so-called "field saturation" (Lamothe et al., 2003; Huntley and Lian, 2006). Two loess samples LC-019 and LC-093 were from the Luochuan section of the Chinese Loess Plateau with sampling depths of 1.9 and 9.3 m, respectively. The sample LC-019 is located at the

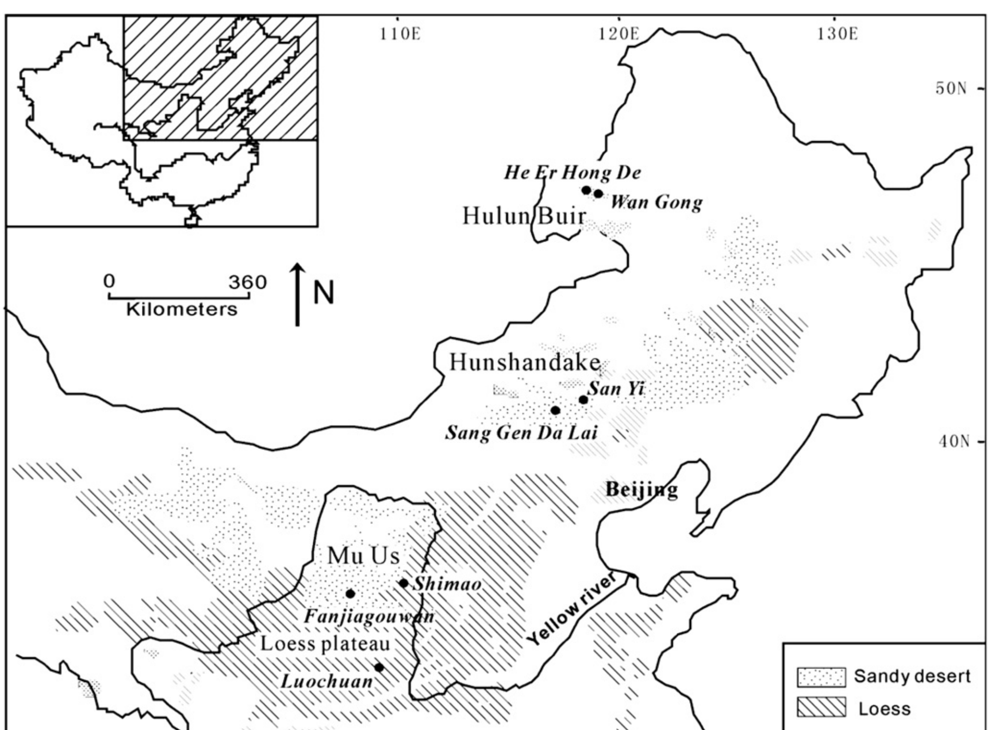

Fig. 1. Deserts and loess plateau in Northern China and sampling sites. Full circles are the sampling locations with names shown in italic.