Quaternary Geochronology 22 (2014) 137–143

Contents lists available at ScienceDirect

Quaternary Geochronology

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

Research paper

Investigating the optically stimulated luminescence dose saturation behavior for quartz grains from dune sands in China

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ARTICLE INFO

Article history:
Received 6 November 2013
Received in revised form
21 January 2014
Accepted 26 January 2014
Available online 4 February 2014

Keywords:
Quartz
Dose response curve
Dose saturation level
Taklimakan desert
Hunshandake sandy land

ABSTRACT

The optically stimulated luminescence (OSL) signals from quartz have been widely used to estimate the equivalent dose (D_e) of environment radiation after the deposition of mineral grains. However, the usage of quartz is often limited due to the lower saturation behavior compared with feldspar. Saturation limits among quartz (defining the upper dating range) vary significantly. It is important to better understand the reason for various dose saturation behaviors of the quartz OSL signals. In this study, coarse quartz grains were extracted from the Taklimakan Desert and the Hunshandake sandy land in north China and the dose saturation behavior of quartz OSL signals were studied. Our results suggest that the quartz grains produce very different aliquot-specific dose response curves, showing the significant variability in dose saturation characteristics for OSL signals. Laboratory dosing, optical bleaching and heating experiments were designed to simulate their effects on the dose saturation behavior for the quartz OSL. The results demonstrate that cycles of dosing and optical bleaching have insignificant impact on the OSL dose growth curves, while the heating to high temperature (above 400 °C) can significantly change the dose saturation characteristics for the quartz OSL. Such results suggest that the different heating history of quartz might be an important factor for the variability in dose saturation characteristics for OSL signals. Additionally, the quartz grains from the Hunshandake sandy land exhibit lower dose saturation level for OSL signals, compared with that from the Taklimakan Desert. This can be explained that the quartz grains from Hunshandake sandy land are mainly of igneous origin, while the quartz grains from Taklimakan Desert are mainly of metamorphic origin.

1. Introduction

Natural quartz serves as an important dosimeter of ionising radiation in luminescence dating of sediments (Aitken, 1998; Wintle and Murray, 2006; Preusser et al., 2009; Rhodes, 2011). The optically stimulated luminescence (OSL) signals from quartz grains have been widely applied to estimate deposition ages of late Quaternary sediments by using the single-aliquot regenerative-dose (SAR) procedure (Murray and Wintle, 2000). In such approach, the measured sensitivity-corrected natural OSL signal is compared with equivalent sensitivity-corrected signals regenerated by laboratory irradiation of the same aliquot of quartz. Comparison of the natural OSL intensity with the laboratory generated dose response curves (DRCs) allows the determination of the equivalent dose (D_e) of the quartz grains. If a single type of trap is assumed to be responsible for the OSL signal, the DRCs of sedimentary quartz can be described by a single saturating exponential function in the form of $I = I_{max}(1 - \exp(-D/D_0))$, where I is the OSL intensity due to dose D (Gy), I_{max} is the saturation luminescence intensity and D_0 (Gy) is the dose characteristic level of the dose response curve (Aitken, 1998). In routine luminescence dating of quartz samples, it is often found that, compared with a single saturating exponential function, the single exponential plus linear function can give much better fitting to the OSL dose response curves, when the regeneration dose reaches beyond 100–200 Gy (e.g. Roberts and Duller, 2004; Lai, 2006; Lai et al., 2008; Pawley et al., 2008; Lowick et al., 2010). This is because there are multiple sources responsible for the OSL production of quartz instead of the single trap source. In order to obtain reliable estimation of natural dose for the quartz grains, it is prudent to ensure that the D_e was less than $2D_0$ (Wintle and Murray, 2006).

The OSL signals from natural quartz grains comprise several physically distinct components, e.g. fast, medium and slow components (Bailey et al., 1997; Jain et al., 2003; Li and Li, 2006). For the OSL signals dominated by the fast component, a variety of D_0 values

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http://dx.doi.org/10.1016/j.quageo.2014.01.003

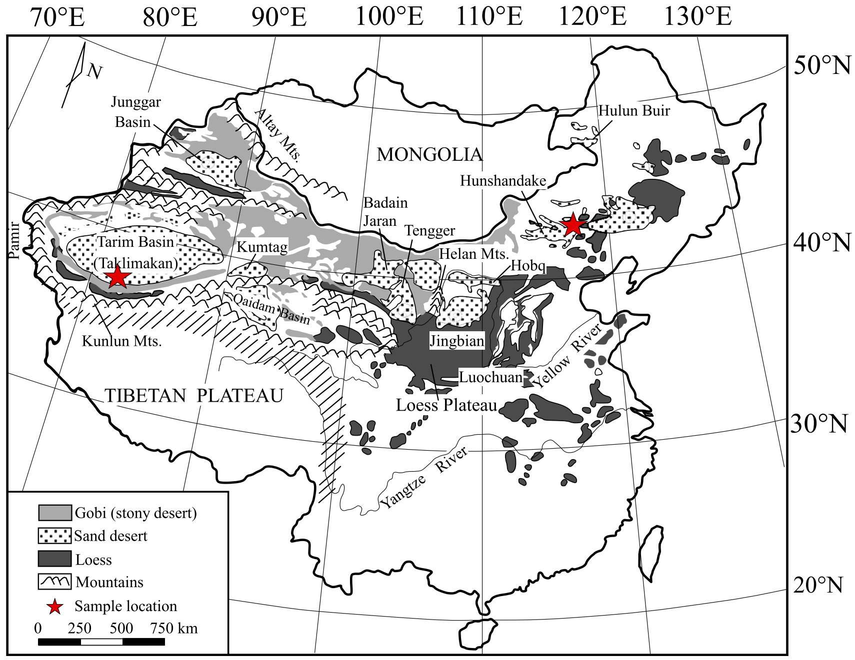

Fig. 1. Map showing mountains, gobi (stony desert), sand desert, and loess distributions as well as the sampling sites in China (modified from Sun and Zhu, 2010).

were reported for the quartz samples in different regions and sedimentary environments, e.g. 55 Gy (Roberts and Duller, 2004), 69 Gy (Singarayer and Bailey, 2004), 75 Gy (Banerjee et al., 2003), 90 Gy (Huntley et al., 1996), 97 Gy (Jain et al., 2005) and 190 Gy (Singarayer and Bailey, 2003). Even for quartz grains of a same sample from a given site, significant variations in dose saturation characteristics were also identified and the values (D_0) were reported from 40 Gy to 600 Gy (Duller et al., 2000). An implication from these studies is that the construction of individual DRCs for quartz OSL signals are necessary for individual aliquot or grain in the estimation of D_e, due to the potential significant variability in the saturation behavior among dose growth curve characteristics. In contrast to above results, some studies on quartz OSL demonstrated that similar DRCs or values (D_0) can be obtained in the laboratory for samples from the same site or geographical area. This idea has been applied in the use of standardized or common growth curves for determining D_e for quartz samples within the same study area (Roberts and Duller, 2004; Lai, 2006; Lai et al., 2007). The advantage of such method is the quick measurement of D_e. However, the assumption of the very similar DRCs or values (D_0) for quartz OSL signals among individual quartz grains must be evaluated.

In this study, coarse quartz grains of aeolian sand samples were extracted and their dose saturation behaviors for the quartz OSL signals were studied. This paper aims to address the following topics: (1) examining the dose saturation behaviors of quartz OSL from the aeolian sands, to see if the quartz grains exhibit different OSL dose saturation characteristics. (2) simulating the effects of irradiation, optical bleaching and heating on the dose saturation behaviors for the quartz OSL signals, because the sedimentary quartz grains might experience different irradiation, bleaching and heating history, which might make their OSL dose saturation characteristics different.

2. Materials and methods

2.1. Geological setting

Modern dune sand samples (TK-1 and HS-1) were collected from the Taklimakan Desert and the Hunshandake sandy land in China, respectively (Fig. 1). The Taklimakan Desert is the largest sand sea in China, occupying an area of 337,000 km^2 (Sun and Liu, 2006). It situates in the Tarim Basin surrounded by the Tianshan mountains to the north, the Kunlun mountains to the south and the Pamir Plateau to the west. A great mount of metamorphic rocks distribute in the orogenic belts surrounding the Taklimakan Desert (Fig. 2a). Previous studies have suggested that quartz grains from the Taklimakan Desert produce relatively dim OSL signals (e.g., Zheng et al., 2009; Lü and Sun, 2011), as the most of quartz grains are metamorphic origin (Ma, 2002; Yang et al., 2008). The Hunshandake sandy land occupies an area of 21,400 km^2 in northeastern China (Fig. 1) (Zhu et al., 1980). Mesozoic (mainly Jurassic and Cretaceous) and Paleozoic volcanic rocks are widespread around the sandy land (Ma, 2002) (Fig. 2b). By investigating oxygen isotopic compositions of quartz, Yang et al. (2008) proved that the sands in the Hunshandake sandy land are mainly of igneous origin. Thus, the quartz grains in the Hunshandake sandy land can produce very bright luminescence signals (Zheng et al., 2009; Lü and Sun, 2011), as they had been subjected to the heating to high temperature during the formation of the host rock or later volcanic activities (e.g. felsic magmas can erupt at temperatures as high as 650–750 °C or even above).

2.2. Sample preparation

The pre-treatments and luminescence measurements for the quartz samples were completed in the Luminescence Dating Laboratory in the Institute of Geology and Geophysics, Chinese Academy of Science. The bulk samples were treated with 10% hydrochloric acid (HCl) and 10% hydrogen peroxide (H_2O_2) to remove carbonates and organic materials, respectively. Grains between 90 and 125 μm were selected by dry sieving. Quartz grains were separated using sodium polytungstate heavy liquid with density between 2.62 and 2.75 g/cm^3. The quartz grains were etched with 40% hydrofluoric acid (HF) for 80 min to remove feldspar. HCl (10%) was used again to dissolve any residual fluorides after etching before final rinsing and drying. The etched grains were mounted as a monolayer on aluminum discs of 10 mm diameter using silicone oil as an adhesive. Grains covered the