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Investigating the components of the optically stimulated luminescence signals of quartz grains from sand dunes in China

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ABSTRACT

The optically stimulated luminescence (OSL) signals from quartz consist of several physically distinct components, which are commonly referred to as fast, medium and slow components. In this study, the OSL components of quartz from the Taklimakan Desert and the Hunshandake sandy land in north China are investigated. Our results show that the relative contributions of OSL components to the bulk OSL signal can be significantly different among quartz grains from both deserts. Laboratory dosing, optical bleaching and heating experiments are used to test their effects on the relative contributions of quartz OSL components. It is found that cycles of dosing and optical bleaching have insignificant impact on the relative contributions of quartz OSL components, while heating to high temperature (500 °C) can significantly enhance the contribution of the fast component to the bulk OSL signals, especially for quartz samples from the Taklimakan Desert. Such results suggest that the different heating history of natural quartz grains plays an important role in controlling OSL components. Additionally, the quartz grains from the Hunshandake sandy land can easily be distinguished from those of the Taklimakan Desert, by using a ternary plot of fast-medium-slow components. The quartz grains from the Hunshandake sandy land exhibit a much stronger fast component than those from the Taklimakan Desert. This can be explained by that the quartz grains from the Hunshandake sandy land are mainly of igneous origin, while most of the quartz grains from the Taklimakan Desert are of low grade metamorphic origin.

1. Introduction

During the last decade, the quartz optically stimulated luminescence (OSL) signal has been widely applied to date late Quaternary sediments from a variety of geographic areas (Sun et al., 2006; Wintle and Murray, 2006; Li et al., 2007; Duller, 2008; Madsen and Murray, 2009; Preusser et al., 2009; Rhodes, 2011; Gong et al., 2013, 2014a). Meanwhile, the properties of quartz OSL signals, such as sensitivity and dose saturation level, are found to be highly variable with geological source and vary even on a grain-to-grain level (Duller et al., 2000), making them a potential tool for tracing sediments. Investigations have been carried out to distinguish the provenance of quartz samples from different geographic areas, using the sensitivity and dose saturation level of quartz OSL signals (e.g. Li et al., 2002; Lai and Wintle, 2006; Li et al., 2007; Zheng et al., 2009; Fitzsimmons, 2011; Lü and Sun, 2011; Sawakuchi et al., 2011, 2012; Gong et al., 2014b; Lü et al., 2014).

The bulk OSL signal emitted from sedimentary quartz consists of several components from discrete trap types, which are broadly referred to as fast, medium and slow components (Bailey et al., 1997). The different OSL components from quartz have different characteristics, regarding photoionization cross-sections, sensitivity, dose saturation level, recuperation and thermal stability (Jain et al., 2003; Singarayer and Bailey, 2003, 2004; Li and Li, 2006; Fan et al., 2009; Steffen et al., 2009). The individual OSL components can be identified by mathematically fitting either continuous wave OSL (CW-OSL) or linearly modulated OSL (LM-OSL) curves (Bulur, 1996, 2000). For the purpose of dating, the fast component is the most favorable because it is highly sensitive to light and it is thermally stable (Wintle and Murray, 2006). However, not all sedimentary quartz contains a strong fast component. Unsuccessful applications have been reported when samples are dominated by

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Table 1
The relative contributions of the fast component to the quartz CW-OSL signals.

Contribution to the OSL signal from the fast component	Signal integration region	Sample/locations	Reference
>90%	0–0.6 s	Loess/Chinese Loess Plateau in northern China	(Lai and Fan, 2014)
70-98%	0–0.8 s	Loess/Northwest Canada	(Demuro et al., 2013)
~94%	0–2 s	Sand dune/West Australia	(Wang et al., 2012)
>90%	0–0.6 s	Sand/Mu Us Desert in northern China	(Fan et al., 2011)
~70%	0–0.4 s	Sedimentary core/Northeastern Italy and northern Switzerland	(Lowick et al., 2010)
80-92%	0–0.64 s	Loess/Linxia in western China and southern Tajikistan	(Zhou et al., 2010)
Very low	0–0.8 s	Glacial sediment/Northwestern highlands of Scotland	(Lukas et al., 2007)
>80%	0–0.4 s	Aeolian sample/China	(Li and Li, 2006)
39–87.9 %	0–0.8 s	Loess/Japan	(Watanuki et al., 2005)
~80%	0–1.6 s	Aeolian dune/Sri Lanka	(Bailey, 2003)

non-fast components (Choi et al., 2003; Li and Li, 2006; Steffen et al., 2009). It has been reported that the relative contributions of the fast component to the bulk OSL signal can be highly variable for samples from different geographical locations (Table 1).

In this study, the OSL components of coarse quartz grains from the Taklimakan Desert and the Hunshandake sandy land in China are analyzed and compared. This paper aims to address the following issues: (1) investigating the compositions of the OSL signal, to see whether the different quartz aliquots from the same sample can display differential relative intensities of OSL components; (2) testing the effects of irradiation, optical bleaching and heating on the relative contributions of quartz OSL components; (3) examining whether the differential contributions of the OSL components in quartz can be a useful tool to distinguish provenances.

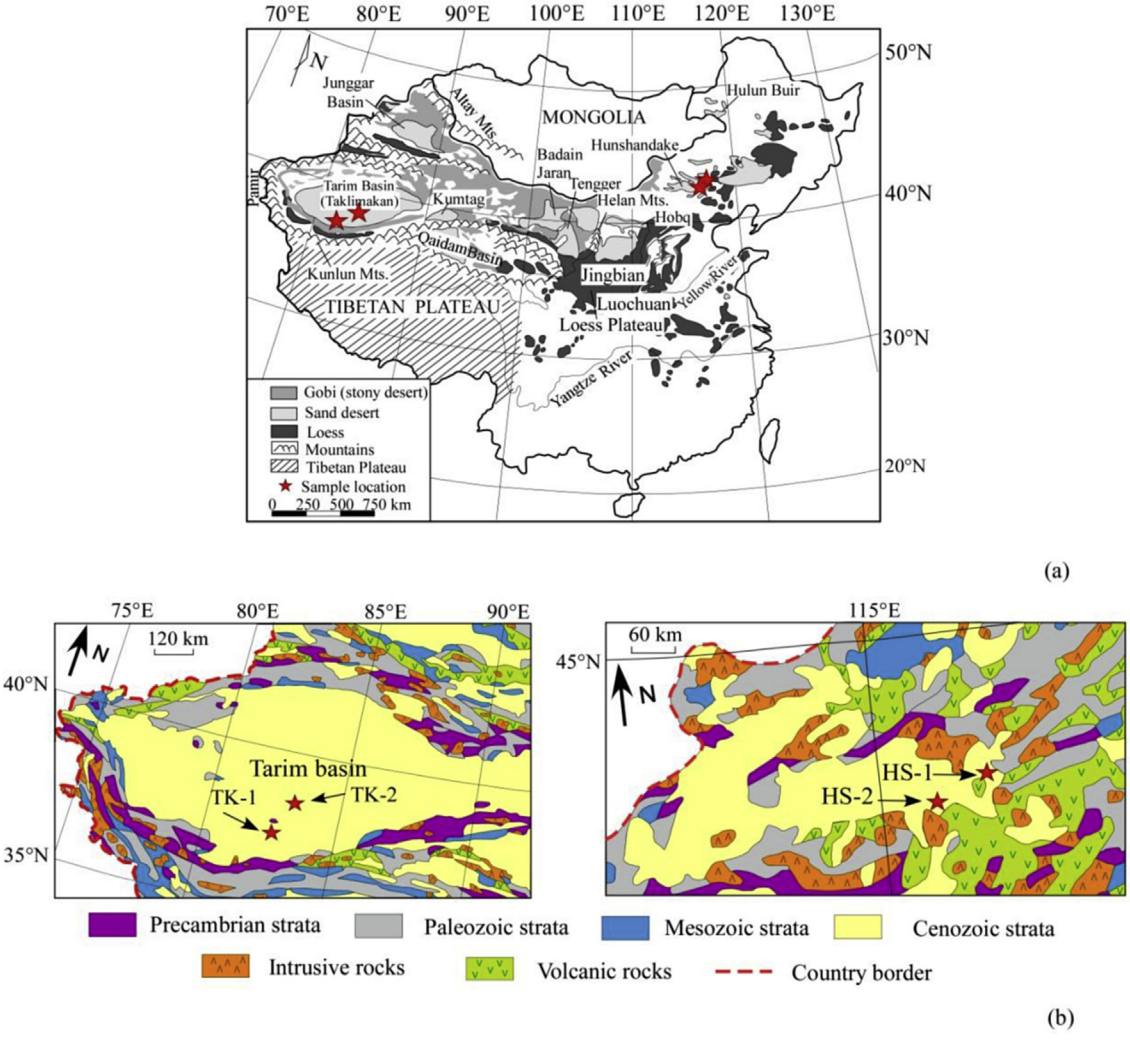

Fig. 1. (a) Map showing mountains, gobi (stony desert), sand desert, and loess distributions as well as the sampling sites in China (from Sun and Zhu, 2010). (b) Geological map showing the strata of the orogenic belts surrounding the Taklimakan Desert and the Hunshandake sandy land (modified after 1:1000000 geological map of China). Red stars indicate sample locations (from Gong et al., 2014b). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

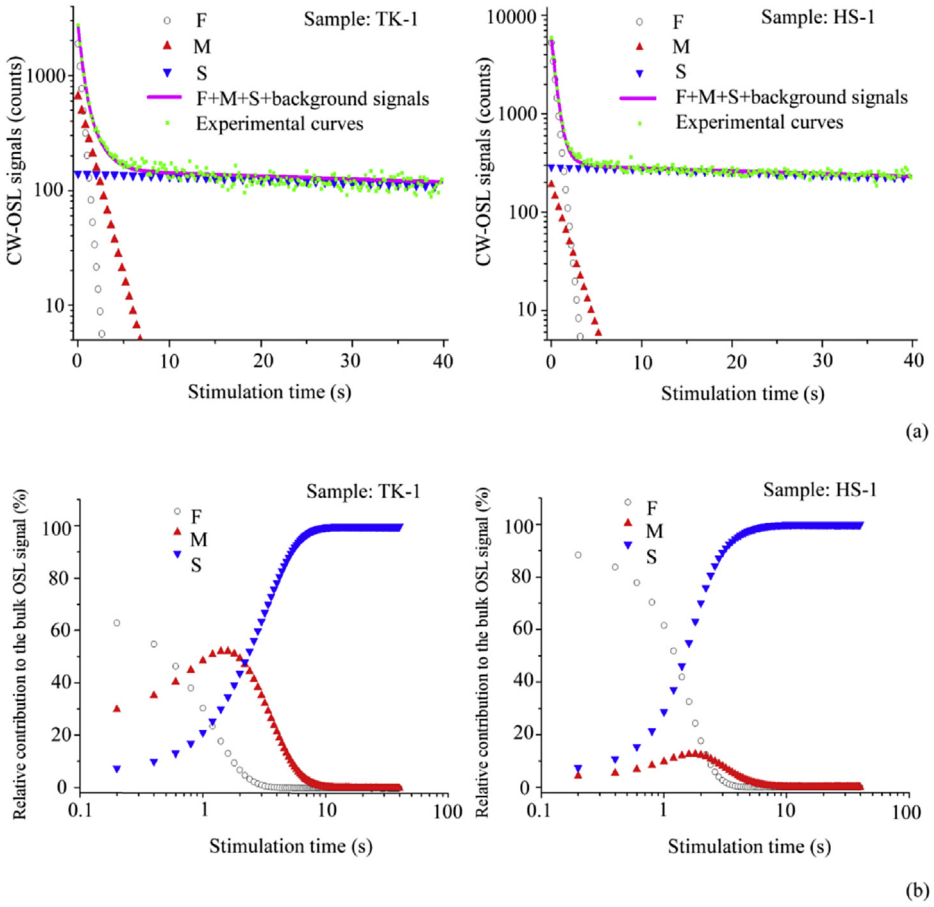

Fig. 2. (a) Representative CW-OSL decay curves of quartz from TK-1 and HS-1. Three exponential components (fast, medium and slow), the fitted bulk OSL as well as the experimental OSL signals are shown. (b) Relative contributions from individual components to the bulk OSL signals are plotted against the stimulation time for TK-1 and HS-1. F: fast component; M: medium component; S: slow component; F + M + S: The sum of fast, medium and slow components of the OSL signals; the acronyms are the same for other figures throughout the paper.

2. Materials and methods

2.1. Geological setting

Quartz grains from four sedimentary samples were used in this study (Fig. 1a). Two modern sand dune samples (TK-1 and TK-2) were collected from the Taklimakan Desert in western China. The desert is the largest sand sea in China, occupying an area of 337,000 km^2 (Sun and Liu, 2006). It is situated 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 are spread over the orogenic belts surrounding the Taklimakan Desert (Fig. 1b). Previous studies have demonstrated that the quartz grains from the Taklimakan Desert produce relatively dim OSL signals and exhibit relatively high dose saturation levels of OSL signals (Zheng et al., 2009; Lü and Sun, 2011; Gong et al., 2014b), which has been attributed to the fact that most of the quartz grains are of metamorphic origin (Ma, 2002; Yang et al., 2008). According to the 1:1 000 000 metamorphic geological map of China, most of the source metamorphic rocks belong to the greenschist facies, indicating low grade metamorphic processes. Because greenschist facies metamorphism typically occurs at temperatures of approximately 300–400 °C, the source metamorphic rocks around the Taklimakan Desert were not subjected to very high temperature heating. Two modern sand dune samples (HS-1 and HS-2) were collected from the Hunshandake sandy land in northeastern China. It has been reported that the quartz grains from the Hunshandake sandy land can produce very bright luminescence signals and exhibit a relatively low dose saturation level of the quartz OSL signals (Li et al., 2002, 2007; Zheng et al., 2009; Lü and Sun, 2011; Gong et al., 2014b). This is because Mesozoic (mainly Jurassic and Cretaceous) and Paleozoic volcanic rocks are widespread around the sandy land (Ma, 2002; Lü and Sun, 2011) (Fig. 1b). Most of the quartz grains from this sandy land have been very likely subjected to high temperature heating during the formation of the host rocks 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 carried out 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 and they were subsequently etched with 40% hydrofluoric acid (HF) for 80 min to remove feldspar. HCl (10%) was used again to dissolve any residual fluorides

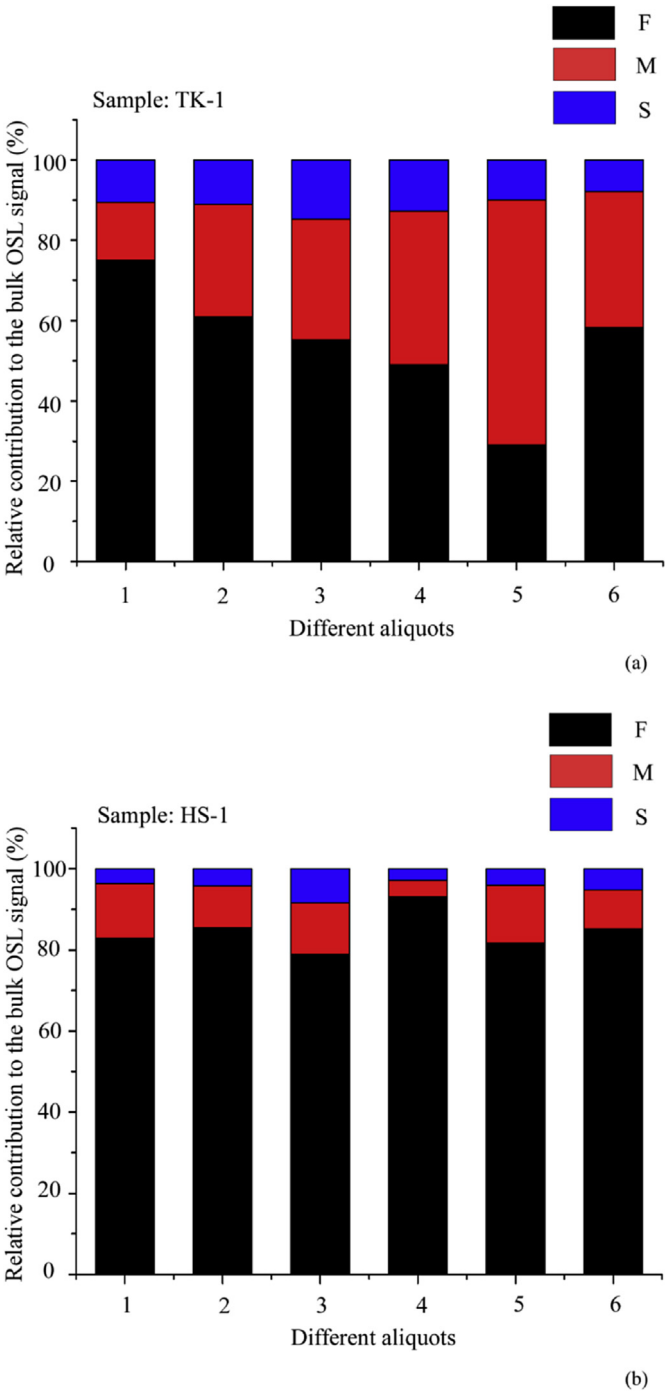

Fig. 3. Comparison of the relative contributions of the OSL components for six quartz aliquots from (a) TK-1 and (b) HS-1.

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 central ~3 mm diameter portion of each disc, corresponding to several hundred grains per aliquot. The aliquots of quartz were checked for the absence of feldspar contamination using IR stimulation at 60 °C on the beta-irradiated quartz. Our aliquots of quartz have no response to the IR stimulation and have the typical 110 °C TL peak (Li et al., 2002; Duller, 2003).

2.3. Experimental techniques

2.3.1. Laboratory equipment

The OSL measurements were performed using an automated TL/OSL reader (Risø-TL/OSL-15). The reader is equipped with excitation units of blue light emitting diodes (LEDs) ($\Delta = 470 \pm 30$ nm) and a solid state infrared (IR) laser ($\Delta = 830 \pm 10$ nm). The blue LEDs deliver up to 50 mW/cm^2 at the sample. 90% of their full power was used for stimulation. In this study, the individual OSL components of quartz are analyzed by deconvolution of the CW-OSL signals. The quartz OSL signals were detected through a Hoya U-340 filter, which allows a transmission from 290 nm to 370 nm with a peak at ~340 nm (Aitken, 1998). Irradiation was carried out using a ^{90}Sr/^{90}Y beta source built into the reader, which delivered a dose rate of 0.0833 Gy/s to the aliquots.

2.3.2. Deconvolution of the CW-OSL decay curves

For each of the four samples (TK-1, TK-2, HS-1 and HS-2), six aliquots of quartz were at first bleached with blue light at 280 °C for 100 s to remove natural OSL signals. The aliquots were then given an irradiation dose of 83.3 Gy, preheat at 260 °C for 10 s and stimulated for OSL measurement with blue light at 125 °C for 40 s. The measured OSL decay curves were then fitted into three exponential components of first order kinetics by Origin 8.0 fitting software, using the following equations:

$$I(t) = I_0 + I_f \exp\left(-b_f t\right) + I_m \exp(-b_m t) + I_s \exp(-b_s t)$$

where I_0 is the background signal, I_f, I_m, I_s are the initial luminescence signal intensity for the fast, medium and slow components at $t = 0$ s, b_f, b_m, b_s are the decay rates of the electrons trapped at three levels corresponding to the fast, medium and slow components (Zhou et al., 2010). The OSL decay curves are fitted with fast, medium and slow components with decay rates of 2.23 ± 0.06 s^{-1}, 0.72 ± 0.05 s^{-1} and 0.0065 ± 0.0008 s^{-1} for the sample of TK-1, and the decay rates of 2.17 ± 0.07 s^{-1}, 0.71 ± 0.06 s^{-1} and 0.0061 ± 0.0009 s^{-1} for the sample of TK-2, respectively. The fitted decay rates of fast, medium and slow components are 2.15 ± 0.09 s^{-1}, 0.67 ± 0.06 s^{-1} and 0.0067 ± 0.0012 s^{-1} for the sample of HS-1, and decay rates of 2.22 ± 0.07 s^{-1}, 0.71 ± 0.08 s^{-1} and 0.0063 ± 0.0014 s^{-1} for the sample of HS-2, respectively. The ratios of fast/medium decay rates for TK-1, TK-2, HS-1 and HS-2 are calculated at 3.10 ± 0.23, 3.06 ± 0.28, 3.21 ± 0.32 and 3.13 ± 0.37, respectively. All ratios are similar to those for the fast and medium component reported by others (Jain et al., 2003; Singarayer and Bailey, 2003; Lowick et al., 2010; Wang et al., 2012). In later investigations, these decay rate parameters are fixed for deconvolution of the CW-OSL signals into components.

3. Results

3.1. Deconvolution of a representative CW-OSL decay curve of quartz from TK-1 and HS-1

Fig. 2a illustrates representative examples of deconvoluted OSL curves of quartz from TK-1 and HS-1. It demonstrates that the OSL signals can be well described by the three components ($R^2 > 0.99$). In order to examine how the different components contribute to the bulk OSL signal, the relative contributions of each component to the bulk OSL signal are plotted against the stimulation time in Fig. 2b. It shows that the relative contributions of individual components change as a function of illumination time. The fast and medium components of TK-1 contribute over 94% to the bulk OSL signal from 0 s to 0.2 s. However, they decrease to below 50% at

Table 2
Separation of aliquots from TK-1 and HS-1 into groups, according to the contributions of the fast component to the bulk OSL signals.

Groups	Aliquot −1	Aliquot −2	Aliquot −3	Aliquot −4	Sample	The contributions of fast component to the bulk OSL signals
A	~40%	~41%	~44%		TK-1	35–45%
A′	~38%	~42%	~43%		TK-1	35–45%
B	~46%	~51%	~54%		TK-1	45–55%
B′	~48%	~53%	~54%		TK-1	45–55%
C	~58%	~62%	~58%		TK-1	55–65%
C′	~57%	~57%	~63%		TK-1	55–65%
D	~66%	~67%	~72%		TK-1	65–75%
D′	~66%	~69%	~72%		TK-1	65–75%
E	~75%	~78%	~83%	~84%	HS-1	75–85%
E′	~75%	~81%	~82%	~83%	HS-1	75–85%
F	~86%	~86%	~91%	~91%	HS-1	85–95%
F′	~89%	~90%	~92%	~94%	HS-1	85–95%

2.4 s. After 2.4 s, the slow component begins to be dominant. For the sample of HS-1, the fast and medium components contribute over 95% to the bulk OSL signal from 0 s to 0.2 s. After 1.6 s, they decrease to below 50% and the slow component begins to be dominant. In later investigations, the integration region of the bulk OSL signals is fixed from 0 to 0.2 s of the OSL decay curves and they are deconvoluted into components for better comparison of the compositions of the OSL signal from different quartz samples.

3.2. Comparison of the relative contributions of OSL components for different multi-grain aliquots of quartz within a same sample

In order to examine whether different multi-grain aliquots of quartz within a same sample can display differential compositions of the OSL signal, six aliquots of quartz for both TK-1 and HS-1 were measured and the OSL curves were deconvoluted with the fixed decay rates as described in Section 2.3.2. The relative contributions of fast, medium and slow components to the bulk OSL signals (0–0.2 s) for the aliquots of TK1- and HS-1 were calculated and compared (Fig. 3). Fig. 3(a) shows that the compositions of quartz OSL components among the six aliquots of TK-1 can be highly variable. The contributions from the fast component to the bulk OSL signal (0–0.2 s) can vary from ~29% to ~75%, the contributions from the medium component vary from ~14% to ~61%, while the contributions from the slow component vary from ~8% to ~15%. The six quartz aliquots of HS-1 exhibit different features from those of the TK-1 and marked by the less inter-aliquot variability in the compositions of the OSL signal (Fig. 3(b)). For the six quartz aliquots of HS-1, the contributions from the fast component to the bulk OSL signal (0–0.2 s) can vary from ~79% to ~93%, the contributions from the medium component vary from ~4% to ~14%, while the contributions from the slow component vary from ~3% to ~8%. Such results clearly show that the different multi-grain aliquots of quartz from the Taklimakan Desert as well as from the Hunshandake sandy land can display very differential compositions of the OSL signal.

Table 3
Measurement procedures for groups A–F with repeated cycles of dosing/bleaching and groups A′–F′ with increasing heating temperatures. Note that the sequence of dosing/bleaching experiment is step 1, 2, 3, 4, 5a, 6, 7, 8, 9 and 10a, and the sequence of heating experiment is step 1, 2, 3, 4, 5b, 6, 7, 8, 9 and 10b.

Step	Procedure	Observed
1	Blue light bleaching for 100 s at 280 °C	
2	Given dose, 83.3 Gy	
3	Preheat (260 °C for 10 s)	
4	Stimulate for 40 s at 125 °C[a]	I_f, I_m and I_s[b]
5a	20 cycles of dosing/bleaching[c]	
5b	Heat to T (300 °C)[d]	
6	Blue light bleaching for 100 s at 280 °C	
7	Given dose, 83.3 Gy	
8	Preheat (260 °C for 10 s)	
9	Stimulate for 40 s at 125 °C[a]	I_f, I_m and I_s[b]
10a	Return to step 5a	
10b	Return to step 5b and T = T + 40 °C	

[a] The quartz OSL signals were deconvoluted into fast, medium and slow components, using the fitted decay rates described in section 3.1.
[b] I_f, I_m and I_s are the intensities of fast, medium and slow component, respectively.
[c] The size of dose is 16.7 Gy, while the aliquots were bleached with blue light at 125 °C for 40 s.
[d] The heating rate operated is at 1 °C/s.

3.3. Simulating the effects of irradiation, optical bleaching and heating on the relative contributions of quartz OSL components

Previous studies have demonstrated that the luminescence sensitivity of quartz grains can be significantly different as they have experienced different irradiation, optical bleaching and heating history (Li and Wintle, 1992; Chen et al., 2000; Moska and Murray, 2006; Pietsch et al., 2008; Preusser et al., 2009; Zheng et al., 2009; Fitzsimmons et al., 2010; Lü and Sun, 2011). In addition, investigations were also carried out to see whether the dose saturation behavior of the quartz OSL can significantly change in response to different laboratory dosing, optical bleaching and heating treatments (Chen et al., 2001; Lai et al., 2008; Gong et al., 2014b). It is found that cycles of dosing and optical bleaching have insignificant effect on the OSL dose growth curves, while heating to high temperatures (above 400 °C) can significantly change the dose saturation characteristics for the quartz OSL (Lai et al., 2008; Gong et al., 2014b). In this study, laboratory irradiation, optical bleaching and heating experiments are further designed to simulate their effect on the relative contributions of the quartz OSL components. To better check the influences of the above processes on the compositions of the OSL signal, twenty-four new quartz aliquots of TK-1 and eight new quartz aliquots of HS-1 were measured and the OSL curves were deconvoluted. Then the aliquots were divided into twelve groups, depending on the relative contribution of the fast components as described in Table 2. Groups A, B, C, D, E and F were examined with laboratory dosing/illumination experiments, while groups A′, B′, C′, D′, E′ and F′ were examined with heating experiments.

The effects of dosing/bleaching on the relative contributions of quartz OSL components were tested by using the experimental procedure described in Table 3. Groups A–F of quartz aliquots were at first bleached with blue light at 280 °C for 100 s. The aliquots were given an irradiation dose of 83.3 Gy, preheat at 260 °C for 10 s and stimulated for OSL signals with blue light at 125 °C for 40 s. The measured OSL signals were deconvoluted into fast, medium and

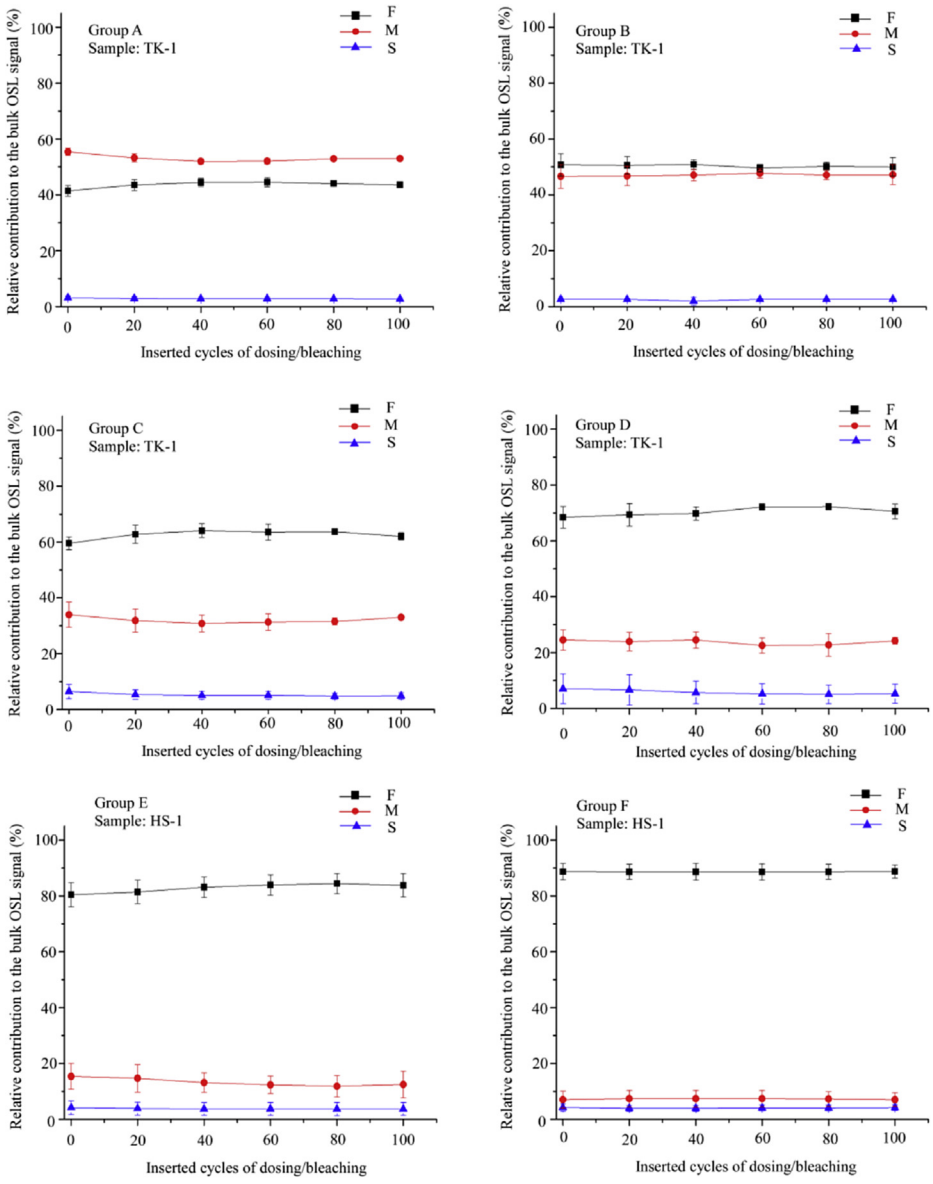

Fig. 4. The relative contributions of individual components to the bulk OSL signals (0–0.2s) after the aliquots were operated with repeated cycles of dosing/bleaching.

slow components. The aliquots were then underwent with twenty cycles of dosing/bleaching (Step 5a) before the next laboratory induced OSL signals were deconvoluted into the fast, medium and slow components (Step 6, 7, 8 and 9 in Table 3). These treatments were repeated to regenerate six OSL decay curves for each aliquot, while twenty additional cycles of laboratory dosing/bleaching treatments were performed between each OSL decay curve. The relative contributions of fast, medium and slow components to the bulk OSL signals (0–0.2 s) were then calculated and plotted as a function of the number of cycles of dosing/bleaching (Fig. 4).

Fig. 4 indicates that cycles of irradiation and illumination treatments have relative insignificant impact on the compositions of quartz OSL components for TK-1 and HS-1. For group A, the relative contributions to the bulk OSL signal (0–0.2 s) from fast, medium and slow components remain at ~44%, ~53% and ~3%, respectively, even though the aliquots of quartz of TK-1 experienced up to 100 cycles of dosing/bleaching treatments. Similarly, the relative contributions of quartz OSL components for the groups B, C, D, E and F also change little after the aliquots of quartz are treated with different cycles of dosing/bleaching (Fig. 4). The results from the samples TK-1 and HS-1 show that cycles of dosing/bleaching treatments do not cause significant change in the relative contributions of OSL components. Lowick et al. (2010) also observed that the relative contributions of quartz OSL components remain fixed throughout the construction of single-aliquot regenerative dose–response curves for their two sedimentary samples.

The effects of heating on the relative contributions of quartz OSL components were tested by using the experimental procedure in Table 3. Groups A′–F′ of quartz aliquots were at first bleached with blue light at 280 °C for 100 s. The aliquots were given an irradiation dose of 83.3 Gy, preheat at 260 °C for 10 s and stimulated for OSL signals with blue light at 125 °C for 40 s. The measured OSL signals were deconvoluted into the fast, medium and slow components. The aliquots were then heated to temperature T (300 °C) (Step 5b) before the next laboratory induced OSL signals were deconvoluted into the fast, medium and slow components (Step 6, 7, 8 and 9 in Table 3). Such treatments were repeated to regenerate six OSL decay curves for each aliquot, while the heating to high

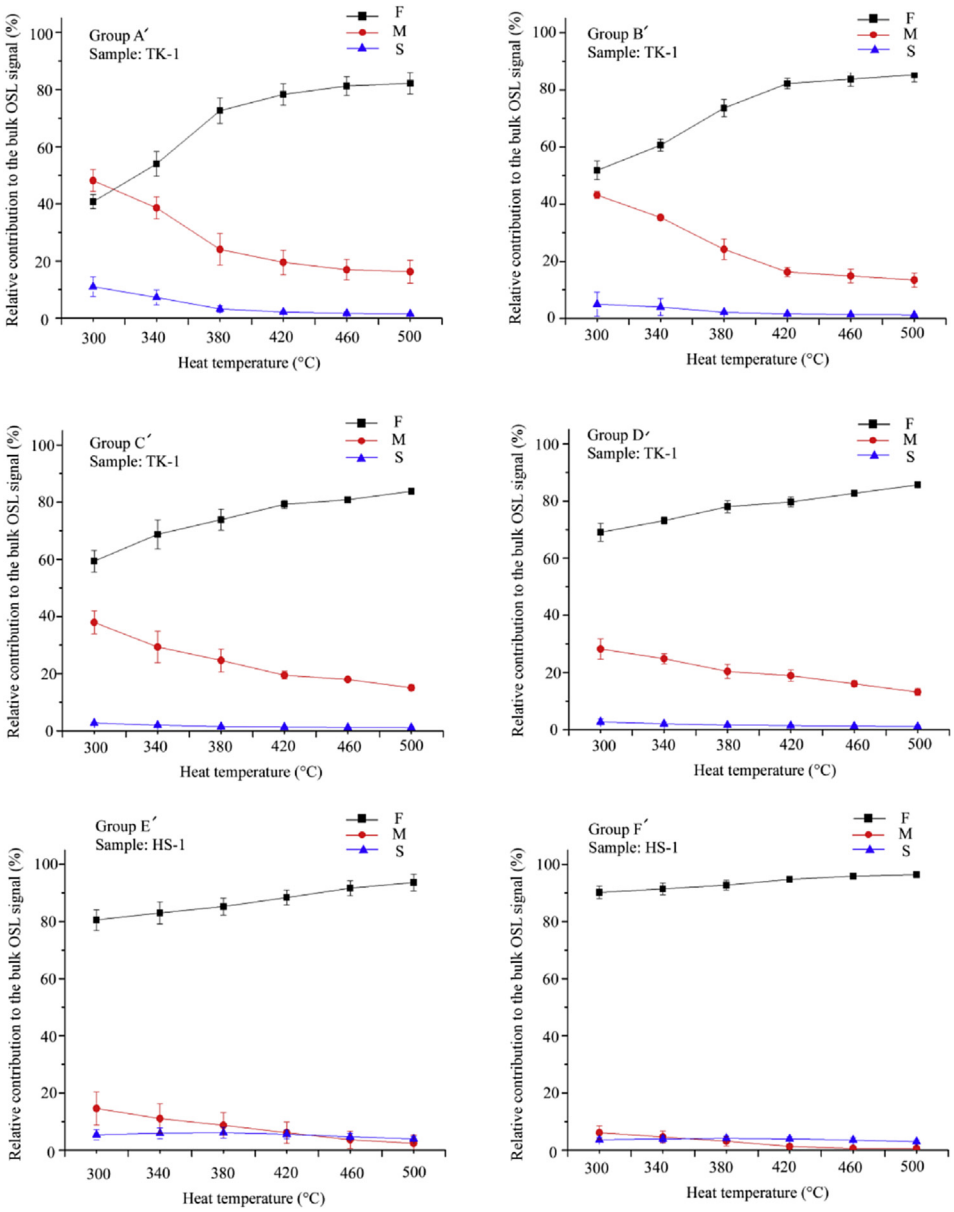

Fig. 5. The relative contributions of individual components to the bulk OSL signals (0–0.2s) after the aliquots were heated to different temperature.

temperature (T) in step 5b was progressively raised to 500 °C in increments of 40 °C. The relative contributions of fast, medium and slow components to the initial bulk OSL signal (0–0.2 s) were then calculated and plotted as a function of the heating temperature (Fig. 5).

Fig. 5 indicates that heating to high temperature has a significant impact on the compositions of the quartz OSL signal. For group A′, when the aliquots were heated to 300 °C, the fast component is not prominent and it contributes only 41 ± 2% to the initial bulk OSL signal (0–0.2 s). However, the relative contribution of the fast component progressively increases nearly twice to 82 ± 4% after the aliquots are heated to 500 °C. The relative contribution to the bulk OSL signal (0–0.2 s) from the medium component also changes significantly, decreasing from 48 ± 4% to 16 ± 4% after the aliquots are progressively heated from 300 °C to 500 °C. As for the slow component, its percentage contribution to the bulk OSL signal changes from 11 ± 3% to 1.5 ± 0.3% after the aliquots are heated from 300 °C to 500 °C. Similarly, the contributions of quartz OSL components for the groups B′, C′ and D′ also significantly changed after the quartz are heated to high temperature (500 °C). For group E′ and F′, the heating treatment to high temperature (500 °C) has a less prominent effect on the relative contributions of quartz OSL components, compared with that of groups A′, B′, C′ and D′. When the aliquots (groups E′ and F′) are progressively heated from 300 °C to 500 °C, the relative contribution of the fast component gradually increases from to 81 ± 3% to 94 ± 3% for group E′ and from 90 ± 2% to 96 ± 1% for group F′. The relative contribution of medium component gradually decreases from to 15 ± 5% to 2 ± 1% for group E′ and from 6 ± 2% to 0.6 ± 0.4% for group F′. As for the slow component, its relative contribution to the bulk OSL signal (0–0.2 s) remains at ~5% for group E′ and ~4% for group F′. Based on the experimental data from the samples TK-1 and HK-1, it is found that the heating to high temperatures (e.g. 500 °C) can significantly enhance the contribution of the fast component to the bulk OSL signals from quartz, especially for quartz grains from the Taklimakan Desert.

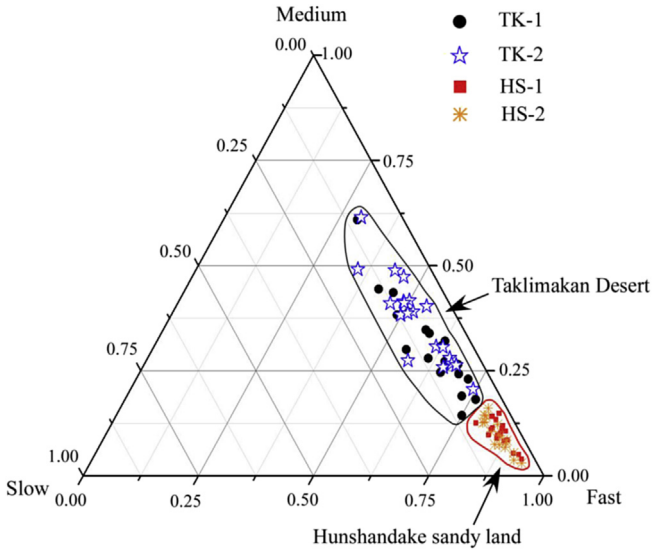

Fig. 6. Ternary plot of fast-medium-slow components of quartz OSL signals from TK-1, TK-2, HS-1 and HS-2.

3.4. Comparing the relative contributions of OSL components for quartz grains from the Taklimakan Desert and the Hunshandake sandy land

In the previous Section 3.2, it is found that the quartz grains of TK-1 exhibit a different composition of the OSL signal from that of HS-1. To further examine the relative contributions of OSL components for the quartz grains from the Taklimakan Desert and the Hunshandake sandy land, another twenty aliquots of quartz for TK-1, TK-2, HS-1 and HS-2 were measured and the OSL curves were deconvoluted with fixed decay rates as described in 2.3.2. The relative contributions of fast, medium and slow components to the initial bulk OSL signal (0–0.2 s) are compared in a ternary plot of the three components for the four samples (Choi et al., 2006; Sawakuchi et al., 2011).

Fig. 6 shows that compositions of the quartz OSL signals (0–0.2 s) of HS-1 and HS-2 can easily be distinguished from those of TK-1 and TK-2, i.e. the quartz aliquots from both HS-1 and HS-2 exhibit a stronger fast component than those from TK-1 and TK-2. For HS-1 and HS-2, the relative contributions of the fast component to the bulk OSL signals range typically from 77% to 95%, the medium component ranges from 3% to 16 % and the slow component is less than 10%. For TK-1 and TK-2, the relative contributions of the fast component to the bulk OSL signals range from 26% to 76%, the medium component ranges from 14% to 62% and the slow component is less than 16%. Such results suggest that the quartz grains from the two deserts experienced a very different thermal history during the geological past.

4. Discussion

Based on the above experiments, it is found that cycles of dosing and optical bleaching have insignificant impact on the relative contributions of quartz OSL components, while the different heating history plays an important role in controlling quartz OSL components. The heating treatment (500 °C) can greatly enhance the fast components of bulk OSL signals for TK-1, while it has less prominent effect for HS-1. A possible reason for the differential impacts of heating on the quartz OSL components for the two samples is due to the different provenances, i.e. most of the quartz grains from the Taklimakan Desert are of low grade metamorphic

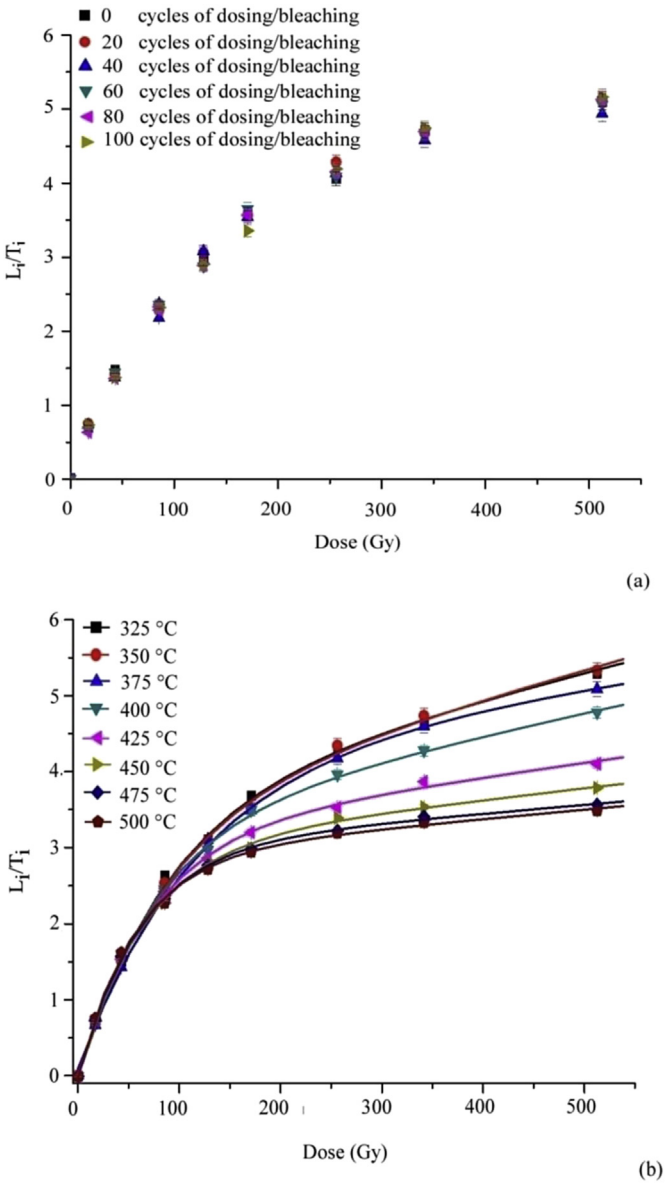

Fig. 7. (a) Laboratory dose response curves for an aliquot of quartz grains of TK-1. Between each construction of a dose response curve, twenty cycles of dosing/bleaching were performed for the same aliquot. (b) Laboratory dose response curves for an aliquot of quartz of TK-1. Between each construction of a dose response curve, a heating treatment to a high temperature T (325–500 °C) is performed. For more details, please refer to Gong et al. (2014b).

origin, while the quartz grains from the Hunshandake sandy land are mainly of igneous origin (Ma, 2002; Yang et al., 2008; Zheng et al., 2009; Lü and Sun, 2011; Gong et al., 2014b). This has been confirmed by Yang et al. (2008) who investigated the oxygen isotopic compositions of quartz from the two deserts. Most quartz grains from the Hunshandake sandy land had been subjected to high temperature heating processes during the geologic past and they are less sensitive to the laboratory heating treatments (500 °C). By examining the OSL components of quartz from the two deserts (Section 3.4), it is also suggested that the quartz grains from the two deserts have different origin. For the quartz grains from the Hunshandake sandy land, the bulk OSL signals (0–0.2 s) are dominated by the fast components, suggesting that most of the quartz grains had been subjected to high temperature heating before burial. For the quartz grains from the Taklimakan Desert, the

fast component is much less prominent and the bulk OSL signals are mainly comprised of both the fast and medium components. This is consistent with the fact that most of the quartz grains from the Taklimakan Desert are derived from a different origin (i.e. the low grade metamorphic origin) rather than the igneous origin (Ma, 2002; Lü and Sun, 2011; Gong et al., 2014b). Thus, it is proposed that the ternary plot of fast-medium-slow components can serve as a useful tool to distinguish quartz grains with different thermal history. In the future, more types of samples should be tested using such a plot to further confirm the relationship between the compositions of the OSL signal and the thermal history.

Examining the influences of irradiation, optical bleaching and heating on the relative contributions of the quartz OSL components, it is also very helpful for understanding the dose saturation characteristics of the quartz OSL signals. When the CW-OSL signals measured from quartz are used to construct the dose response curves (DRCs) as well as to evaluate the equivalent dose (D_e), the luminescence signal broadly used in most cases is calculated by integrating the counts in the initial seconds of the CW-OSL decay curve after subtraction using the averaged signal of the last a few seconds. In this way, the slow component can be largely removed from the bulk OSL signals and the signals targeted consist mainly of the fast and medium components. Because the medium component has a significantly higher dose saturation level than the fast component (e.g. Singarayer and Bailey, 2003, 2004; Wintle and Murray, 2006), the dose saturation level of the bulk OSL signal depends on the relative contributions of fast and medium components. In this study, it is found that cycles of dosing and optical bleaching have insignificant impact on the relative contributions of quartz OSL components of TK-1. Thus, it is expected that the dose saturation characteristics of the OSL signals of TK-1 should not significantly change after different dosing and illumination treatments. This is confirmed by Gong et al. (2014b) who demonstrated that cycles of dosing and optical bleaching have insignificant impact on the OSL growth curves of TK-1 (Fig. 7a). On the other hand, heating to a high temperature (e.g. 500 °C) can significantly alter the contributions of OSL components and enhance the contribution of the fast component to the bulk OSL signals. In this context, the dose saturation characteristics of the bulk OSL signals should significantly change and the dose saturation level are expected to become lower, as the fast component becomes much more prominent in the bulk OSL signals. Gong et al. (2014b) carried out the study to examine the effect of heating on the dose saturation behavior for the quartz OSL of TK-1. They demonstrated that heating to high temperatures can significantly alter the OSL dose growth curves of TK-1 (Fig. 7b) and reduced the dose saturation level of the OSL signals after the natural quartz grains were heated to 500 °C (Gong et al., 2014b). In addition, Gong et al. (2014b) found that most of the quartz grains from the Hunshandake sandy land exhibit a significantly lower dose saturation level than those from the Taklimakan Desert. Such observations are consistent with the fact that the quartz grains from the Hunshandake sandy land contain a significantly stronger fast component than those from the Taklimakan Desert. Thus, heating processes during the geological past can have significant impact on the compositions of quartz OSL signal. Correspondingly, the dose saturation characteristics of the bulk OSL signals of quartz are influenced.

5. Conclusion

Coarse quartz grains from the Taklimakan Desert and the Hunshandake sandy land display differential relative contributions of the OSL components. Through laboratory irradiation, optical bleaching and heating experiments, it has been shown that cycles of dosing and bleaching have relatively insignificant impact on the relative compositions of the OSL signal, while heating to high temperatures (e.g. 500 °C) can significantly enhance the contribution of the fast component to the bulk OSL signals from quartz, especially for quartz grains from the Taklimakan Desert. Our results suggest that a different heating history plays an important role in controlling OSL components of natural quartz from different geographic areas. Moreover, the quartz grains from the Hunshandake sandy land exhibit a stronger fast component than those from the Taklimakan Desert, supporting the fact that sands from the Hunshandake sandy land and the Taklimakan Desert have different provenances, i.e. the quartz grains from the Hunshandake sandy land are mainly of igneous origin, while most of the quartz grains from the Taklimakan Desert are of low grade metamorphic origin.

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