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INVESTIGATIONS ON THE DEGREE OF BLEACHING OF QUARTZ OSL SIGNALS USING MODERN AEOLIAN DUST FROM WESTERN LOESS PLATEAU, CHINA

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Abstract: Optically Stimulated Luminescence signal of quartz extracted from modern aeolian dust with known maximum age (about decades) was analyzed in terms of degree of bleaching. The results of dose recovery tests show that the modified double single-aliquot regenerative-dose protocol with the early background subtraction is robust for dating these modern dusts using small aliquots. Bleaching of these dusts is discussed based on the distribution of D_e values in histograms, scatter plots of D_e versus sensitivity corrected natural OSL signal and comparison between measured D_e and expected D_e. The results indicate that most dusts were completely bleached but some dusts were not completely bleached. For those incompletely bleached dusts in Lanzhou area, the maximum OSL age overestimation is up to ~1 ka, which might be caused by fast deposition accompanied by heavy sand/dust storms. The research suggests that cautions should be given to OSL ages younger than 1 ka in the western China close to deserts.

Keywords: Incomplete bleaching, Quartz, Modern dust, Chinese Loess Plateau.

1. INTRODUCTION

Optically stimulated luminescence (OSL) dating is increasingly used to date late Quaternary sediments on millennial, centurial and even decadal scale depositional events (Madsen and Murray, 2009; Pietsch, 2009). For young sediments, however, OSL dating is inherently problematic and may yield seriously overestimated OSL ages mainly due to potential incomplete bleaching, which has been observed in fluvial sediments (Olley *et al.*, 1998; 1999; Stokes *et al.*, 2001; Jain *et al.*, 2004; Fiebig and Preusser, 2007; Hu *et al.*, 2010), hurricane sediments (Huntley and Clague, 1996; Madsen and Murray, 2009), tsunami deposits (Brill *et al.*, 2012) and glaciofluvial or deltaic sediments (Alexanderson and Murray, 2007; 2012; Fuchs and Owen, 2008; Gemmell *et al.*, 2007; Shen and Mauz, 2012). Generally, aeolian sediment such as loess is an ideal material for OSL dating, because

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quartz grains should have experienced long time of exposure to sun lighting during long distance transportation before deposition (Stokes *et al.*, 2004; Roberts, 2008). However, incomplete optical bleaching was also found in young aeolian sediments (Goble *et al.*, 2004; Costas *et al.*, 2012). Considering that incomplete bleaching can lead to significantly overestimated ages especially for young aeolian sediments, the degree of bleaching of modern dusts from western Chinese Loess Plateau is investigated in order to provide further insights into OSL dating.

2. SAMPLES AND FACILITIES

Deserts of northern China adjacent to the Loess Plateau are regarded as the dominant source of dusts (Zhang, 2007). Dust/sand storms occur frequently and widely during spring in northern China (Qian *et al.*, 2004), providing enough and suitable dust samples to study bleaching characteristics of modern aeolian sediments. High buildings are perfect places for dust deposition. Most modern aeolian dust samples were collected from surfaces or roofs of high buildings situated at the bank of the Yellow River with one from the top of Jiuzhoutai mountain in Lanzhou, western Chinese Loess Plateau which is around 200 km south to the Tengger Desert (**Fig. 1**).

All dust samples were collected only when sunlight was subtle enough to avoid bleaching during sampling. The samples were brushed quickly into light-tight plastic vials. Documents of these ten buildings serve as the independent known maximum age (5-25 a) of these dust samples. The thickness of the dust layer varies between 1-2 mm. Considering that the grains maybe have experienced reworking or deposit very recently, the history of these modern dusts should not be older than the independent control if they were completely bleached before last deposition.

The grain size of modern dusts was analyzed to decide which fraction is dominant and appropriate for D_e measurement. The typical mode size of these dust samples (e.g. TSG, **Fig. 2**), ~26 μm, is similar to that of loess in Lanzhou and adjacent area (Sun *et al.*, 2000), and more than 80% of the grains fall in the 11-63 μm size window while ~12% and ~8% are <11 μm and >63 μm respectively (**Fig. 2**), suggesting that the 11-63 μm fraction is dominant in these samples. Only from sample TSG and HH-5D, enough amount of 38-63 μm fraction was obtained.

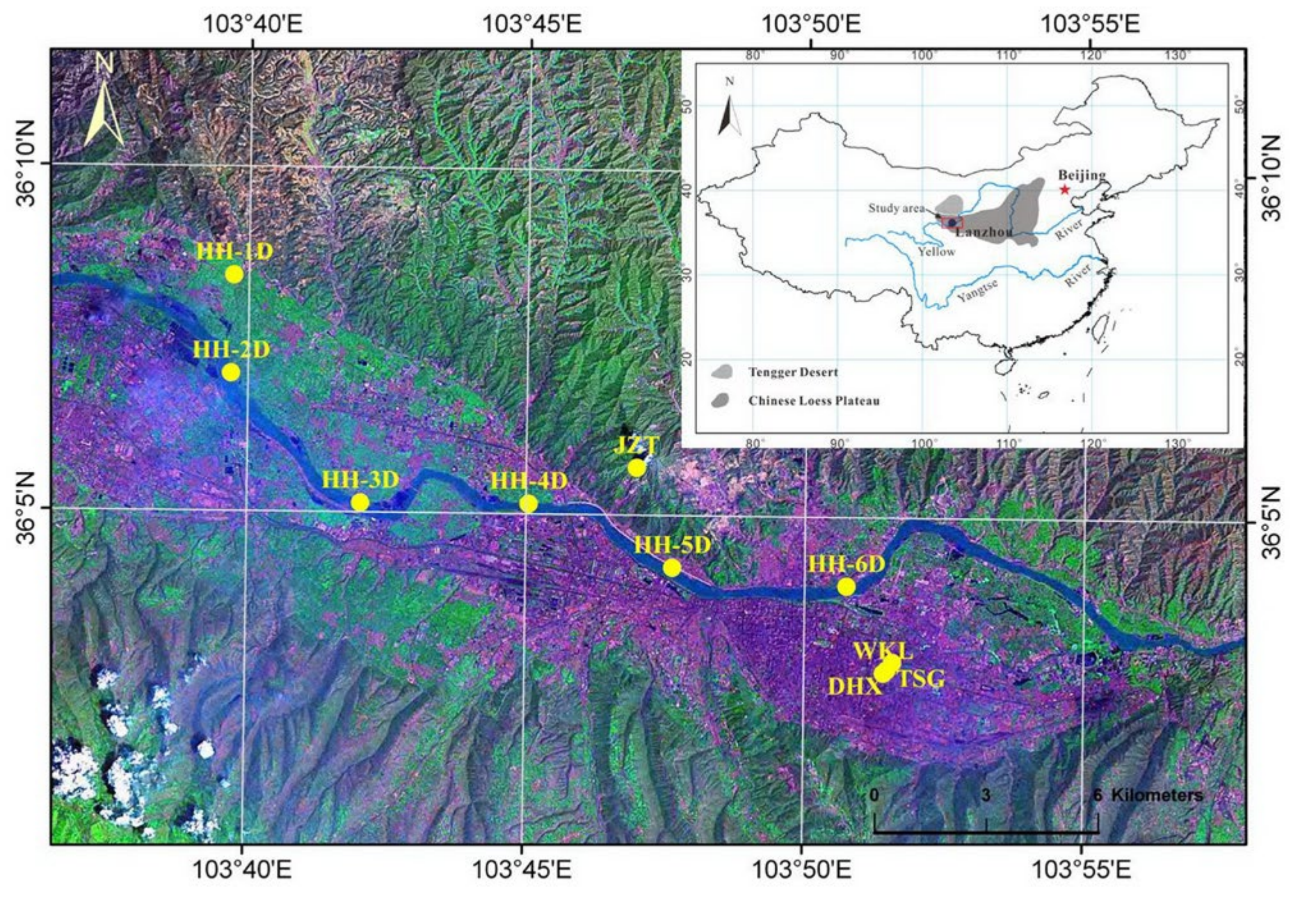


Fig. 1. *Map of the study area and location of sampling sites.*

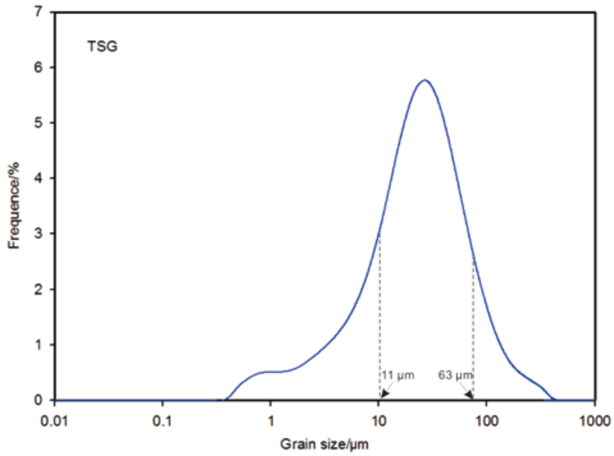


Fig. 2. *Frequency distribution of grain size for a typical dust sample (TSG). Note that the horizontal axis is expressed in logarithmic form. Two dotted lines illustrate the location of the 11 μm and 63 μm on horizontal axis respectively.*

Consequently, OSL signal of the 11-63 μm quartz fraction was used for testing the bleaching property of these dusts based on the assumption that no natural OSL signal above background from quartz fractions should be expected in well bleached modern dust. Routine sample preparation procedure was used to separate quartz from loess to extract 11-63 μm quartz fraction (Berger *et al.*, 1980; Lu *et al.*, 1988; Forman, 1991). Under subtle red light in the darkroom of the laboratory, the dust samples were soaked in 10% H_2O_2 and 30% HCl for a week to remove any carbonate and organic materials. Then the samples were refined to 11-63 μm fraction (including 38-63 μm fraction of sample TSG and HH-5D) using sedimentation procedure based on Stokes's Law. The polymineral fraction was then etched in 10% H_2SiF_6 with ultrasonic bathing for three days to remove feldspar components. And then, the 11-63 μm quartz fraction was treated with 10% HCl to remove any contaminating fluorides, and rinsed with deionized water repeatedly until it reached neutral pH. Subsequently, the purity was checked by depletion of natural infrared stimulated luminescence (IRSL) signal, and those samples that show existence of bright IRSL signal were etched and rinsed again until there was no apparent IRSL signal above background.

A great number of previous studies have demonstrated that small aliquots measurement can identify sediments containing grains with different D_e values (Olley *et al.*, 1999; Tooth *et al.*, 2007; Duller, 2008). In this study, small aliquots were made by mounting 11-63 μm quartz fraction on the 1 mm diameter centre part of stainless steel discs using silicone oil. In the luminescence laboratory of the key laboratory of western China's environmental systems (Ministry of Education) of Lanzhou University, OSL signals were measured on an automated Risø TL/OSL-DA-20 reader equipped with a $^{90}Sr/^{90}Y$ beta source, using 470 nm blue diodes with a power at the sample position of ~50 mW/cm^{-2}, and the IR diodes emitted at a wavelength of 870 nm and power of ~135 mW/cm^{-2}. A 7.5 mm Hoya U-340 detection filter was used (Thomsen *et al.*, 2008). The average of radioactive intensity for the 11-38 μm and 38-63 μm fraction using known D_e values standard samples was taken as the approximate radioactive intensity for the 11-63 μm fraction.

3. METHODS

Modified double singe-aliquot regenerative-dose (SAR) protocol

In order to eliminate the potential contribution of IRSL signal from feldspar inclusions hosted in quartz crystals, the modified double-SAR protocol (Banerjee *et al.*, 2001; Roberts and Wintle, 2001) listed in **Table 1** was used to measure the OSL signal from quartz fractions. In this protocol, preheat at 160-260°C was applied before IRSL measurement at 50°C for 40 seconds which was followed by OSL measurement at 125°C for 40 seconds. Then 180°C cut-heat was conducted before measurements of IRSL signal and OSL signal to the test dose. Finally, a 280°C illumination was carried out before the next regenerative dose irradiation (Murray and Wintle, 2003; Wintle and Murray, 2006). Due to the low intensity of the signals (as illustrated in **Fig. 3a** and **3b**), a relatively large test dose of 0.75 Gy was applied to have an acceptable counting statistics. The protocol was repeated for five cycles with regenerative doses of 0.75 Gy, 1.50 Gy, 2.25 Gy, 0 and 0.75 Gy respectively. Only aliquots that satisfied the following criteria (namely qualified aliquots in the following text) were used in statistics and discussions of D_e distribution: (1) there is no visible IRSL decay above background; (2) the recycling ratio is

Table 1. *The modified double-SAR protocol used in this study.*

Step	Treatment	Observed
1	Regenerative dose	D_i (i=0……5;D_0=0)
2	Preheat (160-260)°C for 10 s	Determined by result of dose recovery test
3	Infrared Optically stimulate for 40 s at 50°C	
4	Blue Optically stimulate for 40 s at 125°C	L_i
5	Test dose	D_t
6	TL at 180°C	
7	Infrared Optically stimulate for 40 s at 50°C	
8	Blue Optically stimulate for 40 s at 125°C	T_i
9	Illumination at 280°C for 40 s	
10	Return to step 1	

Notes: The sequence is repeated for five regenerative doses including a zero Gy dose and a repeated regenerative dose. The five regenerative doses are 0.75 Gy, 1.5 Gy, 2.25 Gy, 0 Gy and 0.75 Gy, respectively. For the natural dose, i=0 and D_0=0. The test dose for all samples is 0.75 Gy. The step 9 of illumination at elevated temperature >preheat temperature is from Murray and Wintle (2003).

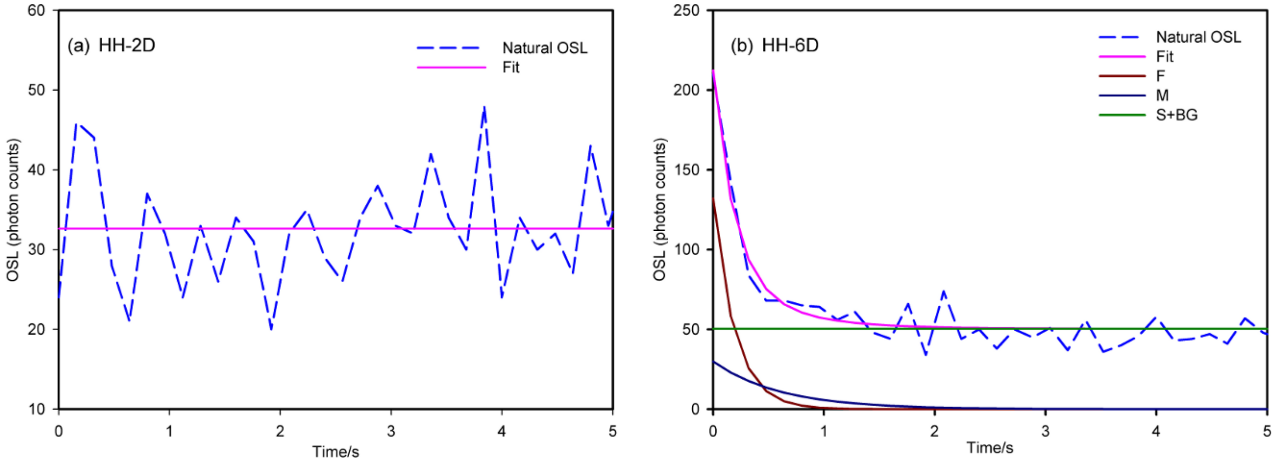


Fig. 3. *Natural OSL decay curves and the curve fitting results for representative aliquots of sample HH-2D (a) and HH-6D (b).*

within 20% of unity (in order to increase number of aliquots involved); (3) insignificant recuperation (<5%), which is adopted to reduce effect of thermal transfer to a negligible level and make the protocol more stringent, though 10% or more was used in the similar study (Madsen and Murray, 2009).

Prior to measurements of OSL signals, dose recovery tests were performed to select suitable preheat and stimulation temperatures (Wintle and Murray, 2006) as well as to test the validity of a modified double-SAR protocol for each sample. Before the dose recovery test, the OSL signal of quartz from each sample was reset by illuminating aliquots under strong sunlight for six hours to empty previous OSL signals. Then a 1.5 Gy dose was given to the bleached aliquots by irradiation through a built-in beta source. Three aliquots were prepared for each preheat temperature. By using the modified double SAR protocol, we obtained the measured doses from the irradiated aliquots and at least one aliquot was used to calculate the dose recovery ratio (=Measured/Given dose ratio) at different preheat temperatures. Only the preheat temperature at which both the dose recovery ratio and recycling ratios were within 10% of unity and where recuperation was smaller than 5% were employed in the modified double SAR protocol to measure OSL signal of quartz fractions. For example, as illustrated in **Fig. 4**, the dose recovery test results indicate that preheat at 240°C is suitable for dust sample HH-3D.

Isolation of the fast-component-dominated OSL signal

Only the fast component is the most suitable for optical dating by using SAR protocol because fast component is the most stable and easily bleached (Wintle and Murray, 2006). The fast component was isolated by using many methods including LM-OSL measurement and curve fitting method (e.g. Bulur, 1996; Bailey *et al.*, 1997; Singarayer and Bailey, 2004; Ballarini *et al.*, 2007; Wallinga *et al.*, 2008; Cunningham and Willinga, 2010). In this study, we isolated the fast component signal by using the early background (EBG) subtraction method (Ballarini *et al.*, 2007; Cunningham and Wallinga, 2009; 2010). Since the selection of integration limit significantly affects the contribution of fast component to D_e values (Cunningham and Wallinga, 2009; 2010), the optimal integration limit of OSL signal and background is selected through fitting method only when the contribution of fast component is maximized. In this experiment, the signal during the first 0.16 s was integrated as the OSL signal with the subsequent 0.64 s (0.16-0.80 s) OSL signal immediately followed as the background as a result of optimal integration limit.

4. RESULTS

In the following sections, we focus on detection of incomplete bleaching based on the decay characteristics of OSL signal, D_e distribution and comparison of measured D_e with the known D_e values of dusts.

Unwanted decay

A modern sample may be considered to have been partially bleached if its fast and/or medium components have not been fully reset (Singarayer *et al.*, 2005). As illustrated in **Fig. 3a**, the absence of natural OSL signal (including fast component) as well as recuperation for sample HH-2D except a constant background, indicates that the previous natural OSL signals (both fast and medium component) have been completely bleached before last deposition and no decay of natural OSL signal should be expected for these fully reset samples. Samples such as HH-1D have the similar decay as sample HH-2D, indicating they are completely bleached. However, significant decay is observed from its natural OSL signal for sample HH-6D, and three components (fast, medium and slow plus background) were successfully isolated (**Fig. 3b**). In addition to sample HH-6D, sample WKL also

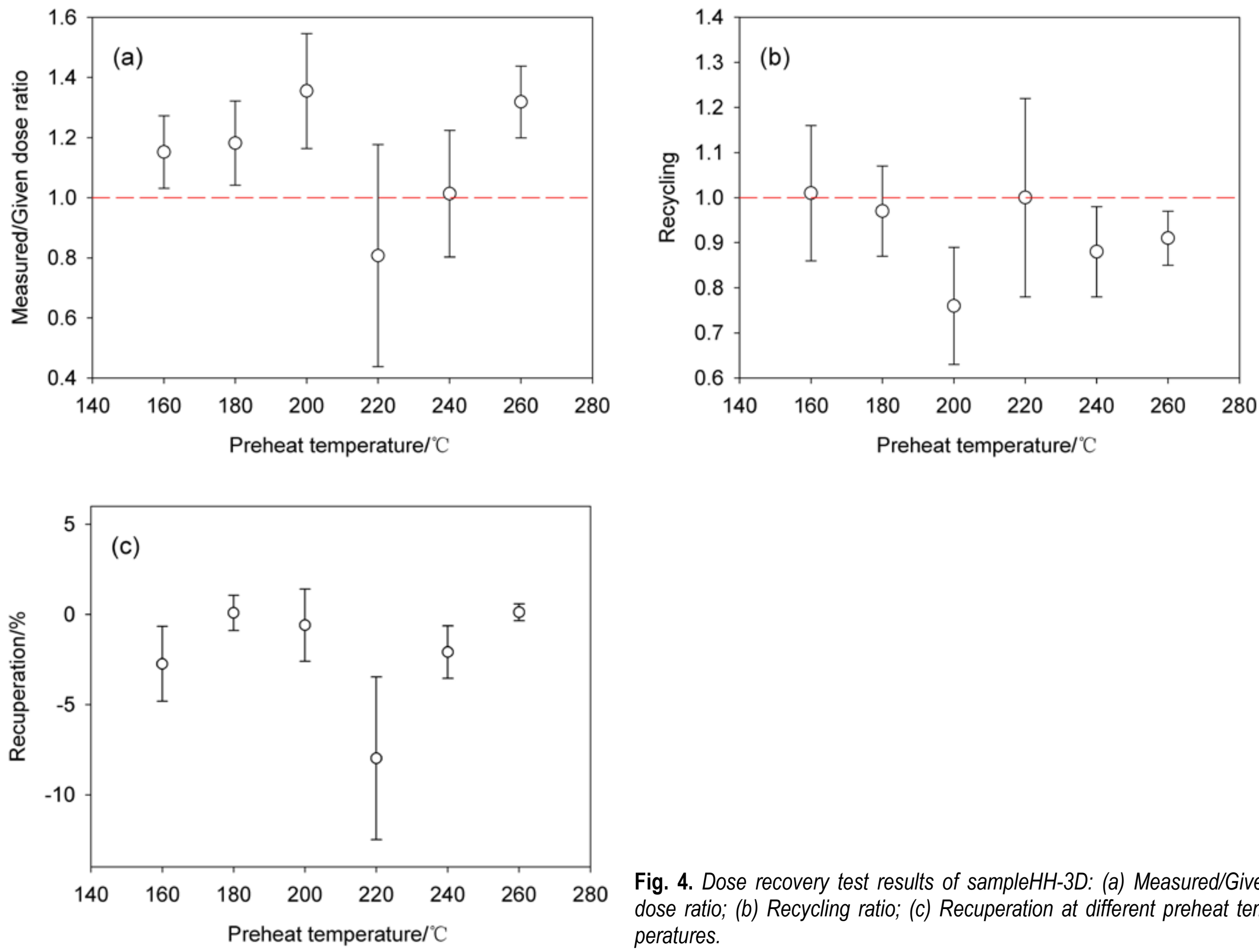


Fig. 4. *Dose recovery test results of sampleHH-3D: (a) Measured/Given dose ratio; (b) Recycling ratio; (c) Recuperation at different preheat temperatures.*

have non-negligible OSL decay. The existence of obvious decay in their natural OSL signal (including both fast and medium components) demonstrates that not only the hard-to-bleach medium decay component but also the easy-to-bleach fast decay component have not been fully reset to zero before burial.

Measured D_e obviously overestimated for some dusts

The expected D_es were estimated based on the known age of buildings and the dose rate of loess from the Loess Plateau. A minimum dose rate of ~3 Gy/ka in loess (past analogue for aeolian dust in the study area) close to earth surface from different profiles is summarized from previous studies on Chinese Loess Plateau (Lai *et al*., 2007; Lu *et al*., 2007; Jiang *et al*., 2009). Subsequently the expected maximal D_e values were obtained for these modern dusts (the third column of **Table 2**). Considering that the grains maybe have experienced reworking after deposition and/or deposit very recently (1-2 mm thick), the history of dusts should be not older than the independent control if they were completely bleached before last exposure to sunlight. That is to say, the equivalent dose for the quartz on roofs should be less than the maximal value of ~0.1 Gy for sample WKL, less than 0.03 Gy for DHX and less than 0.05 Gy for the rest of the samples. We noticed that zero and negative D_es are obtained for some modern dusts. Negative D_es might be produced due to uncertainty of measurements, or poor counting statistics in the measurement of the natural OSL signal (Arnold *et al*., 2009). Here we think that zero and negative D_e values represent well bleached components, and therefore, zero and negative D_es are also involved into statistic and calculation of D_e. Finally, the measured D_e values of each dust sample are calculated in the forms of arithmetic mean and weighted mean D_e (last two columns in **Table 2**) based on all qualified aliquots including zero and negative D_es.

It is more effective to identify incomplete bleaching by using comparison of OSL ages with independent age control than using different age models (Murray *et al.*, 2012). In this study we followed this method to compare the measured D_e with the expected maximal D_e value. For

Table 2. *The comparison between expected maximum D_e and the measured D_e of quartz for all dust samples. The Measured/Given dose ratios and recuperation at the selected preheat temperature are also listed.*

Sample	Known age (a)	Expected maximum D_e (Gy) [a]	Preheat (°C)	Measured/Given dose ratio	Recuperation [b] (%)	Measured D_e (Gy) [c]	
						Arithmetic Mean	Weighted Mean
HH-1D	<10	0.05	220	1.05±0.34	0.55±1.99	-0.01±0.06	-0.01±0.06
HH-2D	<10	0.05	200	1.02±0.07	0.18±0.58	0.01±0.01	NA[d]
HH-3D	<10	0.05	240	1.01±0.21	2.09±1.83	0.17±0.06	NA[d]
HH-4D	<10	0.05	160	1.18±0.11	2.22±1.32	0.16±0.15	NA[d]
HH-5D	<10	0.05	220	1.07±0.10	2.17±4.04	0.39±0.15	NA[d]
HH-6D	<10	0.05	240	1.17±0.11	1.66±3.08	2.12±0.35	1.74±0.33
TSG	<10	0.05	160	1.19±0.17	0.33±0.83	0.02±0.04	NA[d]
DHX	<5	0.03	220	1.01±0.11	0.22±0.38	0.02±0.08	0.08±0.03
WKL	<25	0.13	220	0.99±0.41	0.32±3.2	0.24±0.11	0.31±0.15
JZT	<10	0.05	200	0.93±0.17	3.48±2.57	0.16±0.12	NA[d]

Notes:

a – The expected maximal D_e is obtained by dividing the known age by the minimum dose-rate of 3 Gy/ka.

b – The recuperation is the ratio between OSL response to 0 Gy and to the natural dose.

c – The measured mean and weighted D_es are obtained by calculating arithmetic mean and weighted mean from all qualified aliquots, respectively.

d – For these samples, the weighted mean of D_es cannot be calculated because no valid weight value (=1/ (RSD)^2) is available when a 0 Gy D_e is included.

instance, the measured mean D_es of samples HH-1D and HH-2D are ~-0.01 Gy and 0.01 Gy respectively and very close to the expected maximal D_e, 0.05 Gy, indicating that most of grains of these samples should be bleached completely before last deposition. In contrast, the measured D_e of samples HH-5D and HH-6D are ~0.39 Gy and ~2.12 Gy respectively and apparently larger than their expected maximum D_e, suggesting that these two samples were poorly bleached or at least some grains were bleached incompletely. Of these samples the maximal measured D_e, ~3.39 Gy, of a aliquot of sample HH-6D was obtained and significantly overestimated compared with the expected maximal D_e, 0.05 Gy. In other words, the maximal overestimated OSL age for this sample will be up to around 1 ka.

In order to exclude the potential influence of beta dose heterogeneity to the big grain size range used (11-63 µm) as Armitage and Bailey (2005) noticed in their studies, we measured D_e values of the 38-63 µm from samples TSG and HH-5D and make a comparison with their D_e values of the 11-63 µm size range. The mean D_e of 38-63 µm fractions for samples TSG and HH-5D are 0.13 Gy and 0.63 Gy respectively, which are almost the same as those of the 11-63 µm fraction (~0.02 Gy and ~0.39 Gy respectively) in magnitude. The comparison results between two different size ranges suggest that poor/incomplete bleaching still can be distinguished no matter which size range is used.

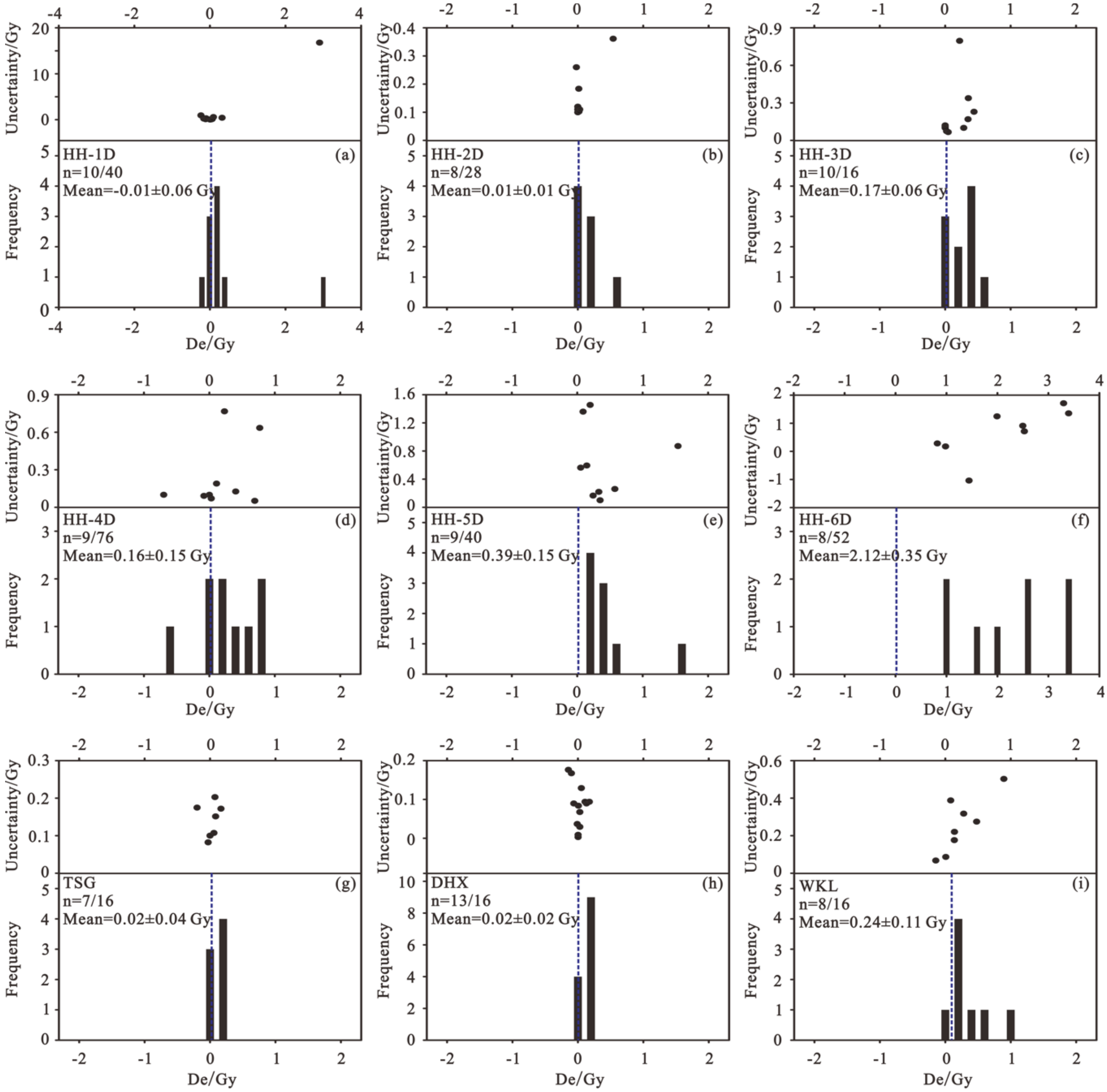
D_e distribution

Two notable and simple forms to demonstrate D_e distribution are histogram and scatter plot (Li and Wintle, 1992; Clarke, 1996; Galbraith and Roberts, 2012). Histograms of D_e values are straightforward if bin size is appropriately chosen with precision of D_e illustrated, although the choice of bin size is arbitrary and precision associated with each D_e is not taken into account (Galbraith and Roberts, 2012). The other alternative, scatter plot of D_e versus sensitivity corrected natural OSL signal, was often used to identify incomplete bleaching (Li and Wintle, 1992; Clarke, 1996; Colls *et al*., 2001). In principle, plots of D_e versus OSL signal intensity showing a statistically significant linear trend are indicative of either partial bleaching or grain mixing (Colls *et al*., 2001; Stokes *et al*., 2001). In order to show D_e distribution visually, we used small bin of 0.02 Gy in D_e values histogram. On top of each histogram, uncertainty of each D_e value is also illustrated to show precision of each measurement (**Fig. 5**). Furthermore, we plot D_e values versus sensitivity corrected natural OSL signal (**Fig. 6**). And in these figures, all D_e values including zero and negative D_es are plotted.

Dispersed D_e distribution in histogram

Also shown in each histogram are number of qualified aliquots, number of all aliquots measured, as well as the mean D_e values based on qualified aliquots. To make a visual comparison, the expected maximal D_e is illustrated as blue dashed line in D_e histogram in **Fig. 5** and scatter plot in **Fig. 6**. We noticed that the natural OSL signals are generally bright, but most aliquots do not satisfy the selected criteria mentioned above and were not involved into statistics. For example, only 8 aliquots of sample HH-6D pass the criteria although 52 aliquots are measured (**Fig. 5f**) and most of them show relatively bright natural OSL signal.

For completely bleached samples, the measured D_es should be smaller than their expected maximal D_e. In **Fig. 5**, D_e of some dust samples HH-1D, HH-2D, DHX and TSG etc. are narrowly distributed (e.g., **Fig. 5a**, **5b**, **5g**,



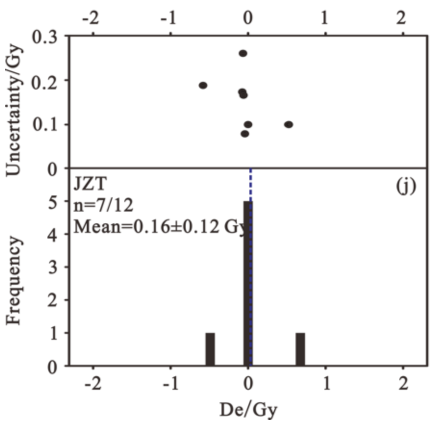


Fig. 5. *Histograms of measured D_e for all dust samples. A class interval of 0.02 Gy was used to illustrate detailed distribution of D_es. The blue dashed lines illustrate the expected maximal D_e for the corresponding samples. Plots of the uncertainty versus D_e are shown above the histograms. Within the plot, number of aliquots used in the measurement of D_e, number of qualified aliquots and mean D_e are shown as text. For instance, for sample HH-1D in* ***Fig. 5a****, 40 aliquots were measured and only 10 aliquots satisfied the criteria, base on which the mean D_e was calculated as -0.01±0.06 Gy.*

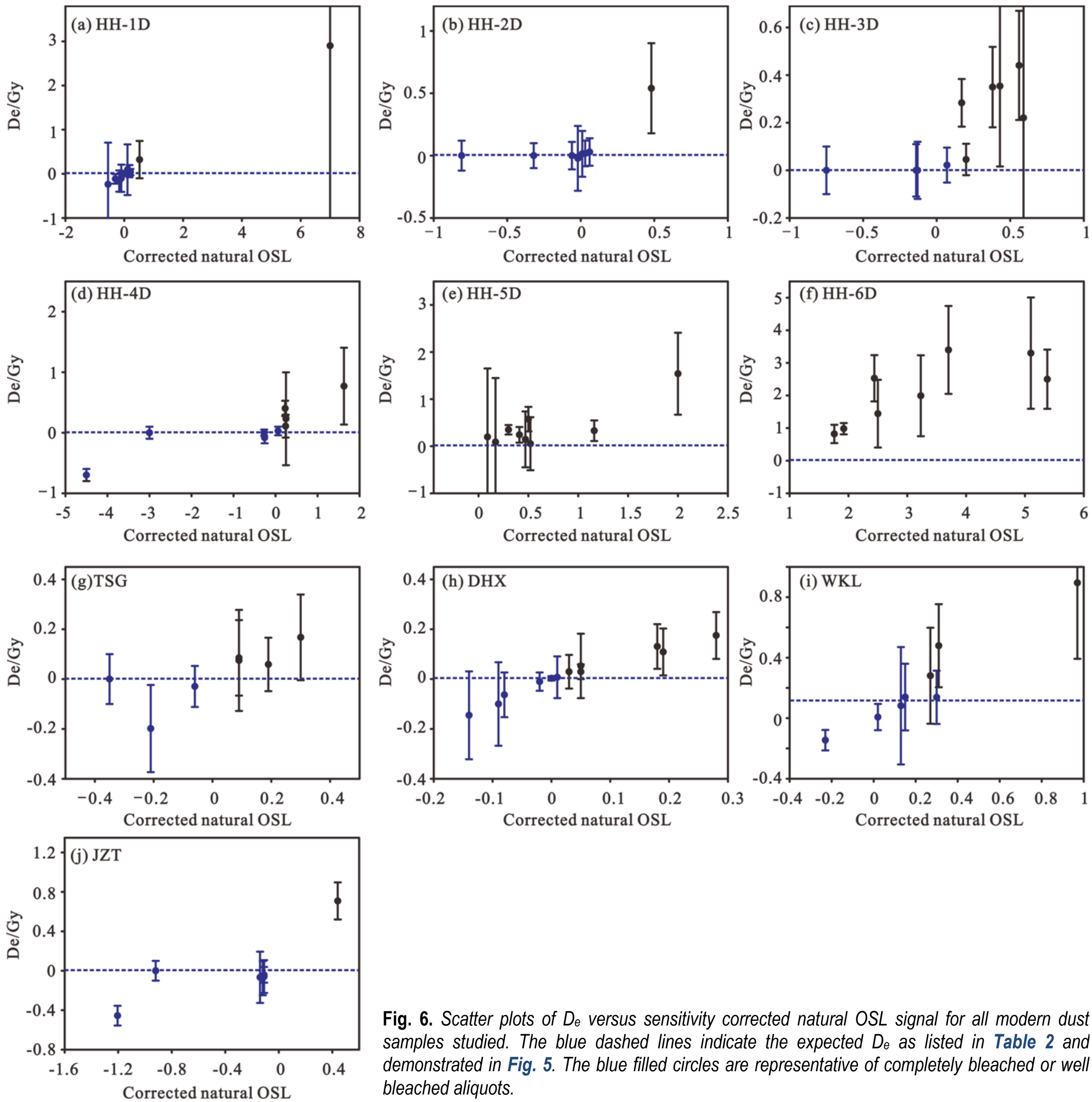


Fig. 6. *Scatter plots of D_e versus sensitivity corrected natural OSL signal for all modern dust samples studied. The blue dashed lines indicate the expected D_e as listed in* ***Table 2*** *and demonstrated in* ***Fig. 5****. The blue filled circles are representative of completely bleached or well bleached aliquots.*

5h). For other samples such as HH-5D and HH-6D, the D_e distribution is relatively dispersed and no D_e is smaller than the expected maximal D_e (**Fig. 5e** and **5f**). The uncertainties of measurement and instrument, however, sometimes can result in low precision of D_e values. An alternative, plot of D_e against uncertainties of measurement and instrument, is often used to exclude the effect of uncertainty of measurement and instrument on D_e and thus D_e distribution (Vandenberghe *et al.*, 2007, 2009; Derese *et al.*, 2009). To demonstrate the precision of each D_e value and if larger D_e is significantly different from a lower one, D_e values are plotted against standard errors to top of each histogram in **Fig. 5**. The uncertainties of some larger D_e values are smaller than those of the smaller D_e values as inferred from samples HH-4D, HH-5D and JZT (**Fig. 5d**, **5e** and **5j**), indicating that the larger D_e is not resulted from uncertainty of measurement and instrument at least in these samples. Therefore we conclude that the dispersed D_e distribution likely supports poor bleaching.

D_e increases with natural OSL signal intensity

Bleaching of luminescence signals can be evaluated in the scatter plot of D_e versus sensitivity corrected natural OSL signal (Li and Wintle, 1992). D_e values of samples with different luminescence property should only cause the random spread of D_e, but D_e will increase linearly with the increased corrected natural OSL signal for incompletely bleached samples (Clarke, 1996; Stokes *et al*., 2001; Li, 2001; Zhang *et al*., 2003). Only D_e values larger than zero are discussed in the scatter plots because zero and negative D_e values are representative of complete bleaching (**Fig. 6h,** blue filled circles). As illustrated in **Fig. 6**, the D_e values do not increase with the sensitivity corrected natural OSL signal (i.e., **Fig. 6d**, **6e**), indicating that they were well bleached. For sample HH-1D, nearly all of its measured D_es except one outlier are centralized and close to the expected D_e without a clear increasing trend (**Fig. 6a**), suggesting that sample HH-1D were well bleached. Likewise, the D_es (except one outlier) of sample HH-2D are independent of the sensitivity corrected natural OSL signal (**Fig. 6b**), indicating apparently this sample was also completely bleached. The samples JZT (except two outliers), TSG (except two outliers with large uncertainty) and DHX (except outliers with large uncertainty) are similar to HH-2D in the scatter plots (**Fig. 6g, 6j** and **6h**). On the contrary, for sample HH-6D, the measured D_es increase apparently with the sensitivity corrected natural OSL signal (**Fig. 6f**). The D_e values of other samples such as HH-4D and WKL obvious increase with sensitivity corrected natural OSL signals (**Fig. 6d, 6i**), indicating these samples potentially suffered incomplete bleaching before last deposition.

In summary, comparison of measured D_e with the expected D_e, the D_e values distributions in histograms and scatter plots of D_e with sensitivity corrected natural OSL signal intensity consistently supports that some dust samples were still incompletely bleached or poorly bleached before burial although most dusts were well bleached. For instance, samples such as HH-1D and HH-2D were bleached completely bleached while samples including HH-5D and HH-6D were not bleached completely because nearly all their D_e values of the latter are apparently larger than the expected control. For the rest samples, both negative and positive D_e values are observed, suggesting that some grains are completely bleached or maybe have experienced reworking after deposition while others are not bleached completely before last deposition.

5. DISCUSSIONS

Both well bleached samples and poorly/incompletely bleached samples have been identified in modern dust samples. This observation stands in contrast to previous ideas that dust would experience complete bleaching before deposition. Unfortunately, we have little knowledge about the reasons that caused incomplete bleaching for the samples studied at present. Here, we discuss the potential reasons for poor bleaching with regard to source difference and sedimentation rates.

Source difference is not the main reason

It is indicated in previous publications that quartz from different sources behave differently in their response to irradiation (Jain *et al*., 2003; Zheng *et al*., 2009). And the TL and OSL signal obtained in response to a fixed dose related to the sources of the grains and their thermal histories (Chen *et al*., 2000; Li, 2001, 2002). By plotting the OSL signal versus 110°C TL signal in response to the test dose, Li *et al.* (2007) studied sample sources of different deserts in northern China and found that sensitivity of quartz will be a sensitive indicator for their sources. We tried to follow such an idea to test whether source differences can give a clue to the difference of bleaching characters of OSL signal and large scatter of equivalent doses for the studied samples or not. The test-dose 110°C TL was plotted against the test-dose OSL of each aliquot for all dust samples in **Fig. 7**. We used the same test dose for all dust samples and found big difference in test dose OSL signals. As illustrated in **Fig. 7**, all samples (except for sample DHX) including the completely bleached samples (e.g., HH-1D and HH-2D) and the incompletely bleached samples (e.g., HH-5D and HH-6D) fall into the same field characterized by low luminescence sensitivity (shaded area), suggesting that they have the same source, maybe local deserts. Another probable explanation for the result is that these sediments maybe come from fluvial grains, since most sites are located at the bank of the river. Some grains of sample DHX show a different source and mixture of aeolian and/or fluvial materials may be responsible for this difference. However, no matter where these dusts come from, source differences should not be the main reason for the difference in OSL bleaching for these dusts.

Fast deposition might cause incomplete bleaching

It is possible that in some circumstances aeolian transport of grains would provide only relatively short duration and/or limited spectrum (Bailey and Arnold, 2006). From the mode of deposition, fast deposition of near-source dust may be responsible for incomplete bleaching. For instance, dust from near source might have less chance and insufficient time to be completely bleached than those transported from distant source. In previous research abrupt changes in sedimentation rates between 0.05-3.45 mm/a was found by using luminescence dating in the thick loess-soil profile in the Chinese Loess Plateau, which was interpreted as a result of change in sedimentation rates caused by near-source contribution (Jiang *et al*., 1998). This research indicated that high sedimentation rates might be a potential cause to difference in OSL signal bleaching. Considering that these modern dust samples are actually collected from the same area within ~10 km (**Fig. 1**), the evidence as mentioned above supports that these aeolian sediments have the same source. Hence, we deduce that fast deposition caused by high sedimentation rates probably contributes

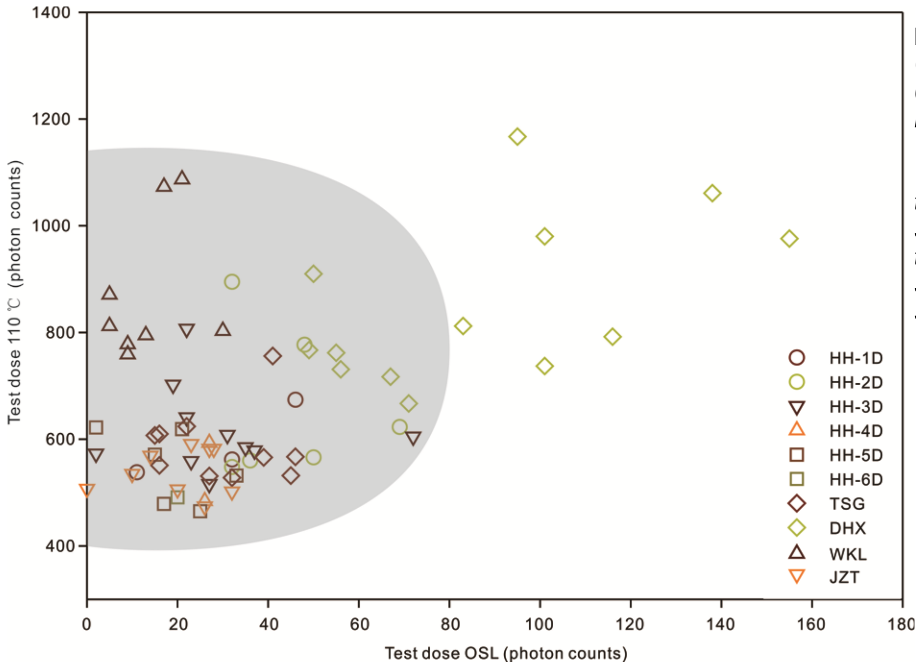


Fig. 7. *Test dose 110°C TL signal versus OSL signal in response to the test dose of 0.75 Gy following the natural OSL measurement for modern aeolian dust samples. The 110°C TL signal was integrated from 80 to 120°C after subtracting the background, and the test dose OSL signal was obtained by subtracting background from the first 0.16 s test dose OSL signals. Samples in the shaded area potentially have the same source.*

to the incomplete bleaching found in this study, which might be accompanied by heavy sand/dust storm, especially at night.

The incomplete bleaching might happen in two situations when heavy sand/dust storm occurs in northern China. Firstly, sand/dust storms is normally accompanied by heavy overcast. When transported during heavy overcast days and/or at night, dust was seldom exposed to sunlight to be bleached. And the sunlight attenuated substantially which lead to limited spectrum considering the ability of reflection, scattering and attenuation of heavy dust. Secondly, near-source dust might also be produced through erosion of sediments on Yellow River terraces when sand/dust storms happen along the Yellow River valley in our sampling area. The near-source dusts are hard to be bleached and deposited rapidly during short distance transportation.

6. CONCLUSIONS

OSL signals of quartz fractions from modern aeolian dust with known maximum age (about decades) were measured to investigate whether they were completely bleached or not before last deposition. Basing on D_e distribution in histogram, scatter plots of D_e with sensitivity corrected natural OSL signal intensity and comparison of measured D_e with their expected D_e, we found that not all modern aeolian dust from western Chinese Loess Plateau experienced sufficient bleaching before deposition. For those poorly bleached samples, the OSL age was overestimated up to around 1 ka. We deduce that fast deposition of near source dust probably contributes to the poor bleaching identified in this study, which might be accompanied by heavy sand/dust storms in northern China. Therefore caution should be given to OSL ages younger than 1 ka in the western China close to deserts.

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