Report for OSL Dating

-Basic conceptions

Materials contain naturally occurring radioactive isotopes, such as uranium-238 (^{238}U), thotium-232 (^{232}Th) or potassium-40 (^{40}K) and they are subject to low levels of radiation. The radiation leads to ionisation of the atoms in the host material and freed electrons may become trapped in structural defects in the mineral crystal lattice. The trapped electrons can be released in in laboratory by light (Huntley et al., 1985). When the trapped charges recombine at luminescence centers in the crystal, an emission of light occurs and the luminescent signal is a reflection of the number of trapped electrons. This technique is referred as optically stimulated luminescence (OSL) dating. For sediments, the clock is zeroed by exposure to sunlight. When the equivalent dose (*De*) (it is an equivalent for the paleo dose) and the environmental dose rate (*D*) are obtained, we can calculate the OSL age:

$$\text{OSL age} = \text{equivalent dose } (De) \text{ / dose rate } (D) \tag{1}$$

-Sample treatment

At the Dujiatuan village site, a trench (38° 6′ 35.68″ N, 102° 2′ 6.58″ E) was excavated on the alluvial fan. This trench reveals conglomerates covered with fine-grained sediments suitable for OSL dating. Samples were collected from both the eolian loess and the fluvial sediments to constrain the upper and lower bound of the abandonment age of the displaced fan surface.

The OSL samples were processed at the Key Laboratory of Crustal Dynamics, Institute of Crustal Dynamics, China Earthquake Administration. The preparation and measurements of the OSL samples followed the standard procedures (Aitken, 1998) (Figure 1). Only sample near the center of the steel tube was used to insure maximal shielding. A small portion of the sample, 20 g, was used to measure the water content. 106 g of each sample was used to measure the environmental dose rate (*D*). As the materials of the samples are finer than silt, quartz grains 4-11 μm in size were used to measure the equivalent dose (*De*). To remove the organic materials, samples were treated with 30% hydrogen peroxide (H_2O_2). 30% hydrochloric acid (HCl) was used to remove carbonates. We obtained grains <90 μm by dry sieving, then grains 4-11 μm in size were extracted by hydrostatic sedimentation. Samples were dried again under temperature of 40 ℃, then etched with 40% hexafluorosilic acid (H_2SiF_6) to remove feldspar. The residual fluorides are further dissolved by 10% HCl.

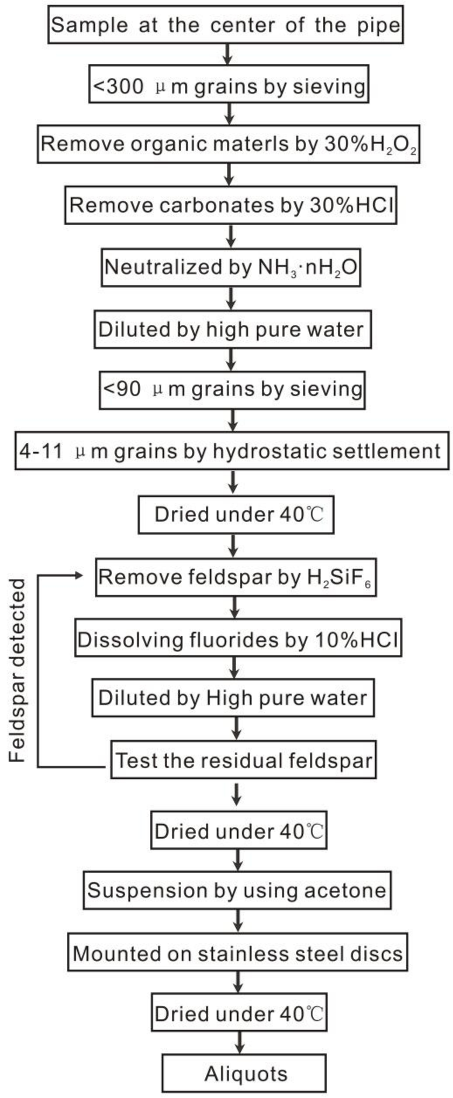

Figure 1. OSL sample treatment procedure

-Determination of the equivalent dose (*De*):

Simplified multiple aliquot regenerative-dose (SMAR) procedure (Wang et al., 2006; Lu et al., 2007) (Table 1). By this method, the natural OSL signal is compared with the artificial signals corresponding to known doses administered from a calibrated laboratory radioisotope source. Then the evaluation of the equivalent dose (*De*) can be done.

In this study, quartz grains 4-11 µm in size were mounted on stainless steel discs. For each sample, one group (8-10 aliquots) is used to measure the natural OSL signal. Another group (6-8 aliquots) is used to measure the regenerated OSL signals. Before the regenerative-dose is given, aliquots are zeroed/blenched under the daylight for 6 hours. To empty thermally unstable traps, both the natural and regenerated groups were preheated to 260℃ for 10s before stimulation. Irradiation and Luminescence measurements were both performed on Risoe DA-20-CD TL/OSL reader made in Denmark. The $^{90}Sr/^{90}Y$ beta source with a dose rate of 0.086 Gy/s was used for dosing. Blue light emitting diodes (LED) (λ =470 $\pm$ 20 nm) was used for stimulation under a temperature of

125℃. To test the purity of the quartz, infrared (λ=830 nm) LED units was used to measured the infrared stimulated luminescence (IRSL) and 110℃ thermoluminescence (TL) peak, which is an indicator of feldspar contamination. When measuring the OSL signal, the background stimulation was subtracted from the initial 0.8 s stimulation. Therefore only the part of the OSL signal that most sensitive to light is measured, giving a enhanced signal-to-noise ratio (Duller and Augustinus, 1997). Depending on different time and temperatures of the preheating procedure, different amounts of light-sensitivity-change take place (Huntley et al., 1993; Murray & Wintle, 2000). To circumvent this problem, calibrations need to be made. After the measurement of natural OSL and regenerated OSL signals (L_i), all the aliquots are given a test dose (*Dt*, ~15% of *De*) then the OSL signals (T_i) are measured. The ratio, L_i/T_i, is define as the calibrated OSL signal (Wang et al., 2005). The calibrated growth curve (Figure 4) was constructed on a calibrated OSL signal-laboratory dose coordinate. The natural OSL (N) is compared with the regenerated OSL, then the equivalent dose (*De*) can be read off from the plotted curve.

Table 1. Sequence description for SMAR protocol (Wang et al., 2005)

	Steps	Statement
1	6-8 aliquots are given different regenerative doses	Before the regenerative-doses are given, aliquots are blenched under the sun
2	8-10 natural aliquots are preheated under 260℃ for 10s	Empty thermally unstable traps
3	Blue light stimulation under 125℃ for 40s	Natural/regenerated OSL signal (Li)
4	All the aliquots are given the test dose (Dt)	Calibrate light-sensitivity change
5	All the aliquots are preheated under 220℃ for 10s	Empty thermally unstable traps
6	Blue light stimulation under 125℃ for 40s	Test OSL signal (Ti)

-Determination of the environmental dose rate (*D*):

Environmental dose rate (*D)* is a measure of the radiation dose per unit of time absorbed by the mineral, quartz in this study, of interest. The dose rate is calculated from an analysis of radioactive elements. The contents of radioactive isotopes of ^{238}U, ^{232}Th and ^{40}K are measured by the Canberra GC4018 (HPGe) gamma spectrometer. Water content affects the radiation dose absorbing rate by quartz. However, as our samples are dry, the measured water content cannot represent the actual water content during the burial period. The water content of all the samples are assumed to be 5%. Based on the relation between the dose rate of quartz, water content and contents of U, Th, K (Aiken, 1998), we can determine the environmental dose rate (*D*). The cosmic ray dose rate was calculated according to Prescott and Hutton (1994).

-Dating result

The report presents the decay curves of natural/regeneration dose OSL intensity (L_i), dose distributions and calibrated (L_i/T_i) growth curves of our samples. The rapidly decaying OSL signals (Figure 2) indicate all of our measured materials are pure quartz free of feldspar. 8-10 aliquots for each simple were used to measure the natural OSL signals. To test whether the sediments were fully bleached before being buried, we potted the dose distributions in Figure 3. The histograms show the equivalent doses concentrate in a small range of dose, indicating the measured grains were well bleached before burial. This may due to the fact that the our fine-grained sediments were fully exposed to the sun-light during a long-way (aerial or fluvial) transportation and hence can be well reset before deposition. Central age model is applied (e.g. Galbraith et al., 1999). The growth curves (Figure 4) show *De* determinations are not affected by the saturation of quartz OSL signal. Based on the equivalent dose (*De*) and the environmental dose rate (*D*), equation (1) yields the OSL age. The dating results are presented in Table 2. The age uncertainty is 1.96 sigma.

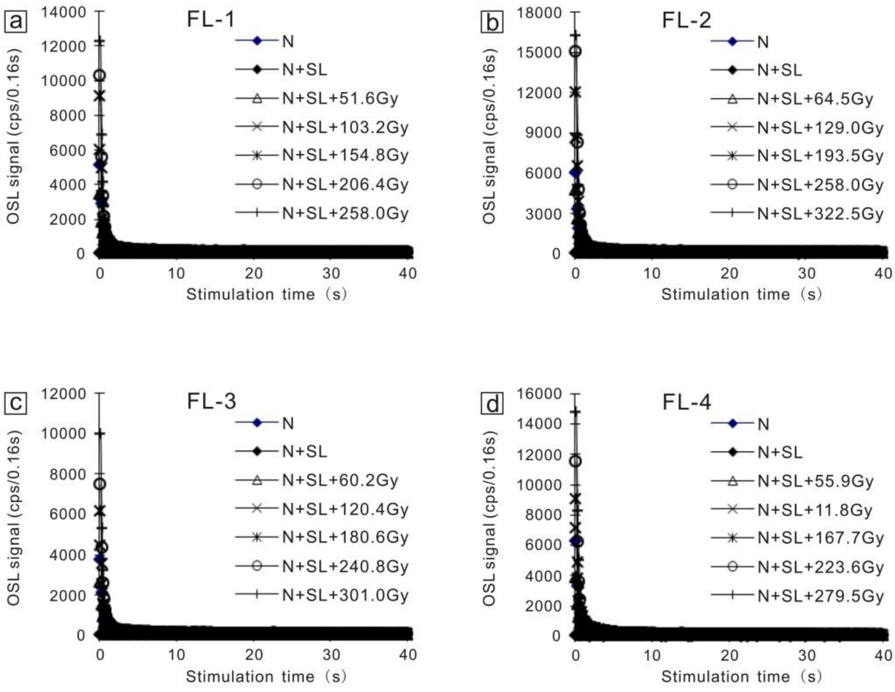

Figure 2. Decay curve of OSL signals.(a) FL-1, (b) FL-2, (3) FL-3, (4) FL-4.

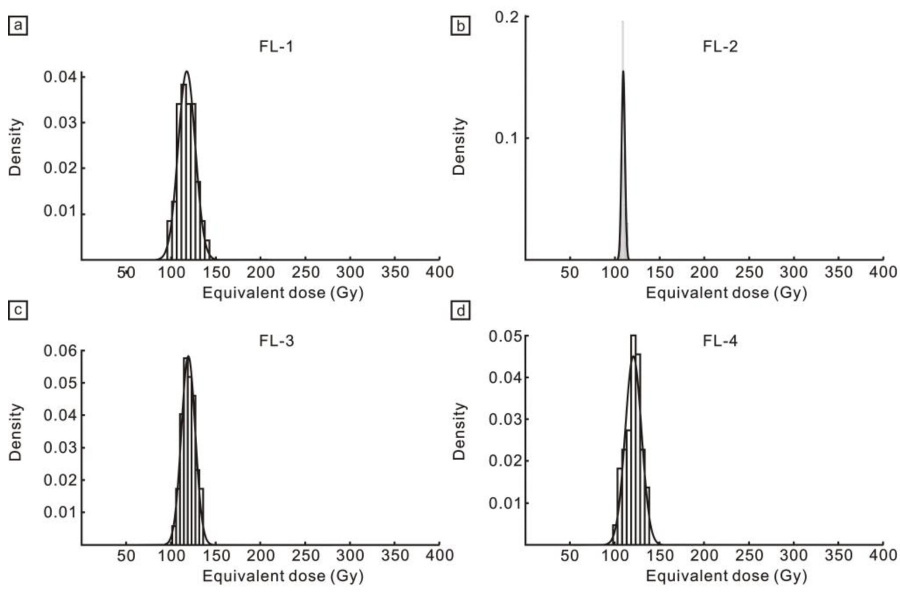

Figure 3. Dose distributions. (a) FL-1, (b) FL-2, (3) FL-3, (4) FL-4.

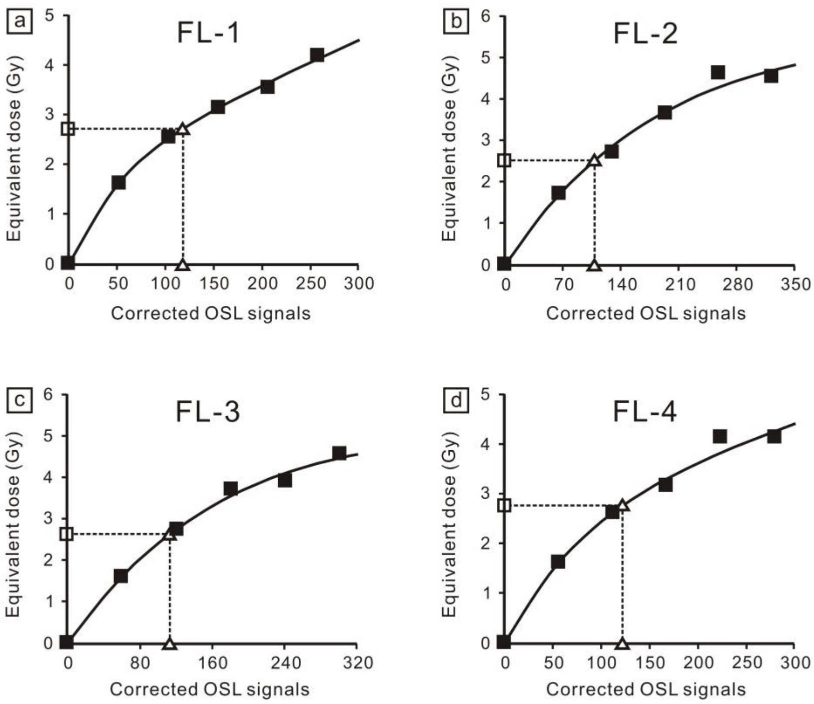

Figure 4. Quartz OSL growth curves.(a) FL-1, (b) FL-2, (3) FL-3, (4) FL-4.

Table 2. Calculated Values of Equivalent Doses, Annual Doses and OSL Ages

Sample ID[a]	Sampling Depth（m）	U(Bq/kg)	Th(Bq/kg)	Ra(Bq/kg)	K(Bq/kg)	Annual Doses (Gy/ka)	Method[b]	Equivalent Doses (Gy)	OSL Age[c]（ka）
FL-1	0.5	43.80±1.42	53.97±2.05	518.37±27.96	41.93±7.65	4.28±0.29	SMAR	118.63±19.30	27.8±5.0
FL-2	0.2	45.10±1.45	54.69±1.98	522.93±28.25	41.58±7.75	4.38±0.30	SMAR	107.85±4.61	24.6±2.0
FL-3	0.18	48.98±1.58	74.49±2.67	611.84±32.92	33.42±6.94	5.18±0.36	SMAR	112.91±10.10	21.8±2.5
FL-4	0.15	52.52±1.71	103.88±3.50	710.16±38.15	35.58±9.46	6.31±0.45	SMAR	121.75±12.61	19.3±2.5

[a]The sampling locations are shown in Figure 5. [b]5% water content is assume when calculating the environmental dose rate. [c]SMAR-Simplified Multiple Aliquot Regenerative-Dose Protocol. [d]The age uncertainty is 1.96 sigma.

-Reference

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