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# CONSTRUCTION OF A QUARTZ OSL STANDARDISED GROWTH CURVE (SGC) FOR AEOLIAN SAMPLES FROM THE HORQIN DUNEFIELD IN NORTHEASTERN CHINA

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**Abstract:** It has been suggested that the standardised growth curve (SGC) method can be used to determinate $D_e$ accurately and reduce the measurement time. However, different opinions regarding the applicability of the SGC method exist. In this paper, we report the construction of quartz OSL SGC for 35 aeolian samples from different parts of the Horqin dunefield in northeastern China, and then test their applicability for $D_e$ determination. Our results suggest that: 1) up to a regeneration dose of 80 Gy, the SGC of the Horqin dunefield can be fitted using the exponential plus linear equation, with the $r^2$ value of 0.97, and all the regeneration dose points closely stick to the fitting line, implying that all samples share a very similar dose-response curve; 2) for samples with $D_e$s ranging from 1 to 50 Gy, the ratios of SAR $D_e$ to SGC $D_e$ fall within the range of 0.9-1.1, and the average ratio of SAR $D_e$ to SGC $D_e$ is 1.01±0.01, close to unity. Therefore, the construction of SGC is correct, and the SGC is an effective procedure for accurate $D_e$ determination for samples from the study area.

**Keywords:** Standardised growth curve (SGC), OSL dating, Aeolian samples, Horqin dunefield in northeastern China.

## 1. INTRODUCTION

The standardised growth curve (SGC) method in optically stimulated luminescence (OSL) dating has been tested and applied to equivalent dose ($D_e$) determination when using the single aliquot regenerative-dose (SAR) protocol (Murray and Wintle, 2000) by many researchers (Roberts and Duller, 2004; Burbidge *et al*., 2006; Lai, 2006; Lai *et al*., 2007; Stevens *et al*., 2007; Hong and Choi, 2008; Telfer *et al*., 2008; Long *et al*., 2010). It is widely accepted that using a SGC, accurate estimates of $D_e$ may be made through a simplified procedure, thus can potentially speed up the measurement process and reduce the measurement time (e.g. Roberts and Duller, 2004; Lai, 2006). However, different opinions regarding the applicability of the SGC method have been reported. Roberts and Duller (2004) examined the growth characteristics of coarse-grained quartz from Tasmania and polymineral fine-grains of loess from China. They found that a universal SGC exists for different samples from different continents. Lai (2006) tested the use of SGC using silt-sized quartz for loess samples from the Chinese Loess Plateau, and concluded that there is a good SGC for samples younger than 270 ka, while older samples have different characteristics. Lai *et al*. (2007) further examined 18 loess samples collected from four continents

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(Asia, America, Africa and Europe). They showed that, except the three samples from Chile in South America, 15 samples display similar dose-response curves up to a regeneration dose of 200 Gy using the SAR protocol, suggesting the existence of a global SGC for loess from different continents, and that the deviation of the Chilean samples is due to the contamination of heavy minerals. Long *et al*. (2010) tested the performance of SGCs for lacustrine sediments of three cores from Qinghai-Tibetan Plateau in China. Their results demonstrated that the $D_e$s determined by the SGC are in agreement with the $D_e$s by SAR protocol, and that the feldspar contamination will cause difference in growth curve shape. Telfer *et al*. (2008) tested the performance of SGCs derived from samples from a range of environments in southern Africa and Florida (United Stated of America). Their data suggested that the method performed well when determining low $D_e$ values (< 50 Gy) for samples with different geological provenances within South Africa. However, the application of a SGC built from South Africa data performed poorly when used to estimate the palaeodoses of samples from Florida, with seven out of ten samples failing to replicate the SAR-derived $D_e$ value to within ±10%. They thus advocate the use of regionally based SGCs only for $D_e$ determination. Furthermore, using samples from the Chinese Loess Plateau, Stevens *et al*. (2007) claimed that the SGC approach is probably only valid where a SGC is constructed and applied to samples from the same section. They reported that samples from the two sections in Beiguoyuan, located within a few kilometers of each other, do not share dose-response characteristics.

Recently, research was initiated to investigate the dune evolution of the Horqin dunefield in northeastern China (**Fig. 1a**) (Yang *et al*., 2010). A total of 64 aeolian samples were collected for luminescence dating from throughout this dunefield (**Fig. 1b**). The SAR protocol has been used for $D_e$ determination for some of these samples. If a SGC could be produced for these aeolian samples by the existed SAR data, the subsequent measurement workload will be significantly reduced. In this paper, we explore the SGC and test its applicability for $D_e$ determination for samples from throughout the Horqin dunefield.

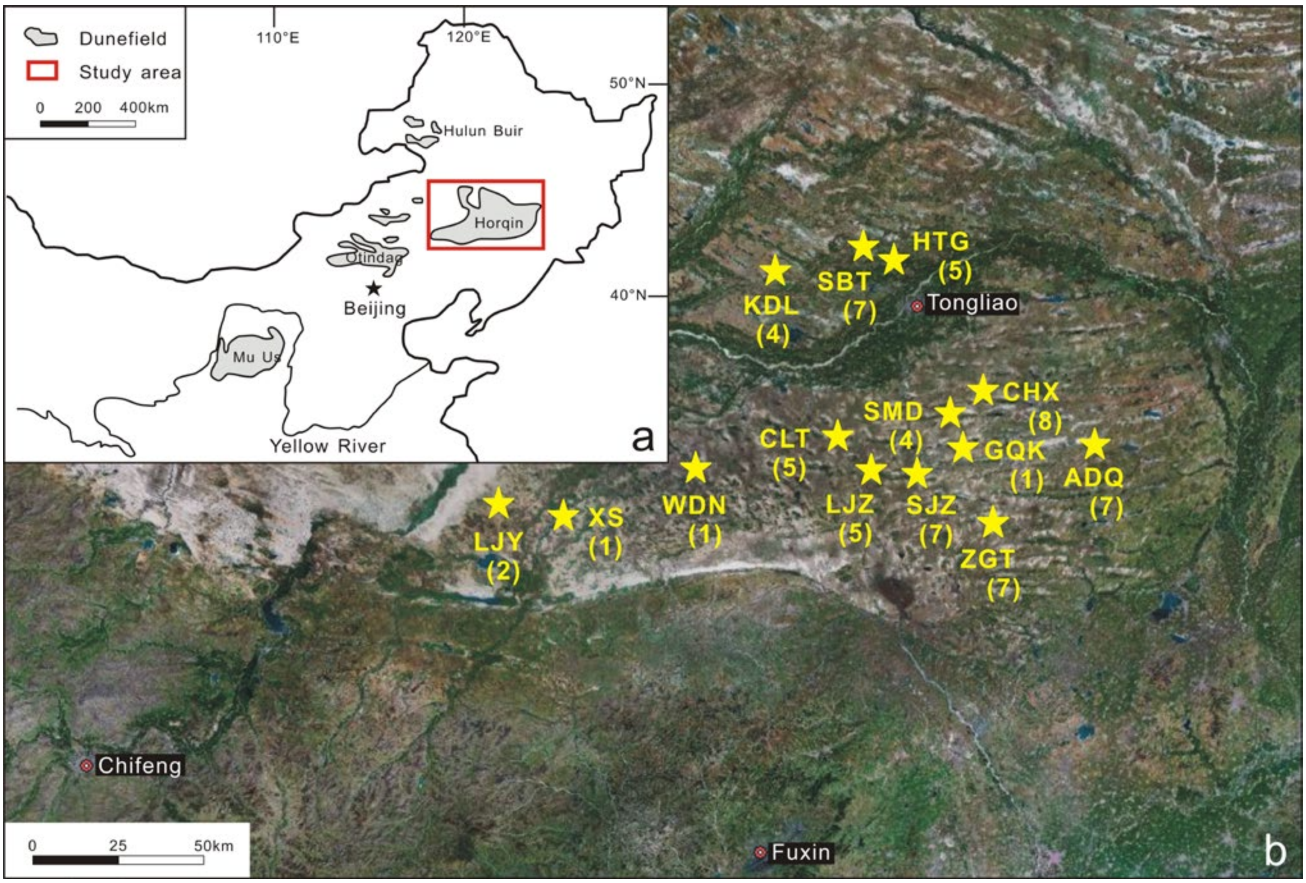


**Fig. 1.** *Location of the Horqin dunefield in northeastern China (a), and the distribution of the sections under investigation (b). The number in bracket means the sample amount of that section.*

## 2. STUDY AREA

The Horqin dunefield, located in the Xiliao river drainage area, is one of the dunefields in northeastern China (**Fig. 1a**). It lies between 42°40′-45°15′ N and 118°30′-124°30′ E, with a total area of about 50,000 km$^2$, and an elevation of 120-800 m above the sea level. The mean annual temperature is 3-7°C. The mean annual precipitation ranges from ~500 mm in the southeast to ~350 mm in the northwest, with about 70% of the monsoonal rainfall occurring in summer (Ren *et al*., 2004). The major form of recent desertification has been the development of nebkha dunes in the alluvial and flood plains of dunefield margins due to the decline in groundwater levels, and some anchored and semi-anchored dunes also evolved into semi-anchored and mobile dunes respectively (Wang *et al*., 2008).

Geomorphologically, the Horqin dunefield is located in the Songliao plain which formed during the Quaternary. The Songliao plain originated from the development of the Songliao subsidence zone (Kailu basin) where an extensive palaeolake existed in the early Cretaceous and left a mass of deposits (Yang, 1995). Nowadays, the Quaternary deposits (alluvial, lacustrine and aeolian deposits) which exist underneath the modern topsoil reach a thickness of ca. 100 m (even 200 m in some place). These various deposits are composed of medium sand, fine sand, silt and clay, and provide plentiful source materials for subsequent formation of dunefields (Qiu, 2008).

In order to establish a reliable chronology of dune evolution in the Horqin dunefield, 14 aeolian sand-sandy soil sections in the interior of Horqin dunefield were investigated and 64 samples were collected for quartz OSL dating (**Fig. 1b**).

## 3. SAMPLE PREPARATION AND MEASUREMENT TECHNIQUES

In the laboratory, all samples were treated with 10% HCl and 30% $H_2O_2$ to remove carbonates and organics, respectively. The quartz fraction of the grains with diameter 38-63 μm was separated by dry sieving or wet sieving and then treated with 35% $H_2SiF_6$ for about two weeks (Berger *et al*., 1980) to remove feldspars. The purity of the prepared quartz was tested by routine IR stimulation. Any sample with detectable decaying IRSL signal above the background will be re-etched with $H_2SiF_6$ for several days to avoid age underestimation which may originate from the contamination of feldspars (Lai and Brückner, 2008). The quartz grains were then mounted on the centre part (with a diameter of ~0.5 cm; in our discs the grains are sparsely distributed and about 3,000-5,000 grains could be mounted according to Duller (2008)) of stainless steel discs (with a diameter of 1 cm) using silicone oil.

The OSL measurements were carried out in a Risø DA-20 automated TL/OSL system at the Luminescence Dating Laboratory of Qinghai Institute of Salt Lakes, Chinese Academy of Sciences. Stimulation was done using blue LEDs (λ = 470±20 nm) for 40 s at 130$^o$C. 90% diode power was used. The OSL signal was detected by a 9235QA photomultiplier tube through a 7.5 mm thick Hoya U-340 detection filter.

## 4. STANDARDISED GROWTH CURVE CONSTRUCTION

In order to establish a chronology to examine the dune evolution in Horqin dunefield, 35 out of the 64 samples were selected to be measured using SAR protocol (Murray and Wintle, 2000, 2003). These samples were from 14 sections distribute throughout the study area. In order to select an appropriate preheat temperature for $D_e$ determination using the SAR protocol, preheat plateau test was conducted for two samples, SJZ-05 and ADQ-05. Preheat temperatures from 220 to 300°C (for 10 s) with an interval of 20°C were tested, using a cut-heat of 220°C for 10 s, with a heating rate of 5°C/s. A good preheat plateau was observed from 220°C to 280°C for the two samples. So, a preheat temperature of 260°C was selected for $D_e$ determination. The dose recovery test was also performed on other two samples, YLH-LJY2 and CHX-05. The ratios of the given doses to the measured doses were 1.03±0.01 and 1.05±0.01, respectively. This result suggested that the SAR procedure is able to recover a laboratory dose. As a result, the SAR conditions were: preheat at 260°C for 10 s, cut-heat at 220°C for 10 s; test doses ($T_D$) of 2.4 Gy, 2.5 Gy and 3.8 Gy were used for different samples; for each sample, six regeneration doses (0 Gy, R1, R2, R3, R4, R5=R1, and their values were assigned according to the magnitude of the natural dose of that sample) were used for the construction of the growth curves; regeneration doses range from 0 Gy to 80 Gy were applied. All aliquots satisfied the prerequisite that the recycling ratio is to be within the range of 0.9-1.1.

### Comparison of growth curves of individual aliquots from the same sample

**Figs. 2a** and **b** show the individual growth curves of six aliquots for samples SMD-04 (young) and ZGT-07 (old), respectively. The growth of the normalised OSL signal with regeneration dose is very similar for all six aliquots within a sample. This pattern is seen for all samples which have been dated using SAR protocol in this study.

### Comparison of growth curves of individual samples from the same section

**Fig. 2c** shows the average growth curves of six aliquots for samples YLH-07 and YLH-08 from the ADQ

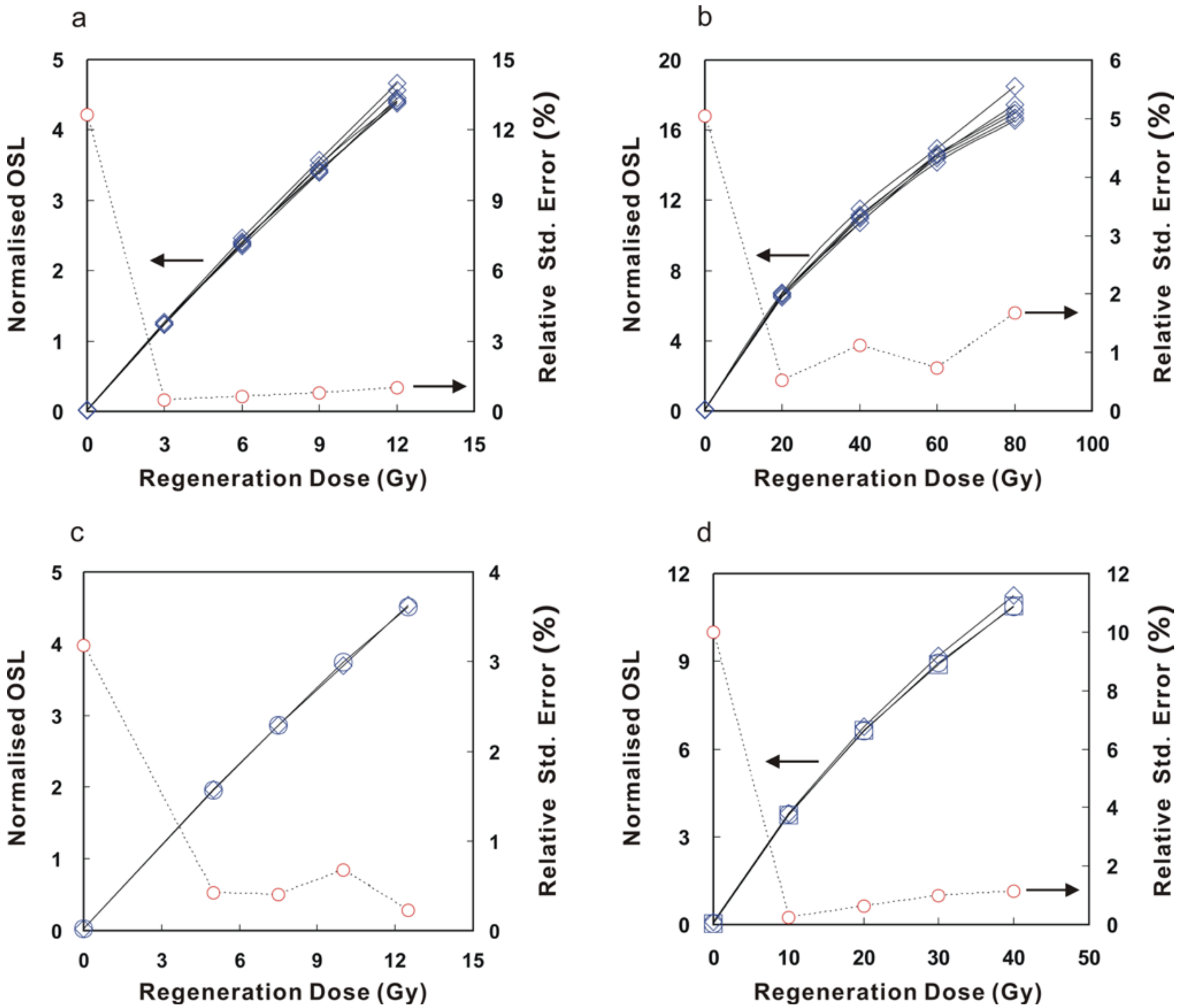


**Fig. 2.** *(a) Growth curves of six aliquots for sample SMD-04. (b) Growth curves of six aliquots for sample ZGT-07. (c) Average growth curves of samples YLH-07 and YLH-08 from section ADQ. (d) Average growth curves of samples ZGT-04 from section ZGT, LJZ-02 from section LJZ, and HTG-02 from section HTG. The relative standard error for the regeneration dose points is shown as empty circles (right-hand y-axis).*

section. The normalised OSL signal levels for a given regeneration dose are identical, with a standard error smaller than 1% (except for the zero dose). This implies that the samples from the same section shared the same dose-response curve.

**Comparison of growth curves of individual samples from different sections**

In order to investigate the dose-response characteristics of samples from different sections, three samples from three sections were selected for comparison. Fig. 2d shows the average growth curves of six aliquots for samples ZGT-04, LJZ-02 and HTG-02 from sections ZGT, LJZ and HTG, respectively. It can be seen that the growth curves of these three samples are almost overlapped with each other. The normalised OSL signal levels for a given regeneration dose have a relative standard error of within 2% (except for the zero dose). This observation suggests that the samples from different sections have the same dose-response characteristics.

**Standardised growth curve construction of the Horqin dunefield**

The above comparison of growth curves of the same sample, different samples from the same section, and different samples from different sections demonstrated that it is likely to construct a regional SGC for the Horqin dunefield.

We used all of the data of all the 35 samples measured by SAR to establish the SGC for the Horqin dunefield

(6 aliquots were measured for each sample, providing 210 regeneration dose points covering a dose range of 0 Gy to 80 Gy). For the construction of the SGC, the average data of the same regeneration dose point were used. The standardised OSL signal levels for a given regeneration dose have a standard error of within 4% (except for the zero dose). As can be seen from **Fig. 3**, the SGC yielded from these data can be well fitted using the exponential plus linear form of (Lai, 2010):

$$Y=k(1-\exp(-X/D_0))+cX+d, \quad (4.1)$$

where $Y$ is the standardised OSL, $X$ is the regenerative dose, $k$ is the standardised OSL intensity at the saturation level for the exponential growth part, $D_0$ is the characteristic dose at which point the slope of the growth curve (exponential part) is equal to $1/e$ of the initial value, $c$ and $d$ are constants defining the linear component. Here, the fitting equation of the established SGC of the Horqin dunedield is:

$$Y=25.27(1-\exp(-0.03X))+0.23X+0.07 \quad (4.2)$$

In statistics, the coefficient of determination, $r^2$, is a statistic that will give valuable information about the goodness of fit for a set of observed data. In general, the higher the value of $r^2$, the more confidence one can have in the fitting equation. An $r^2$ value of 1 indicates that the regression line perfectly fits the data (Nagelkerke, 1991). In this study, the $r^2$ value of the fitting equation of the established SGC is 0.97, implying that the exponential plus linear equation describes the constructed SGC of the Horqin dunefield fairly well. As can be seen from the **Fig. 3**, all the regeneration dose points stick closely to the fitting line. The constant of 0.07 implies that the recuperation for these samples is negligible. Thus, the construction of the SGC is excellent.

Once the SGC had been constructed, a $D_e$ of an aliquot can be determined by fitting the standardised natural signal level ($L_N/T_N{*}T_D$) of the aliquot into the SGC.

## 5. $D_e$ DETERMINATION USING THE SGC

In order to evaluate $D_e$ estimates generated by SGC, we apply the SGC to determine the $D_e$s for the 35 samples which had been measured already by SAR protocol. For $D_e$ determination using the SGC, 12 aliquots were prepared for each sample. The natural signal ($L_N$) and the response to the test dose ($T_N$) were measured. The measurement conditions were the same as those for growth curve construction.

The values of standardised OSL ($L_N/T_N{*}T_D$) can then be matched on the SGC to obtain $D_e$s. The comparison between the SAR $D_e$ and the SGC $D_e$ are shown in **Fig. 4**. For the very young samples with $D_e$s < 1Gy, five out of ten samples fail to replicate the SAR $D_e$ within ±10% (see inset of **Fig. 4**). This discrepancy implies that for very young samples, considerable errors may originate from the using of the SGC method for $D_e$ determination. However, for other 25 samples with $D_e$s ranging from 1 to 50 Gy, all SAR $D_e$/SGC $D_e$ ratios fall within the range of 0.9 to 1.1 (**Fig. 4**). The average SAR $D_e$/SGC $D_e$ ratio is 1.01, with a standard error of 0.01 (n = 25, σ = 0.05), implying that the SGC method yields $D_e$ values consistent with those from SAR.

## 6. CONCLUSIONS

Based on the data derived from the using of SAR pro-

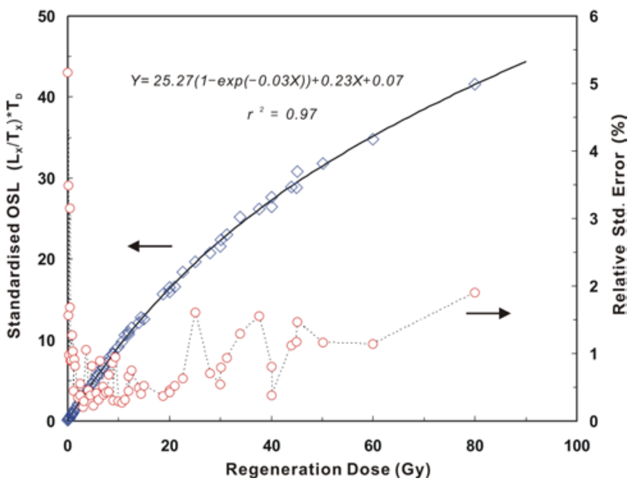


**Fig. 3.** *The SGC constructed using the data of 35 samples from the 14 sections of the Horqin dunefield. Also shown is the fitting equation of the SGC, together with $r^2$ value. The recuperation is negligible for these samples, as the fitting line almost goes through the original point. In all cases, the error bar is smaller than the symbol.*

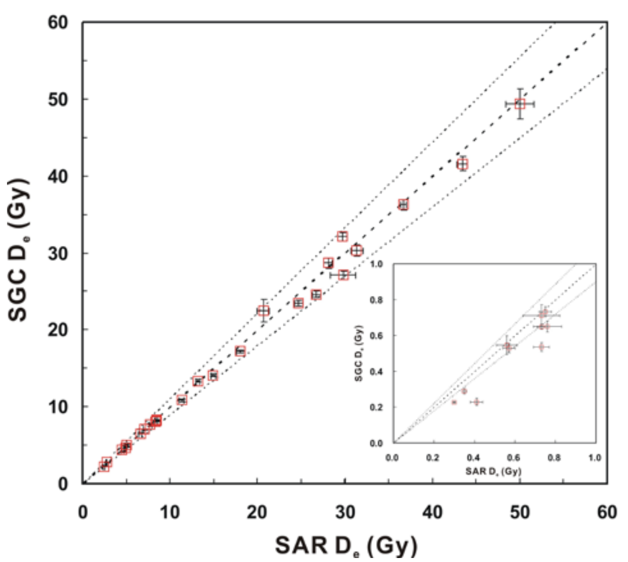


**Fig. 4.** *Comparison of $D_e$s obtained by the SAR protocol against those obtained by the SGC method for 35 samples. The dotted lines represent ratios of 0.9, 1 and 1.1 respectively. The average SAR $D_e$/SGC $D_e$ ratio is 1.01, with a standard error of 0.01.*

tocol for $D_e$ determination for aeolian samples from the Horqin dunefield in northeastern China, this paper examined the quartz OSL growth curves of different aliquots of the same sample, different samples from the same section, and different samples from different sections and then constructed a SGC for the Horqin dunefield. The result shows that, up to a regeneration dose of 80 Gy, the SGC can be well fitted using the exponential plus linear equation, and that all the regeneration dose points stick closely to the fitting line. These demonstrate excellent construction of the SGC. Further test of the application of the SGC demonstrated that the $D_e$s determined by the SGC method are in agreement with the $D_e$s by the SAR protocol for samples with $D_e$s ranging from 1 to 50 Gy from the Horqin dunefield.

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