Equivalent dose in quartz from young samples using the SAR protocol and the effect of preheat temperature

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Received 16 August 2005; received in revised form 23 March 2006; accepted 17 April 2006

Abstract

Major concerns in the dating of samples younger than a few hundred years by the optically stimulated luminescence (OSL) technique are thermal transfer and partial bleaching. Thermal transfer during preheating enhances the OSL signal due to the charge transfer from thermally sensitive, but light-insensitive, traps to optical centres of quartz and results in an overestimate in equivalent dose, especially for very young samples. In this study, the single-aliquot regenerative-dose protocol is used to obtain values of equivalent dose \((D_e)\) from young samples taken from various environments around Istanbul. Within this framework, we aim to investigate the effect of preheat temperature on equivalent dose from 150 to 300 °C, the reproducibility of \(D_e\) measurements for young deposits and the contribution from thermal transfer of charge to the equivalent dose estimation. It was observed that the measured dose is influenced significantly by preheat temperature and the increase in the \(D_e\) is clearly due to thermal transfer of charge from deep thermally sensitive traps to OSL trap during preheating of the samples prior to the main OSL measurements.

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1. Introduction

The Sea of Marmara, the body of water connecting the Black Sea and the Aegean Sea, lies on the continuation to the west of the North Anatolian Fault (NAF) that produces destructive earthquakes. It is one of the most energetic earthquake zones in the world and ruptured during a series of earthquakes in 1939 through 1999. The last two were the İzmit (Mw 7.4) and Düzce (Mw 7.1) quakes in 1999. The North Anatolian Fault is more than 1000 km long, lies parallel to the Black Sea coasts due west, enters the Sea of Marmara at İzmit Bay and splits into two branches. Numerous earthquakes and tsunamis have been reported in historical records for this region. It is assumed that the accumulation rates in the sedimentary basin of the Sea of Marmara and coastal area bordering it might have been controlled by these tectonic activities. Considering that luminescence dating may be used as a tool for obtaining chronological data about historical earthquakes and tsunamis, we present a preliminary investigation of the luminescence characteristics of natural local quartz extracted from samples taken from various locations in that area. This study covers the dependence of equivalent dose \((D_e)\) on preheat temperature applied prior to main luminescence signal measurement in the single-aliquot regenerative-dose (SAR) protocol, the degree of repeatability of a point on the dose–response curve (recycling ratio) for each thermal treatment and thermal transfer of charge from deep light-insensitive traps to the OSL trap.

2. Sampling and OSL measurements

Samples from very young coastal dunes were collected from diverse locations surrounding the Istanbul area, from the Anatolian and European coasts of the Black Sea and the Sea of Marmara (Fig. 1). Black Sea sampling sites, Şile (sl-s) and Altınkum (alt-s), are located on the Anatolian and European sides relative to the Bosphorus, respectively. The Sea of Marmara coast samples were collected from Ataköy (atk-s) to the west of the Bosphorus, and Pendik (pdk-s) located on the
The single-aliquot regenerative-dose protocol (SAR) was applied to all samples with the same range of temperature at low temperatures (especially above 200°C), at higher temperatures (especially > 250°C) the value of $D_e$ significantly increases (Fig. 2), probably due to the thermal transfer of charge during preheating.

In order to investigate the effect of thermal transfer on $D_e$ estimates, aliquots were stimulated first by the LEDs for 40 s at room temperature and were then kept for 4000 s in the dark at room temperature to empty the 110°C TL trap. The stimulation was repeated in order to ensure complete emptying of the rapidly bleached OSL signal (Ballarini et al., 2003). Then the SAR protocol was applied to all samples with the same range of preheat temperatures as described above. The results are presented in Fig. 3; each point was the average of four measurements. We observed that $D_e$ was consistent with zero below the temperature of 200°C (no thermal transfer); above 200°C there was a significant contribution from thermal transfer to the measured dose and the rise in the measured equivalent dose with preheat temperature matches the increase in $D_e$ obtained from the preheat-plateau measurements. This observation confirms that the rising trend in the preheat-plateau is a result of thermal transfer during preheating of the samples prior to OSL measurements.

The $D_e$ values and relevant recycling ratios for all samples are presented in Fig. 4. The uncertainties arising from the random errors are plotted as error bars. The youngest sample (pdk-s) has a mean $D_e$ of 0.005 ± 0.002 Gy. The $D_e$ values of the other samples were 0.008 ± 0.009 Gy (alt-s), 0.018 ± 0.001 Gy (atk-s) and 0.011 ± 0.001 Gy (sle-s) for temperatures below 250°C. The relevant recycling ratios in this temperature range were close to unity (1.01 ± 0.06; 0.95 ± 0.05; 0.98 ± 0.02 and 0.92 ± 0.02, respectively). Since the doses are very small, $D_e$ was interpolated between the origin and the first regeneration dose, with the assumption that the dose–response curve passes through the origin; in other words the recuperation signals due to thermal transfer may be considered negligible as demonstrated in Fig. 3.
Fig. 2. \( D_{E} \) values and recycling ratio values for two samples (atk-s and sle-s) as a function of preheat temperature. Filled circles indicate the \( D_{E} \), each data point is the average of four measurements. Regeneration doses used were 0.5, 1, 1.5, 3.0, 0 and 0.5 Gy, respectively, and the test dose was 0.2 Gy. The open cycles show the average value of the recycling ratios for each temperature, the cut-heat temperature was fixed at 160 °C during measurement sequences.

3.2. Growth curves

Dose response curves for all samples are presented in Fig. 5. The regeneration doses used in the SAR protocol were 0, 50, 70, 100, 200, 500 and 1000 Gy together with a preheat temperature of 220 °C for 10 s and a cut heat temperature of 160 °C. The test dose used was 20 Gy. The upper limit in a dose–response curve allows us to measure the equivalent dose before saturation of the luminescence signal. It is seen that a natural dose of 500 Gy could be measured before saturation for samples pdk-s and sle-s. The samples from European side (especially atk-s) show relatively rapid saturation. Recycling ratios are satisfactory for all samples and the recuperated signal, observed when zero dose is applied, is less than 3.5% of the sensitivity-corrected natural signal for samples atk-s, pdk-s and sle-s; sample alt-s has a very high value (39% of the natural signal).

3.3. Dose recovery tests

A dose recovery test is used to test the reliability of the SAR protocol in dose estimation. Six aliquots of each sample [alt-s, atk-s, pdk-s and sle-s] were bleached at room temperature for 40 s by LED blue light stimulation, before being given a known beta dose of 1 Gy. The only difference from the thermal transfer test is that a known dose is given after the bleaching procedure prior to the OSL measurement described above. The bleached samples were then given 1 Gy beta dose and the SAR sequence
Fig. 3. Thermal-transfer test results of the same samples (atk-s and sle-s); the aliquots were bleached twice using blue light 40 s at room temperature separated by a 4000 s pause. Bleached aliquots were measured using the SAR protocol at various preheat temperatures from 150 to 300 °C. $D_e$ estimate (filled circles) is zero below 200 °C, above 200 °C, there is a significant increase in $D_e$. The recycling ratio is close to unity at lower temperatures (open circles).

Fig. 4. $D_e$ values and relevant recycling ratios for the samples measured at temperatures defined by plateau tests. The uncertainties arising from the random errors are plotted as error bars.

was applied for $D_e$ estimation. The preheat-temperature range was 200–280 °C. Fig. 6a displays the dose recovery test result for sample alt-s together with the recycling ratios and recuperation values at each preheat temperature between 200–280 °C. Results of the test for all samples measured at 220 °C preheat temperature are given in Fig. 6b; the average ratio of observed dose to given dose for those samples was 0.99 ± 0.02.

4. Conclusion

The samples studied here were checked with IR stimulation for feldspar contamination and no significant IRSL signal was observed in any of them. Quartz extracted from these young
local samples was sensitive enough to measure dose, and sensitivity changes were monitored and corrected by the OSL signal of a test dose in SAR applications. We observed that the measured dose is influenced significantly by preheat temperature and the influence of preheating was investigated by both preheat-plateau tests and thermal-transfer tests for all samples. Plateau tests for the samples (alt-s, atk-s, pdk-s and sle-s) indicated that the measured dose ($D_e$) is independent of preheat temperature below 200°C and above this temperature there is a significant rising trend in the $D_e$ (when 10 s preheats were used). The increase in the $D_e$ could be due to thermal transfer and, to investigate this, a thermal-transfer test was conducted. Thermal transfer of charge gave a relatively large OSL signal at higher preheat temperatures (above 200°C), which results in an overestimate dose; the increase in the measured equivalent dose with preheat temperature matches the increase in $D_e$ obtained from the preheat-plateau measurements. Therefore the rising trend in the preheat plateau can be concluded to be the result of thermal transfer of charge from deep light-insensitive traps to OSL trap during preheating of the samples prior to the main OSL measurements. Our results are in good agreement with the recent work (Madsen et al., 2005; Ballarini et al., 2003;
Murray and Olley, 2002). In conclusion, the SAR protocol has been applied successfully to young samples from the sedimentary basin in Istanbul, noted for large earthquakes and tsunamis. No luminescence data in the literature has been reported so far on quartz from this region. Our study shows the potential of using natural local quartz in OSL dating as a chronometric tool for reconstructing coastal evolution and for providing information about historical tectonic activities and tsunamis. The resulting luminescence ages and the probable chronology will be presented in a further study in terms of stratigraphy and sedimentary accumulation rates.

References


