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Influence of radiation used by the security control at airports on the TL signal of quartz

M. Haustein[1], M.R. Krbetschek[2], E. Pernicka[1]

[1] TU Bergakademie Freiberg, Institute of Archaeometry, Gustav-Zeuner-Str. 5, D-09596 Freiberg, Germany
[2]Saxon Academy of Sciences, Quaternary Geochronology Section at TU Freiberg, Bernhard-von-Cotta-Str. 4, D-09596 Freiberg, Germany

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Abstract *In some cases samples for luminescence age determination have to be transported by plane. At all airports these samples have to pass a security control. For this purpose the baggage is X-rayed. In the past it was assumed that a low X-ray dose, as used in the case of security controls, does not influence the luminescence signal. However, in this paper an example is given for quartz from archaeometallurgical slag that is strongly influenced by the radiation used in security checks. Tests were carried out on sample material that passed a simulated security control at Dresden Airport. From these measurements we obtain evidence that the radiation influences the TL signal. The consequence may be a complete change of the luminescence signal, which would lead to a dating error.*

Introduction

Since the 11th of September 2001 the intensity of security controls has strongly increased. Especially the transport by plane includes security checks using X-rays. The doses applied are in a range of µGy in case of the low dose X-ray systems (Heimann Systems GmbH) or much higher in case of high dose X-ray scanners (InVision Technologies INC). The X-radiation might be not much different in energy from γ-radiation, but it is important that the low dose given to the sample in nano- or milliseconds, leads to very high dose rate. Thus, the effect on the TL properties of a sample can be completely different from β- or γ-radiation used in the case of luminescence dating.

A first suspicion of X-ray influence arose with quartz isolated from slag samples from Cyprus, which were transported by plane to Germany. The TL signals measured appeared unusual. It was impossible to determine an exact palaeodose from the glow curves. By excluding all other possibilities an influence of X-rays used by the security check at Larnaca airport was suggested to explain this phenomenon. In order to validate this possibility a security check was deliberately passed at Dresden airport with a slag sample with a well known TL behaviour.

The slag samples from Cyprus

As part of a research project for dating archaeometallurgical slags by TL (Haustein 2002 and Haustein and Krbetschek, 2002) six slag samples from ancient slag heaps on Cyprus were taken. To protect the samples from light, the slags were packed into metal containers. For transport by plane the samples were added to the baggage and hence, they passed the security control at Larnaca Airport.

In the laboratory quartz grains were separated from the slag body by a procedure described by Haustein and Krbetschek (2002). The preparation includes crushing and sieving of the sample, followed by density separation and etching with aqua regia and hydrofluoric acid. With this procedure quartz grains with sizes ranging from 90 to 125 µm were obtained. TL measurements were carried out on the separated quartz grains using a Risø TL 8 unit. For determination of the palaeodose the red TL (RTL) emission at about 620 nm combined with a single aliquot regeneration technique (SAR protocol) was employed. The conventional bialkali PMT was replaced by a trialkali PMT SbKNaCs type RFT M12FC51 (equivalent to EMI 9558B). For cutting out the RTL emission an optical interference filter type LOT-ORIEL D630 with 85% transmission in the range 605-650 nm was chosen.

For the regeneration of the natural signal it was necessary to irradiate the sample with a β-dose of about 290 Gy. An exact determination of the palaeodose was not possible because of the small plateau range (Figure 1). Additionally the natural glow curves were untypical for quartz. Especially the peak at 210 °C (heating rate 3 K/s) was completely missing, while this peak was present in regenerated signals. For general information about typical TL emissions of quartz see e.g. Krbetschek et al. (1997).

Most of the slag samples from Cyprus are from the roman period or later. Therefore a palaeodose of 290 Gy is impossible since the dose-rate determined was about 1 Gy/ka. The glow curves of the six samples from Cyprus are similar to one another. The natural and the regenerated signal of sample Z2 (Figure 1) gives an example for all of the other quartz samples.

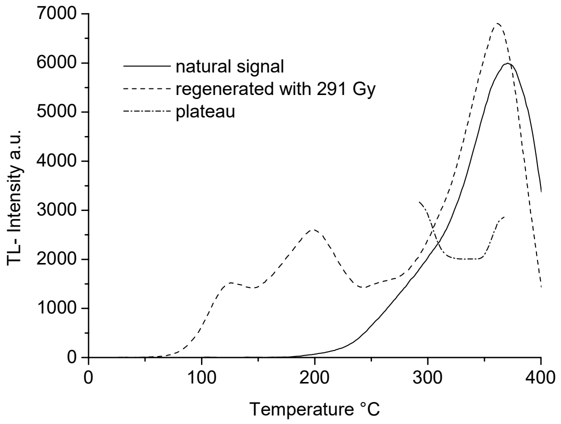

Figure 1.
Natural and regenerated glow curve of quartz from sample Z2 from Cyprus (RTL-signal, heating rate 3K/s). For regeneration a β-dose of about 290 Gy was needed. The dose-rate was determined about 1 Gy/ka. Thus, it is impossible that the sample has accumulated such a high palaeodose. To explain the effect an influence by X-rays used at security control was suggested.

By measuring samples from other locations prepared by the same procedure as in the case of samples from Cyprus, the effect was not found. Therefore, we can be sure that the quartz-separation procedure did not change the TL sensitivity. Since the grains used for TL measurements are included in large slag aggregates during sampling and transport light exposure is unlikely. The only difference was that all other samples were not transported by plane so that we suspected that the security control at the airport was the reason for the dubious phenomenon. To test this assumption a reproduction of the effect was necessary.

Simulation of security control and palaeodose measurement

Unfortunately it was not possible to repeat the security control at Larnaca airport. There is also no exact information about the procedure used because all informations concerning security are kept secret. Alternatively we simulated a security control by using a low-dose X-ray scanner HI-SCAN 6040 from Heimann Systems at Dresden Airport. The dose of this system is about 2 µGy with an energy of about 140 keV (Heimann Systems, 2002). Although it was clear that we can not reproduce the conditions of the earlier exposure exactly, because it was suspected that different instruments were used at Dresden and Larnaca Airports.

A slag sample from the old smelting site "Versunkene Kirche" in Austria (see Presslinger 1998), with a well known natural TL signal (Haustein 2002) was divided into two parts called Oe11 and Oe11 SC (SC=**S**ecurity **C**ontrol). The sample Oe11 SC was packed into a metal container and added to a baggage as typical for air travel. This baggage was subjected to a security check by the German Federal Border Guard (BGS) at Dresden Airport. The second part of the slag (Oe11) was not exposed to artificial radiation.

In the next step the quartz was separated from the two samples. The TL measurements were carried out using a Risø TL 12 unit with a bialkali PMT type EMI 9635. An optical interference filter type SCHOTT OG 530 was employed. The glow curves of natural RTL obtained from sample Oe11 and Oe11 SC (mean of ten aliquots with 1-sigma standard deviation) are shown in Figure 2.

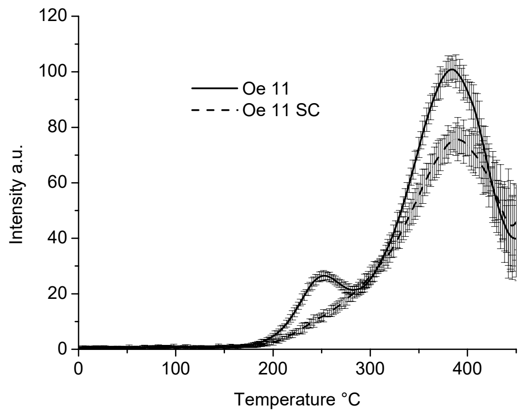

Figure 2.
Glow curves of quartz from sample Oe11 and Oe11 SC (RTL signal, heating rate 10K/s). Mean of ten measurements with 1-sigma standard deviation. Security control was simulated on sample Oe11 SC by the Federal Border Service at Dresden Airport. The signal intensities differ significantly from one another. As found in the samplesfrom Cyprus, in the X-rayed slag the peak at about 250°C is completely absent.

After measuring the natural RTL the heated aliquots were irradiated with β-doses (Sr-90 source). The glow curves of Oe11 and Oe11 SC obtained after a radiation dose of 17 Gy are given in Figure 3. They were performed by mean of 10 measurements. In addition to the regeneration technique (SAR) an additive irradiation was carried out. The additive glow curves with the determined plateau areas of Oe11 and Oe11 SC are shown in Figures 4 and 5.

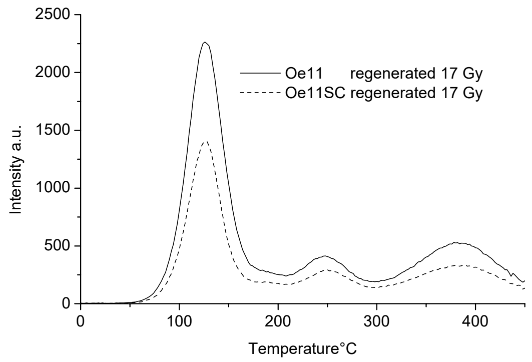

Figure 3.
Regenerated glow curves (17 Gy β-dose) of quartz from sample Oe11 and Oe11 SC (RTL signal, heating rate 10K/s). Mean of ten measurements. For clarity of the figure the signals are shown without error bars. The regeneration of X-ray influenced sample leads to a lower TL intensity as in the case of not influenced sample.

Results and **Discussion**

The natural glow curves of the sample exposed to X-rays and the unexposed sample (Figure 2) differ significantly. The glow curve of Oe11 is typical for heated quartz, with peak maxima at about 250 and 380°C (heating rate 10K/s). In contrast, the glow curve of Oe11 SC rises to 390°C, without a maximum at 250°C. Additionally, the intensity is lower than for the unexposed sample. For typical TL signals of quartz see Scholefield and Prescott (1999) or Fattahi and Stokes (2000).

In Figure 3 the regenerated glow curves of the two samples are shown. It is obviously that the β-dose applied to Oe11 SC results in a lower signal than in Oe11, i.e. to obtain the same signal intensity a much higher dose is necessary. The glow curves obtained from the two samples by an additive irradiation are also very different. For Oe11, the natural signal and the signals determined after an additive irradiation of 4.25, 8.5 and 17 Gy are shown in Figure 4. A good plateau was found in the temperature range from 300 to 390°C. Again much lower signal intensities were found in glow curves of Oe11 SC (Figure 5). Thus, the results of the regeneration experiment (Figure 3) could be confirmed.

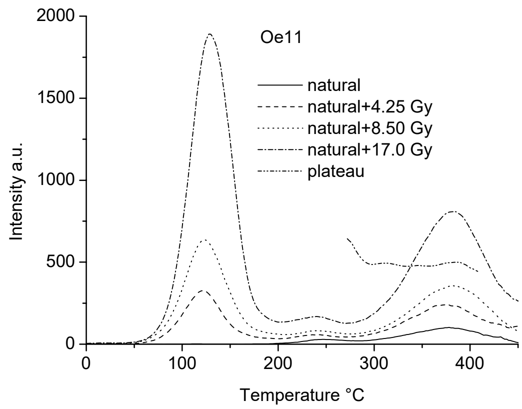

Figure 4.
Additive dose growth of TL signal of quartz from sample Oe11 (RTL signal, heatingrate 10K/s). The plateau was determined in the range from 300 to 390°C.

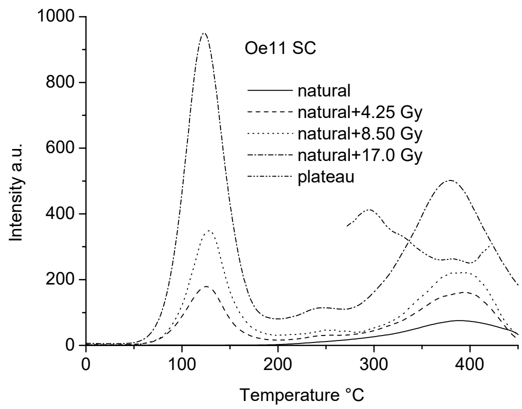

Figure 5.
Additive dose growth of TL signal of quartz from sample Oe11 SC (RTL signal, heating rate 10K/s). A plateau was found only in the small temperature range from 360 to 390°C. The signal intensity is significant lower than in the case of the not X-ray influenced sample Oe11 (Figure 4).

It is important to note that the regeneration of the X-rayed sample Oe11 SC with a β-dose of 17 Gy leads to a lower signal intensity compared with sample Oe11 which was not exposed to X-rays (Figure 3). This means that for regeneration of the natural TL signal of Oe11 SC a higher dose is necessary. Similar to the Cyprus samples the determined palaeodose of the X-rayed sample becomes too high. Additionally the natural signal after X-raying at Dresden airport is very similar to the signal of Cyprus samples (Figure 1 and 2). The 250 °C peak, typical for heated quartz in the RTL, is completely absent.

The plateau of Oe11 SC is in a very small temperature range from 360 to 390°C (Figure 5), so that the palaeodose could not be exactly determined. Nevertheless, by applying the SAR-technique in the range from 300 to 390°C a palaeodose of 6.8±0.8 Gy (mean with 1-sigma standard derivation) could be calculated, while for Oe11 5.4±0.3 Gy was observed. By use of the additive technique 6.1 Gy for Oe11 SC and 5.0 Gy for Oe11 were found. These results show that the exposure of samples to X-rays in security controls results in higher palaeodoses. Qualitatively these observations are identical to those observed in our samples from Cyprus.

Summary

Anomalous TL signals were found on quartz separated from slags that were transported from Cyprus by plane. The palaeodoses determined were unexpected high. To explain this phenomenon an influence on the TL properties of the slag material by X-rays used for security control was suggested. To validate this assumption the effect had to be reproduced. Therefore a slag sample with a well known TL signal was X-rayed at Dresden airport. As in the case of samples from Cyprus after X-raying the palaeodoses determined were to high. Additionally the TL signals look very similar to the glow curves of Cyprus samples. The peak at about 250 °C is absent. Thus, there is evidence that X-ray as used for security checks may lead to an influence on the red TL signal of quartz. There is no exact explanation of this phenomenon at the moment. A likely scenario might be a competition effect leading to de-sensitization of the luminescence from the material.

It must be pointed out that the effect is found on quartz included in slag matrix. There is no information if this or a similar phenomenon can be observed for other sample types or emissions. However, the exposition of sample material by X-ray should be strongly avoided.

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Reviewer

S. McKeever