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OSL technique for studies of jasper samples

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HIGHLIGHTS

- ▶ Jasper sample is a material that can be exploited for high-doses dosimetry.
- ▶ Jasper color is fairly uniform: green, red, brown, ocean and striped.
- ▶ The OSL dose response of the red jasper is higher relative to the other jasper samples.
- ▶ All detectors presented a sublinear behavior, in the range 50 Gy–1 kGy.

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ABSTRACT

Jasper samples (green, red, brown, ocean and striped) were studied in relation to their optically stimulated luminescence (OSL) dosimetric properties, in this work. Since 2000, the radiation metrology group of IPEN has studied different stones as new materials for application in high-dose dosimetry. The jasper samples were exposed to different radiation doses, using the Gamma-cell 220 system (⁶⁰Co) of IPEN. Calibration curves were obtained for the jasper samples between 50 Gy and 300 kGy. The reproducibility of the OSL response and the lower detection doses were determined. All five types of jasper samples showed their usefulness as irradiation indicators and as high-dose dosimeters, using the OSL technique.

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1. Introduction

The optical stimulated luminescence technique (OSL) has been studied for applications in dosimetry following the development and introduction of the first commercial personal monitoring system. The OSL technique was applied for luminescence dating and retrospective dosimetry (McKeever, 2001; Bøtter-Jensen et al., 2003).

The OSL technique presents some advantages in relation to the thermoluminescent technique (TL): OSL is typically measured at ambient temperature, is less destructive and potentially more sensitive than TL; the OSL signal can be measured several times in the same sample; and the TL signal can be generally measured after the OSL measurements of the same sample. The OSL technique measures the trapped electrons that are more sensitive to light, and is extremely important to geological dating of

sediment samples (Bøtter-Jensen, 2000; McKeever, 2001; Bøtter-Jensen et al., 2003).

The dosimeter characteristics of silicate samples have been studied for application in high-dose dosimetry by the radiation metrology group of IPEN. Topaz (Souza et al., 2002), amethyst (Rocha et al., 2003), jade (Melo et al., 2008); onyx (Teixeira et al., 2001) and jasper (Teixeira and Caldas, 2012) were tested for the possibility of their use in gamma dosimetry, using the TL and OSL techniques.

McLaughlin et al. (1989) described several kinds of high-dose dosimeters, showing their advantages and disadvantages. In this work, the dosimetric properties of jasper samples (green, red, brown, ocean and striped) were studied by the OSL technique.

Jasper is included in the chalcedony group. The fine-grained jasper always contains strange materials, sometimes even in a proportion of 20%. These impurities determine its color tone, the design of the jasper samples, but in general such materials may be sub-divided into chalcedony (sometimes called jasper) and agate. Jasper color is fairly uniform (green, red, brown, ocean and striped), and agate color is arranged in bands or in concentric zones (Klein and Dana, 2002).

The areas of sterilization of pharmaceutical products, food preservation and treatment of several materials radiation processing

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using high doses would profit from the development of high-dose detectors.

2. Materials and methods

In the present work, jasper samples (red, green, striped, brown and ocean) were obtained from different Brazilian mines.

The jasper samples were initially cleaned, pulverized, and grain diameters between 0.074 and 0.177 mm were obtained. The samples were thermally treated at 300 °C during 1 h in open atmosphere. At the laboratory for production of dosimetric materials, IPEN, sintered jasper pellets were prepared, using Teflon as binder, and the parts were mixed in the ratio 2 (Teflon): 1 (powdered sample) in open atmosphere nitrogen, to facilitate its handling. This mixture was cooled with liquid nitrogen to optimize the homogenization. These pellets are 6 mm in diameter \times 1 mm thickness, and 50 mg of mass. For sintering, the samples were thermally treated at 300 °C for 30 min followed by 400 °C for 1.5 h. Before reutilization of the samples, a thermal treatment 300 °C for 1 h was performed.

The samples were irradiated using a Gamma Cell-220 System of ^{60}Co (dose rate of 1.52 kGy/h), for doses of 50 Gy up to 30 kGy. In order to guarantee the occurrence of electronic equilibrium during the irradiations the samples were fixed between 3 mm thick polymethyl methacrylate plates (Lucite), and packed in aluminum foils. The irradiations were made at ambient temperature. The OSL measurements were taken using a RISÖ TL/OSL Reader and Controller, model DA-20, and the data acquisition was realized using a personal computer.

3. Results

The main dosimetric properties of the jasper samples studied in this work were to establish reproducibility of the response, lower detection limits and dose-response curve to gamma radiation (^{60}Co).

The OSL response versus time is presented in Fig. 1 for all jasper samples irradiated with 1 kGy (^{60}Co). It can be observed that the ocean jasper presents a lower OSL signal, while the red jasper response is higher relative to the other samples.

The OSL dose response curves of the jasper pellets were obtained for ^{60}Co in the dose range of 50 Gy–300 kGy. Fig. 2 presents the dose–response curves of the jasper samples; these measurements present a maximum relative standard deviation of 2.5%. All detectors presented a sublinear behavior, in the range

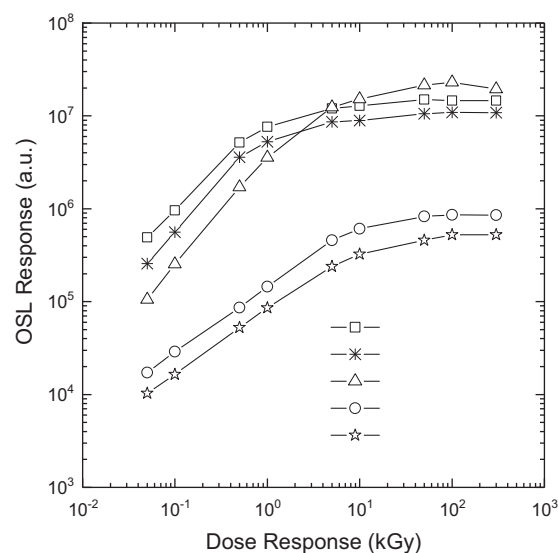


Fig. 2. Dose–response curves of OSL response of Jasper samples for ^{60}Co radiation.

50Gy–1 kGy; the red jasper samples are the most sensible to the OSL technique.

The lower detection limits for the OSL jasper samples were obtained taking three times the values of the standard deviation of five measurements of three non-irradiated jasper samples of each jasper type (thermal treatment at 300 °C/1 h), expressed in units of absorbed dose. The values obtained for the lower detection limits were: 30 mGy, 300 mGy, 350 mGy, 150 mGy and 500 mGy for the red jasper, green jasper, striped jasper, brown jasper and ocean jasper samples, respectively.

The reproducibility of the OSL response of jasper samples was obtained by five measurements of each sample. These measurements, for each sample, were taken after the reutilization procedure (thermal treatment) and irradiation with the ^{60}Co source to an absorbed dose of 2 kGy. This procedure was repeated five times consecutively. The maximum values are presented in Table 1. The results of standard deviations did not exceed 5.4% for the five types of jasper samples. The results show an adequate reproducibility of the jasper sample response for high-dose dosimetry.

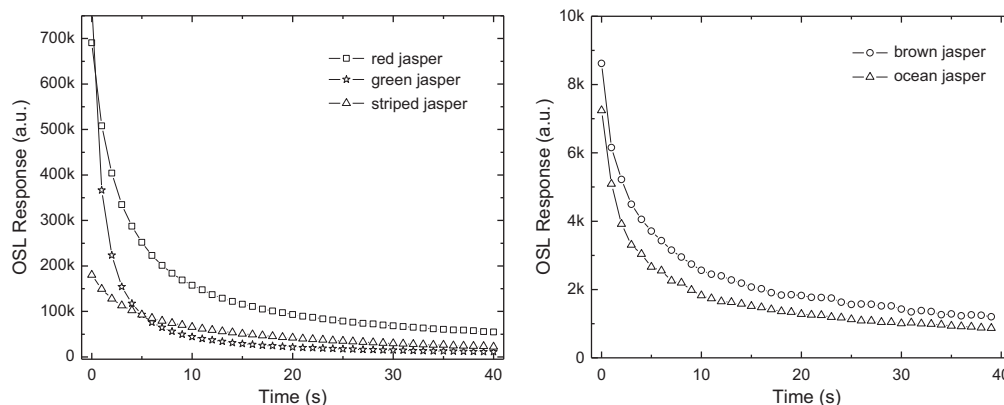


Fig. 1. OSL response of Jasper–Teflon pellets irradiated with 1 kGy (^{60}Co).

Table 1
OSL response reproducibility as CV_{\max} (%) of jasper samples.

Jasper	Red	Green	Striped	Brown	Ocean
Reproducibility (%)	3.8	4.1	4.5	4.8	5.4

4. Conclusions

In this work it can be observed that all five types of jasper samples may be applied as irradiation indicators or even as dosimeters for high doses using the OSL technique. They may be used for dosimetry in the main radiation processes of disinfection (10–100 Gy), water purification (1–10 kGy), pasteurization (1–10 kGy), and sterilization of materials in hospitals (10–100 kGy).

The studied dosimetric characteristics (reutilization, reproducibility, dose response) show that the red jasper samples presented the highest radiation sensitivity in relation to the other jasper samples. One basic advantage of using jasper samples is their very low cost, reduced size and easy handling. An advantage of the OSL technique is that the measurements can be carried out several times on the one sample.

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