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Thermoluminescent characteristics of mineral samples acquired as jade

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Abstract

Green samples acquired as jade from New Zealand, Austria, USA and Brazil were powdered and mixed with teflon (composites jade–teflon). They were studied in this work using the thermoluminescent technique to investigate their potential for applications in gamma-radiation dosimetry in the range of 10 Gy to 10 kGy. The samples were analysed by X-ray diffractometry and neutron activation. The glow curves and calibration curves of these composites were obtained, showing usefulness for high-dose dosimetry.

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Keywords: Jade; Thermoluminescence; Gamma dosimetry; High doses

1. Introduction

The increasing use of radiation in processes associated with medical and industrial applications has motivated research on new materials with adequate dosimetric properties. There are several studies covering the application of silicates using the thermoluminescent technique for radiation dosimetry. Studies on different kinds of glasses [1–3], quartz [4] and topaz [5] demonstrated their potential application for radiation dosimetry; however, the papers on jade only address its crystalographical aspects, where synthetic samples were compared to natural ones [6], or on thermodynamics properties [7], mainly for jadeite.

Jade is the common denomination of two silicates: jadeite, $NaAl(Si_2O_6)$ and actinolite, $Ca_2(Mg,Fe)_5(Si_4O_{11})_2(OH)_2$ that belong, respectively, to the subclasses of pyroxenes and amphiboles. The similarities between them and other cheaper minerals have confused specialists that use traditional techniques such as specific gravity, hardness and refraction index for their characterization. In this work the modern techniques of neutron-activation analysis and X-ray diffractometry were used to identify the samples acquired as jade, in order to investigate their dosimetric properties.

Samples were acquired at stores specialized in minerals in New Zealand, Austria, USA and Brazil

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for this work. They were studied using the thermoluminescent technique to investigate their potential applications for high-dose gamma dosimetry.

2. Materials and methods

All mineral samples were initially cleaned, and pulverized to grain diameters between 0.074 and 0.177 mm. The samples were submitted to chemical analysis by neutron activation and to X-ray diffractometry (Siemens D-500) in order to determine the composition of the green materials acquired as jade.

Composites of jade–teflon were prepared in the open atmosphere, and the parts were mixed in the ratio 2 (teflon) : 1 (powdered sample). This mixture was cooled with liquid nitrogen to optimize the homogenization. Later it was pressed, and pellets of 25 mg were obtained with 0.8 mm of thickness, and diameter of 6 mm. For sintering, the samples were thermally treated at 300 °C for 30 min followed by 400 °C for 1.5 h. The cooling of the samples was performed slowly in the same oven.

The thermal treatments for reutilization of the materials were performed at 300 °C for 1 h in the open atmosphere.

The irradiation of the samples was made using a Gamma Cell-220 System (^{60}Co), for doses of 10 Gy up to 10 kGy. The TL measurements were taken with a Harshaw Chemical Co. reader, model 2000 A/B, and the data acquisition was realized using a virtual instrument (ADC-212), Pico Technology Ltd., and a personal computer.

3. Results

Measurements of X-ray diffractometry and neutron activation analyses were obtained to identify the jade sorts, jadeite or nephrite, present among the mineral samples.

3.1. X-ray diffractometry

From the X-ray diffractograms (Fig. 1) we find that jade from the USA is composed of several other minerals such as: calcite, $CaCO_3$; magnesiohornblende rich in iron, $CaF_2(Mg,Fe+2)_4Al(Si_7Al)O_{22}(OH,F)_2$; actionolite, $Ca_2(Mg,Fe+2)_5Si_8O_{22}(OH)_2$; clinochlore $(Mg,Al)_6(Si,Al)_4O_{10}(OH)_8$ and talc, $Mg_3Si_4O_{10}(OH)_2$. In the cases of jade from New Zealand and from Austria, the results indicated that both are actionolites; however, jade from Brazil is green quartz, SiO_2.

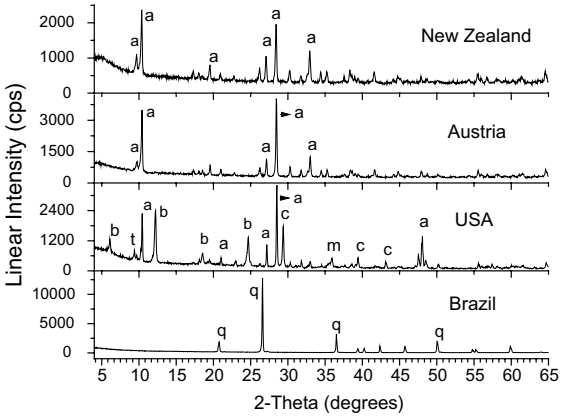

Fig. 1. Results of the X-ray diffractometry of the mineral samples acquired as jade. The symbols a, b, c, m, t and q means, respectively, actinolite, clinochlore, calcite, magnesiohornblende, talc and quartz.

3.2. Neutron-activation analysis

The chemical analysis by neutron activation was applied to samples of jade from USA, Austria and New Zealand (Table 1). In these samples, the

Table 1
Neutron-activation analysis results of jade samples

Element	Samples		
	Austria	USA	New Zealand
Mg (%)	13.2 ± 0.3	14.2 ± 0.4	12.1 ± 0.3
Ca (%)	5.8 ± 0.4	9.8 ± 0.7	6.6 ± 0.5
Fe (%)	3.72 ± 0.07	0.64 ± 0.01	–
Al ($\mu g\,g^{-1}$)	5078 ± 5	16.021 ± 165	3924 ± 69
Ti ($\mu g\,g^{-1}$)	–	462 ± 95	–
Cr ($\mu g\,g^{-1}$)	1925 ± 82	133 ± 6	1686 ± 71
Mn ($\mu g\,g^{-1}$)	1072 ± 29	185 ± 6	853 ± 23
Na ($\mu g\,g^{-1}$)	–	165 ± 71	460 ± 50

major elements present are magnesium, calcium and iron, except in the case of New Zealand jade that did not present iron. Among the trace elements, aluminum and chromium are prominent. Chromium is responsible for the green color in the samples.

3.3. Glow curves

All samples present two main TL peaks (Figs. 2–4), one around 90 °C and the second near 180 °C, except in the case of Brazilian jade (green quartz) for which the TL peak appears at about 140 °C (Fig. 5). The TL sensitivity varies depending on the treatment of the samples.

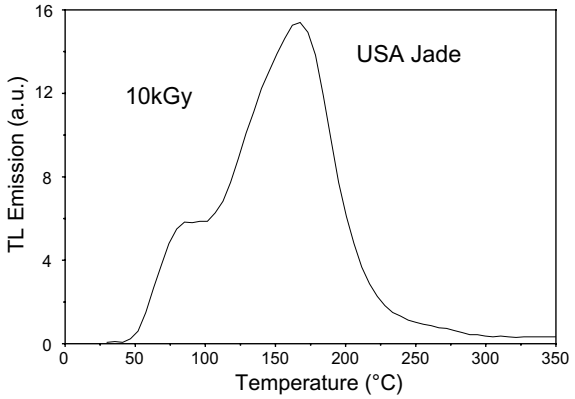

Fig. 2. TL glow curve of a sintered pellet of USA jade irradiated with 10 kGy (^{60}Co).

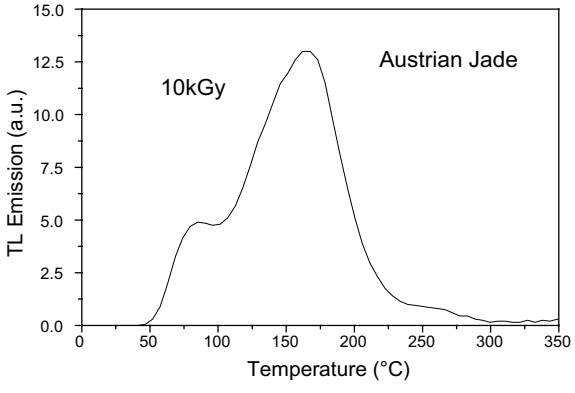

Fig. 3. TL glow curve of a sintered pellet of Austrian jade irradiated with 10 kGy (^{60}Co).

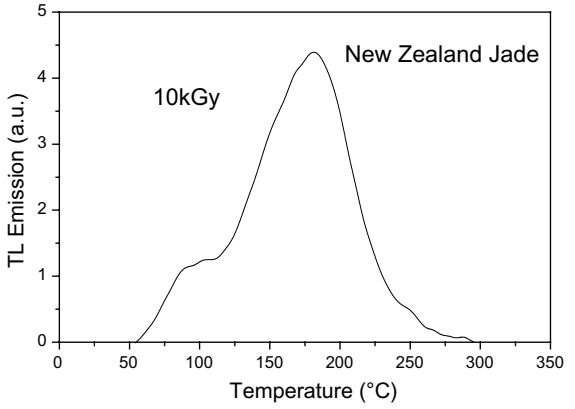

Fig. 4. TL glow curve of a sintered pellet of New Zealand jade irradiated with 10 kGy (^{60}Co).

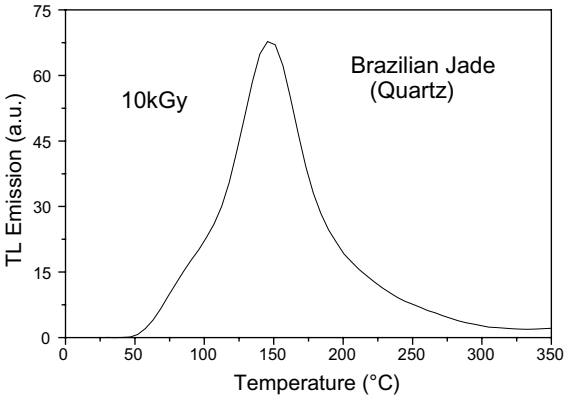

Fig. 5. TL glow curve of a sintered pellet of Brazilian jade irradiated with 10 kGy (^{60}Co).

3.4. Calibration curves

The calibration curves of the sintered jade pellets are presented in Fig. 6. Their behavior suggest linearity up to 1 kGy, and then supralinearity (Brazilian and Austrian jade) or sublinearity (USA and New Zealand jade).

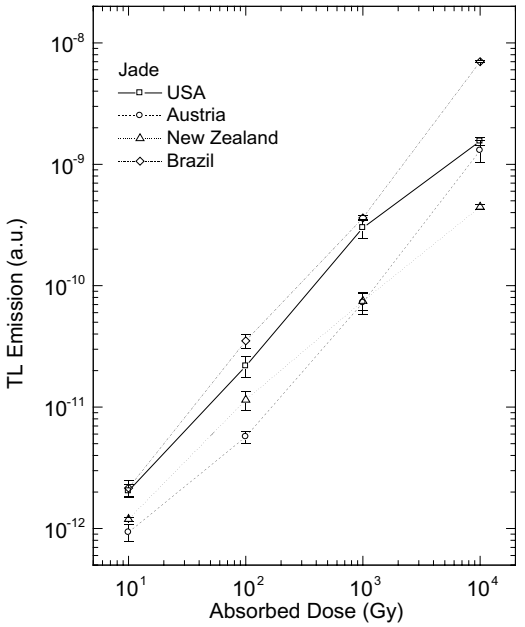

Fig. 6. Calibration curves of sintered jade pellets (^{60}Co).

4. Conclusion

The results obtained for the samples acquired as jade from New Zealand, Austria, USA and Brazil showed their usefulness as radiation detectors for high-dose gamma dosimetry. They may be applied in the dose range of 10 Gy to 10 kGy, that meets industrial, agricultural and medical areas, where high doses are utilized.

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