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Study of jadeite-like minerals

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Three samples of silicate minerals sold to us as being *jadeite* have been investigated concerning their TL properties and also EPR spectrum of one of them denominated here as JQ1. XRF has shown that one of them is an alkaline feldspar and two other, varieties of quartz; one was called JQ1 and the second one JQ2. JQ1 absorption spectrum is characterized by absorption bands at 410 and 600 nm, responsible for green colour. JQ1's 260 °C and 330 °C TL peaks respond to very high dose, therefore it can be used as high dose dosimeter. The EPR spectrum presented g =4.5 Fe^{3+} signal and several non-identified signals in the 3460 to 3500 G interval. The typical E'_1 centre in quartz was not observed here.

1 Introduction Except for gemologically or industrially important silicate minerals, a large number of other natural silicate minerals have been investigated only concerning geological/mineralogical aspects. There is a group of silicate minerals with chemical formula with Si_2O_6 as anion and it is called Pyroxene group [1]. The subgroups are characterized by cations composing the minerals. Thus, we have magnesium-iron, calcium, calcium-sodium, sodium and lithium subgroups. To the sodium pyroxenes subgroup belong jadeite ($NaAlSi_2O_6$), kosmochlor ($NaCrSi_2O_6$) and aegirine ($NaFe^{3+}Si_2O_6$). In the present work, the aim was to investigate physical properties of jadeite, however, samples of minerals sold to us were shown not to be jadeite. Therefore, we called such minerals jadeite-like and they were investigated as to their thermoluminescence (TL), optical absorption (OA) and electron paramagnetic resonance (EPR) properties.

2 Materials and experimental Three samples of minerals have been sold to us as being jadeite. The first one, called here JF, is lilac coloured rounded pieces imported from Turkey by *Luiz Menezes* Minerals in Belo Horizonte, Minas Gerais State. Two others green coloured, one was called JQ1 and the other one JQ2. JQ2 is also rounded pieces. Both of them purchased from LEGEP Minerals in São Paulo. We, further, produced synthetic jadeite (JS) by devitrification method, using "pure" oxides of silicon, aluminium and sodium, for comparison.

As usual, they were pulverized and sieved to retain grains sizes between 0.080 and 0.180 mm for TL and EPR measurements. Those with size smaller than 0.080 mm have been used for X-ray diffraction (XRD) and X-ray fluorescence (XRF) measurements. From JQ1 samples, slabs with 1.0 mm thickness have been obtained for OA measurements. The TL measurements have been carried out on Harshaw model 4500 TL reader (temperature range: 50 °C up to 400 °C and heating rate: 4 $°Cs^{-1}$). The EPR measurements were performed in a Bruker EMX spectrometer using a rectangular cavity (ST ER4102) with a microwave frequency of 9.767 GHz. The OA measurements were carried out in the Varian Cary 500 UV-VIS-NIR spectrophotometer. For irradiation, Institute for Energy and Nuclear Researches Radiation Center's Co-60 source was used for γ-doses below 50 kGy. Higher dose irradiation was carried out at CBE-EMBRARAD. The XRF and XRD measurements were carried out at Department of Mine and Petroleum, University of Sao Paulo (USP) and Crystallography Laboratory "Cecília A.F. Pimentel" Department of Applied Physics, USP, respectively.

3 Results and discussions To compare with the glow curve of α-quartz, sample of α-quartz and those of

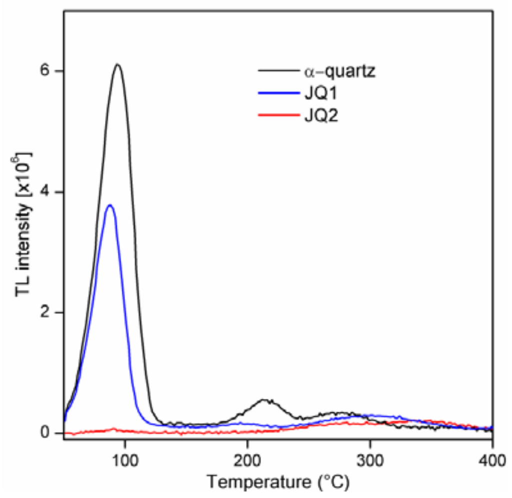

Figure 1 TL glow curves of JQ1, JQ2 and α-quartz samples.

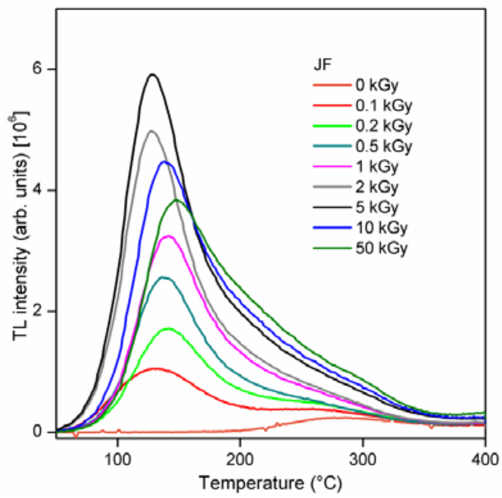

Figure 3 Glow curves of JF samples irradiated with γ-rays.

JQ1 and JQ2 have been irradiated with β-rays for 20 minutes and their TL read out with small delay (Fig. 1). Figure 1 shows that the 110 °C peak is very prominent of α-quartz, less intense in JQ1 and absent in JQ2.

The XRD measurements have shown that JQ1 and JQ2 have a same diffraction pattern (data not shown here) as of α-quartz and JF that of an alkaline feldspars. Table 1 shows the oxides present in the samples studied.

Figure 2 shows OA spectra of irradiated JQ1 sample in the 300 to 800 nm interval. Two main absorption bands occur around 410 nm and 600 nm, they are reason for green colour of JQ1. These bands do not change with irradiation, whose effect is only to raise the background radiation, however not enough to cause the smoky aspect.

Figure 3 shows the glow curves of irradiated JF sample. They are very similar to those of k-feldspar, confirming the XRD measurements. JF sample has not been investigated further.

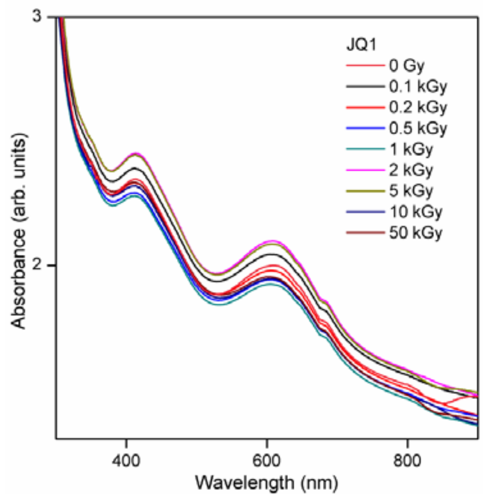

Figure 2 OA of JQ1 irradiated with γ-rays.

Figure 4 (a, b, c and d) presents glow curves of JQ1 and JQ2 irradiated with low and high radiation doses. Except for 340 °C peak, lower peaks are observed at different temperatures. On the other hand, in both of them the peak around 210-215 °C grows very fast so that it becomes predominant for very high (about 70 kGy) dose irradiation. JQ2 sample has been irradiated with dose as high as 1500 kGy and its TL response as function of dose is shown in Fig. 5. 330-340 °C peak behavior was added. For no specific reason JQ1 sample was not irradiated to γ-dose above 70 kGy. It will be done in near future.

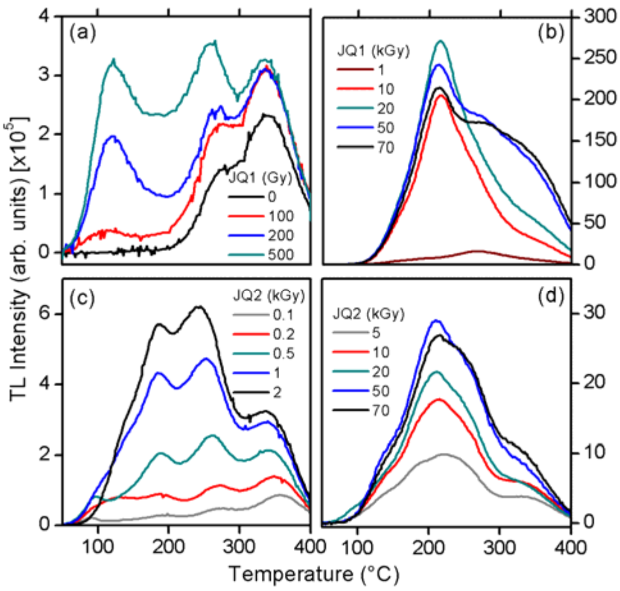

Figure 4 (a-b) Glow curves of JQ1 samples irradiated with γ-rays. (c-d) Glow curves of JQ2 samples irradiated with γ-rays.

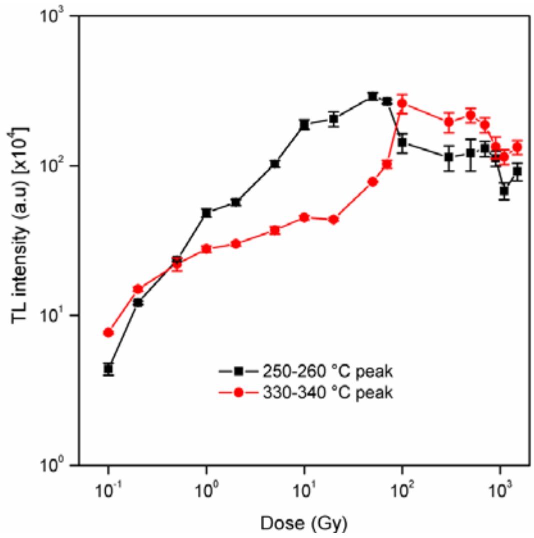

Figure 5 TL intensity behavior of 250-260 °C peak (in black) and of 330-340 °C peak (in red) of JQ 2 sample.

Figure 6(a, b) shows glow curves of green quartz, investigated by Farias and Watanabe [2], and of JQ1, respectively irradiated with 10 kGy γ-dose, showing quite distinct glow curves.

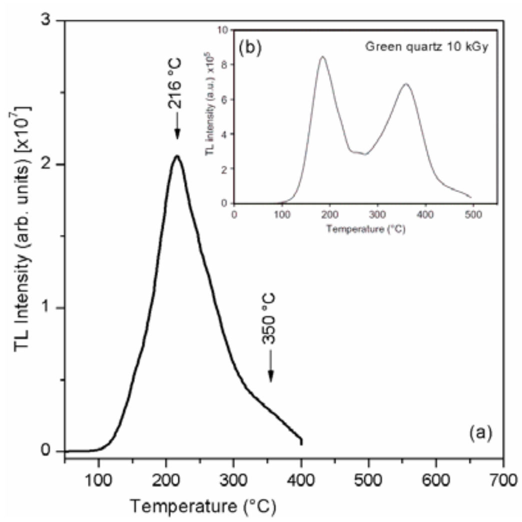

Figure 6 Glow curves of JQ1 sample irradiated with 10 kGy (a) and of green quartz (b) [2].

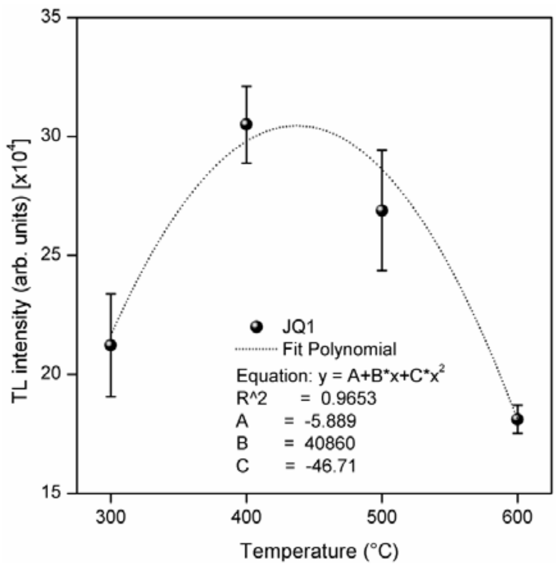

Figure 7 TL responses vs. temperature (peak 260 °C).

Figure 7 shows the effect of annealing JQ1 sample at 300, 400, 500 and 600 °C for one hour and irradiated with 1 kGy. The TL value of 260 °C as function of pre-irradiation annealing temperature describes a parabola with downward concavity, maximum at around 425 °C. It is not shown here, but JF describes a parabola with upward concavity and the minimum TL value occurring at 350 °C.

Figure 8 shows glow curves with TL peaks at 140, 170 and 320 °C for JS samples

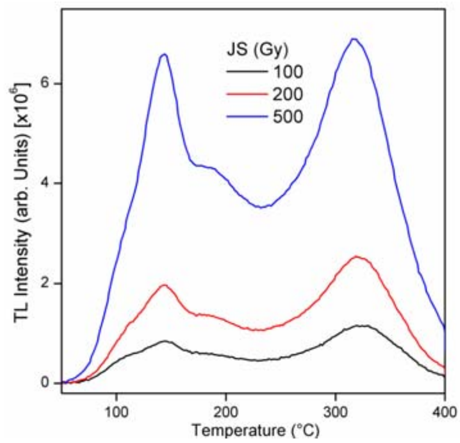

Figure 8 Glow curves of JS samples irradiated with gamma-rays.

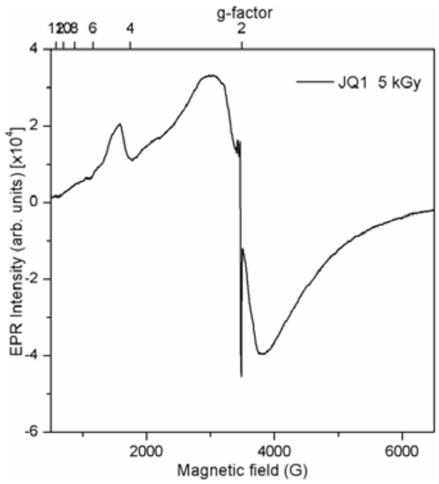

Figure 9 EPR spectra of JQ1irradiaded with 5 kGy.

The important fact is that 140 and 320 °C peaks are very intense, namely the samples is highly crystalline. Furthermore, these TL peaks are due to intrinsic defects, probably involving aluminium centre, oxygen vacancies and E'$_1$-centres.

Table 1 Oxides in weight (%) of JQ1, JQ2 and JF samples.

Oxides	JQ1	JQ2	JF
SiO_2	89.0	87.2	58.7
Al_2O_3	4.88	4.55	20.4
Fe_2O_3	0.20	0.14	1.49
Na_2O	0.18	0.19	3.96
K_2O	1.62	1.48	8.21
Cr_2O_3	<<	0.40	<<

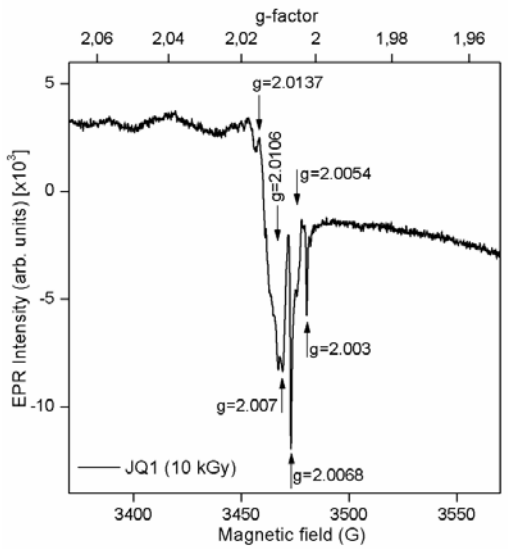

Figure 10 EPR spectra of JQ1irradiaded with 10 kGy.

The EPR measurements have been carried out on JQ1 only. Figure 9 shows g=4.5 signal due Fe^{3+} and an intense signal extending from about 2200 to 5000 G due to spin-spin interaction of Fe^{3+}. Figure 10 shows the detail of the spectrum from 3440 to 3500 G. Several lines have been observed, none of them has been identified, although they seem to be due to hole attached to oxygen. The usual E'$_1$ centre signal at g=2.0023 has not been observed [3].

4 Conclusions Two samples of silicate minerals obtained from a stone dealer as being jadeite were revealed by X-ray fluorescence analysis to be variety of quartz. However, their TL behavior differs from each other and also from that of α-quartz, so that although they have a same XRD pattern as that of α-quartz, it is difficult to identify them as being a variety of quartz. Both JQ1 and JQ2 respond to high radiation dose up to 70 kGy, such they can be used as high dose dosimeter. Actually, an additional irradiation of JQ2 with γ-rays up to 1500 kGy has shown that it can be used as very high dose dosimeter. JQ1 presented TL values that describe parabola with downward concavity as function of pre-irradiation annealing temperature in the range 300-600 °C. The usual E'$_1$ centre signal at g=2.0023 has not been observed.

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