Color images of infrared stimulated luminescence (IRSL) from granite slices exposed to radiations

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Abstract: *Color luminescence images, associated with stimulation by infrared light, were obtained from some granite slices after X-ray irradiation of 200 Gy. The infrared stimulated luminescence color images (abbreviated to IRSL-CI) showed two colors, separable into intense yellow and blue portions. The former was assigned to be originated from a plagioclase feldspar constituent and the latter to potassium feldspar one. Quartz parts scarcely gave distinct IRSL-pattern. From spectrometry of the IRSL, two main emission peaks, consisting of 550 nm (yellow) and 580 nm (orange), were revealed besides moderate emission in wavelengths shorter than 450 nm (blue). Unexpectedly, reddish IRSL was observed in white mineral, probably feldspar of one granite. This IRSL-CI method can be useful for the examination of feldspar purity as well as for the filter selection of IRSL-dating.*

Introduction

In the optical dating method, Hütt et al., (1988) have discovered the infrared-stimulated luminescence (IRSL) phenomena for most of feldspars; when ionizing radiation-exposed feldspars were stimulated with infrared light in the range of 800-900nm, the strong IRSL has been detected in the wider wavelength range including almost visible light. According to a review paper by Krbetschek et al., (1997), various kinds of luminescence windows in wavelengths were reported to the IRSL of feldspar. In our laboratory, some luminescence color imaging methods, including thermoluminescence color images (TLCI), afterglow color images (AGCI), photo-induced phosphorescence (PIP), color center images (CCI) and 2-dimensional monochromatic OSL-images, have been established using varieties of granite slices (Hashimoto et al., 1995). Subsequently, the color imaging methods of radiation-induced luminescence have been applied to 16 kinds of feldspar minerals on the basis of a ternary diagram of feldspar. As a result, the AGCI could be separated into two groups, giving intensely bluish or green coloration along the alkali feldspar line and weak reddish coloration along the plagioclase line. In most feldspar slices, heterogeneous color distribution has been revealed according to the mineral formation and historical conditions (Hashimoto et al., 2001).

Since the IRSL of feldspar is much effectively bleached at deposition (Aitken, 1998), the IRSL-dating of feldspars has been expected to be more hopeful for the widespread quaternary-sediment layers, applicable to complete bleaching effects with the sunlight. In the IRSL-measurements, the selection of filter-combination is very important to choice the objective feldspar suitable for dating with low background conditions as well as for checking the purification of feldspar samples.

From these situations, a simple IRSL-color imaging method from granite slices has been developed using a high sensitive photographic system accompanied with combination of color filters. In the 2-dimensional color images, mainly yellowish and slightly bluish IRSL parts have been recognized as well as with heterogeneous distribution on every sample exposed with a γ-ray standard source.

Experimental

1. Preparation of granite slice samples

The following granites were selected to prepare the slice samples in the 2-dimensional color images described below; A) HW-5 granite, mylonite-like sub-facies (granodiorite), B) HW-36 granite, porphyritic sub-facies (granodiorite) and C) HW-23 granite, foliated granodiorite-tonalite facies. All of the HW granite samples were collected from Hanawa pluton adjacent to Tanakura Shear Zone, by which the main fault divided North-eastern Japan from Southwestern Japan during the Mesozoic period (Ohira, 1992, 1994).

After cutting roughly into square planes (approximately 8x8x0.5 mm), each surface was polished with an alumina emulsion solution. Every sliced rock sample was followed by the X-ray irradiation.

2.Radiation exposure and observation of IRSL-color images

All luminescence color images were observed after the irradiation of X-rays using a fluorescent X-ray analysis apparatus (SX3063p, Rigakudenki Co. Ltd.) and a ^{137}Cs standard γ-ray source (Pony Co. Ltd., PS-3000 SB Type) for the dose standardization. Following X-ray irradiation with the absorbed dose of 200Gy (for 15min exposure time), slice samples were stored to eliminate completely afterglow emission, by letting the samples stand for 1 day in a dark box. The IRSL-color imaging (IRSL-CI) observation of the slice samples was carried out by means of a photographic apparatus as illustrated in Fig. 1(a). Infrared light emitting diode (IR-LED, Hamamatsu Photonics, L2690-02) is certified to offer 890 nm emission peak with 50 nm FWHM value. Sixteen LEDs were installed to a LED holder having a hole of 20 mm in diameter and the applied current was fixed here to 100mA per LED. The applied IR-power was evaluated to be 3.0 mW/cm^2 on the surface of the slice samples using a power meter. For the IRSL-CI photography, a glass filter (Asahi-techno Glass Co. Ltd., CF-50E) for correction in visible light was inserted to eliminate the stimulation IR-light. The optical properties of the filter and stimulation light-ranges from IR-LED are indicated in Fig. 1(b). To attain most sensitive photography, a camera (Nikon, F-3) with a lens of F-1.2 was employed as well as the use of highly sensitive color film (Fuji ISO-400). The practical photography has been conducted in a dark room and the camera shutter was opened for 90 sec from start of the IR-LED stimulation.

3. IRSL-spectrometry by an on-line spectrometric system

An on-line spectrometric system for extremely weak photon-emission was applied to the spectrometry of IRSL from the granite slices in the similar way to the TL-spectrometry (Hashimoto et al., 1997). Instead of the camera, a small spectrometer, connected to image intensified photo-diode array, was placed in the same arrangement as shown in Fig. 1(a). Every scanning interval was 22 ms and 512 channel data in wavelength width were summed up to 45 cycles to form one spectrum per second. Thus, 100 spectra during the period of 100 sec stimulated with IR-light, could be acquired to the microcomputer memory. All of the spectrum data were plotted in a spectrum figure for every slice sample.

Results and discussion

Infrared-stimulated luminescence color images (IRSL-CIs) of some X- irradiated granite slices were obtained using photon detection are shown in Fig. 2.

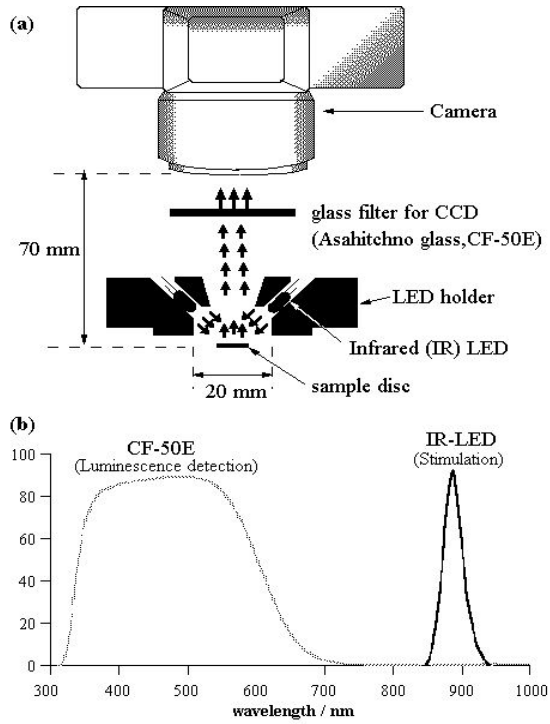

Figure 1.
Schematic view of photographic assembly for infrared stimulated luminescence color imaging (IRSL-CI) from slices exposed radiation (a) and optical properties of IR-LED and a IR-cut filter (CF-50E).

The present results from IRSL-CIs show evidently that feldspar portions in the real images tend to cause strong yellowish luminescence, while quartz portions bring on no IRSL-CI because of extremely weak luminescence emission with IR-illumination. In addition to scattered distribution of the IRSL-images, there appears heterogeneous distribution on the IRSL-CIs within single feldspar grain part. The similarly heterogeneous distribution of afterglow and thermoluminescence was observed within every single feldspar slice (Hashimoto et al., 2001).

In the preceding publication (Hashimoto et al., 1995), it has been recognized that among several kinds of white mineral constituents in granite, albite, plagioclase and potassium feldspars are sensitive to the radiation-induced luminescence, involving radio-luminescence (RL), TL, afterglow, photo-induced phosphorescence as 2-D color images. On the other hand, quartz constituent shown relatively poor sensitivity to luminescence phenomena. The present results are in good agreement with the highest sensitivity natures of plagioclase portions in any kinds of the luminescence (Hashimoto et al., 1995, 2001).

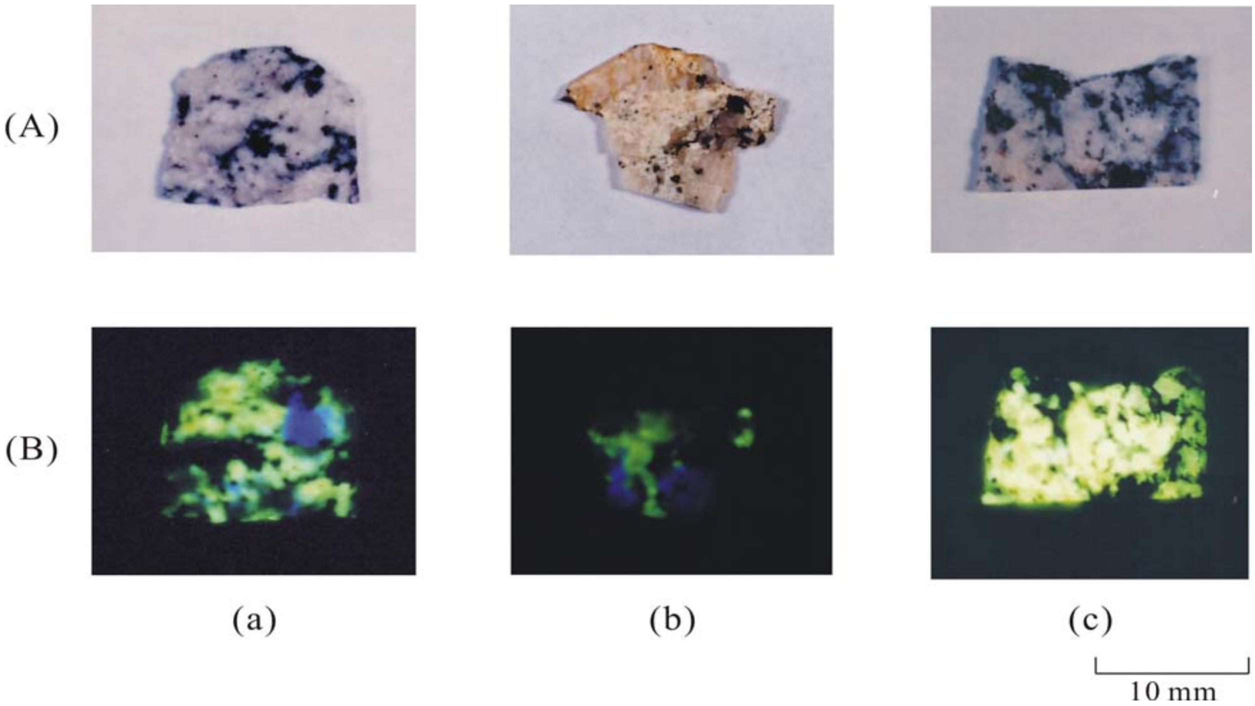

Figure 2.
Typical infrared stimulated luminescence color images (IRSL-CIs) from granite slices. Real surface images (A) and IRSL-CI (B) were obtained from three kinds of granite slices; (a) HW-5, (b) HW-36, and (c) HW-23.

Additionally, it is well known that light-sensitive trapped electrons (and hole centers) in minerals should be greatly dependent on the kinds of minerals in which they are located, as well as the geological history of the rock body formation (Hashimoto et al., 1994). From this viewpoint, the IRSL-CIs themselves were considered to reflect such mineral properties. However, there appears no significantly different pattern among the present slices, except for two samples, HW-5 and HW-36, which show the mixture images distinguishable into yellow and blue part, while HW-23 sample renders intense yellowish patterns alone. The HW-23 sample is known to contain almost plagioclase constituent as feldspar, so that the intense yellow IRSL-CI portions are attributable to plagioclase mineral. Two other granites, HW-5 and HW-36 have been analyzed to contain small parts of potassium feldspar constituent in addition to large amount of plagioclase portions according to Ohira, (1994). Therefore, the blue IRSL-CI portions seen in HW-5 and HW-36 were assumed to originate from potassium constituents. In fact, single potassium feldspar gave blue luminescence color in both afterglow and thermoluminescence. The identification of plagioclase and potassium feldspar portions was also confirmed by a mineralogist. Anyway, it should be emphasized that IRSL-color images in Fig. 2 are the first visualization, by which the researchers could admit simply the IRSL-CIs, helpful for the selection of IRSL-detection filter, superior to the monochromatic IRSL-images from our laboratory (Hashimoto et al., 1995).

In further precise way, the results from an IRSL-spectrometry could serve for the determination of detection wavelength range, although the two-dimensional information couldn’t be obtained. Spectral results from three granite slice samples are presented in Fig. 3.

Every highest spectrum is corresponding to first IRSL just after beginning of IR-LED illumination because of decaying behavior of IRSL as well known. In the HW-5 sample, there exists a prominent yellowish emission having a peak at 550 nm. In addition to 550 nm peak (yellow color), there appears another 580 nm (orange color) peak and other emission in shorter wavelength than 450 nm ranges (blue or violet color) in two granites, HW-36 and HW-23. Among these luminescence wavelength ranges, yellow and orange colors tend to decay out immediately after the IR-illumination, whereas the blue or violet emission continues for a relatively long period. This result will support also the two different minerals for IRSL-emission, probably plagioclase and

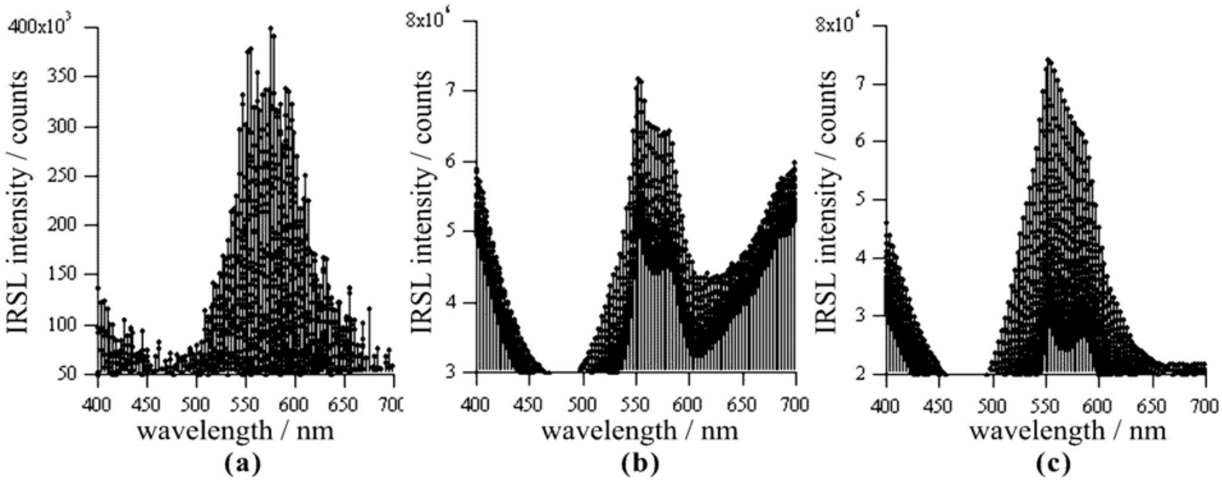

Figure 3.
IRSL-spectra measured by an on-line spectrometry installed with an image intensifier. Every spectrum is consisting of 100 spectra dependent on decaying behavior after IR-LED-illumination. Granite samples are (a) HW-5, (b) HW-36, and (c) HW-23

potassium feldspars in these granite slices.

It is noteworthy that the spectra (b) from HW-36 offer the existence of longer wavelength side beyond 600 nm, corresponding to reddish color ranges. In a preceding paper (Hashimoto et al., 1995), the similarly originated granite showed reddish PIP (photon-induced-phosphorescence) pattern (HW-38). Although the IRSL-spectrum shows certainly reddish emission, it must be questionable that there appears no red part on the IRSL color image of HW-36 (Fig. 2(b)). The reason should be attributable to the use of IR-cut filter (CF-50E) as indicated optical property in Fig. 1(b), in which the reddish wavelength ranges were almost completely absorbed (c.f. emission spectrum in Fig. 3(b)).

Similar color images of the IRSL will be realized using highly sensitive CCD-camera in near future. To approach this direction, we are starting the color imaging visualization and decay curve analysis into red, green and blue coloration of the imaging data.

Since the PIP-phenomena should be derived from the same photon-sensitive trapped electrons, the PIP-color images might be displaced to the IRSL-color photography in the case of weak IRSL-emitting minerals.

These IRSL-CI technique must be useful for the examination of feldspar purity and the filter selection for the establishment of the reliable IRSL-dating, together with emission spectrum data.

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Reviewer

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