Cathodoluminescence dependence on feldspar mineral structure and implications for forensic geology

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ABSTRACT

A collection of 42 feldspar mineral samples from a wide geographical range of North America was examined by cold-cathode cathodoluminescence (CL) spectroscopy. Characteristic wavelength peaks, which were determined to be independent of geographic origin, were associated with each feldspar phase. Most of these peaks were attributed to previously assigned Mn2+ and Fe3+ luminescent centers and structural defects. An unattributed set of infrared (IR) peaks was observed in many samples; one uncommon ultraviolet (UV) peak was observed in samples from two locations. The peak centroids associated with the Mn2+ and Fe3+ luminescent centers vary with stoichiometric changes in the K-Na-Ca composition of the feldspars. For both alkali and plagioclase feldspars, shifts in CL peak centroids correlate well with lattice size, as measured by X-ray diffraction (XRD). Additional analyses of the feldspar samples by electron microprobe analysis (EMP), particle-induced X-ray emission spectroscopy (PIXE), energy-dispersive micro-X-ray fluorescence spectroscopy (µXRF), and/or laser-ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) were conducted for confirmation of elemental composition. These results demonstrate the potential of CL spectroscopy, a relatively nondestructive analytical technique, to facilitate rapid discrimination between feldspar samples. The addition of CL spectroscopy of feldspars to existing forensic analytical protocols for geologic materials has the potential to provide support for casework, both to discriminate sources in a forensic comparison, as well as to constrain the provenance of an unknown sample.

Keywords: Luminescence, feldspar, forensic geology, spectroscopy

INTRODUCTION

Mineral luminescence can occur when electrons excited by the passage of ionizing radiation relax and release photons. Luminescence is only possible when the deposited energy of the incident radiation is sufficient to allow electrons to jump the band gap of a crystal lattice. Specific trace elements, as well as lattice defects within the mineral’s crystal structure, create intermediate energy levels between valence bands and conduction bands for additional electron transitions, allowing certain minerals to luminesce brightly at specific wavelengths in the ultraviolet, visible, and near infrared (UV-vis-NIR) regions following irradiation (Götzé et al. 2000; Götzé 2002). Although these electronic transitions occur at specific wavelengths, interactions with non-shielding electrons produce broad peaks typical of a cathodoluminescence (CL) spectrum (Götzé 2000, 2002). The peak centroids of these transitions are dependent on the crystal field experienced by the luminescent center and on the chemical composition of the mineral (Krbetschek et al. 2002).

Although the mechanisms that give rise to mineral luminescence are widely known, most CL experimental studies remain qualitative in nature because the relative peak intensity within samples is highly variable. This variability of luminescence intensities has been attributed to many factors, including instrumental/analytical factors [e.g., incident radiation intensity variation (Thomas 1987)], crystal-chemical factors [e.g., defect/element concentration (Götzé et al. 1999; Haberman 2002; Parsons et al. 2008), sensitizing, quenching (Kabler 1964), etc.], and interactions between the solid and the incident electron beam [e.g., orientation angle dependence of the crystalline sample with respect to the ion beam (Walderhaug and Rykkjø 2000; Finch et al. 2003; Munisso et al. 2007; Garcia-Guinea et al. 2007)]. Recently, a quantitative use of CL peak centroid wavelengths has been proposed as a forensic method to identify minerals and characterize the mineral chemistry of geological trace evidence (Palenik and Buscaglia 2007). The study reported in this paper describes the reproducibility of CL spectra from feldspar samples and the forensic utility of geographical source attribution using...