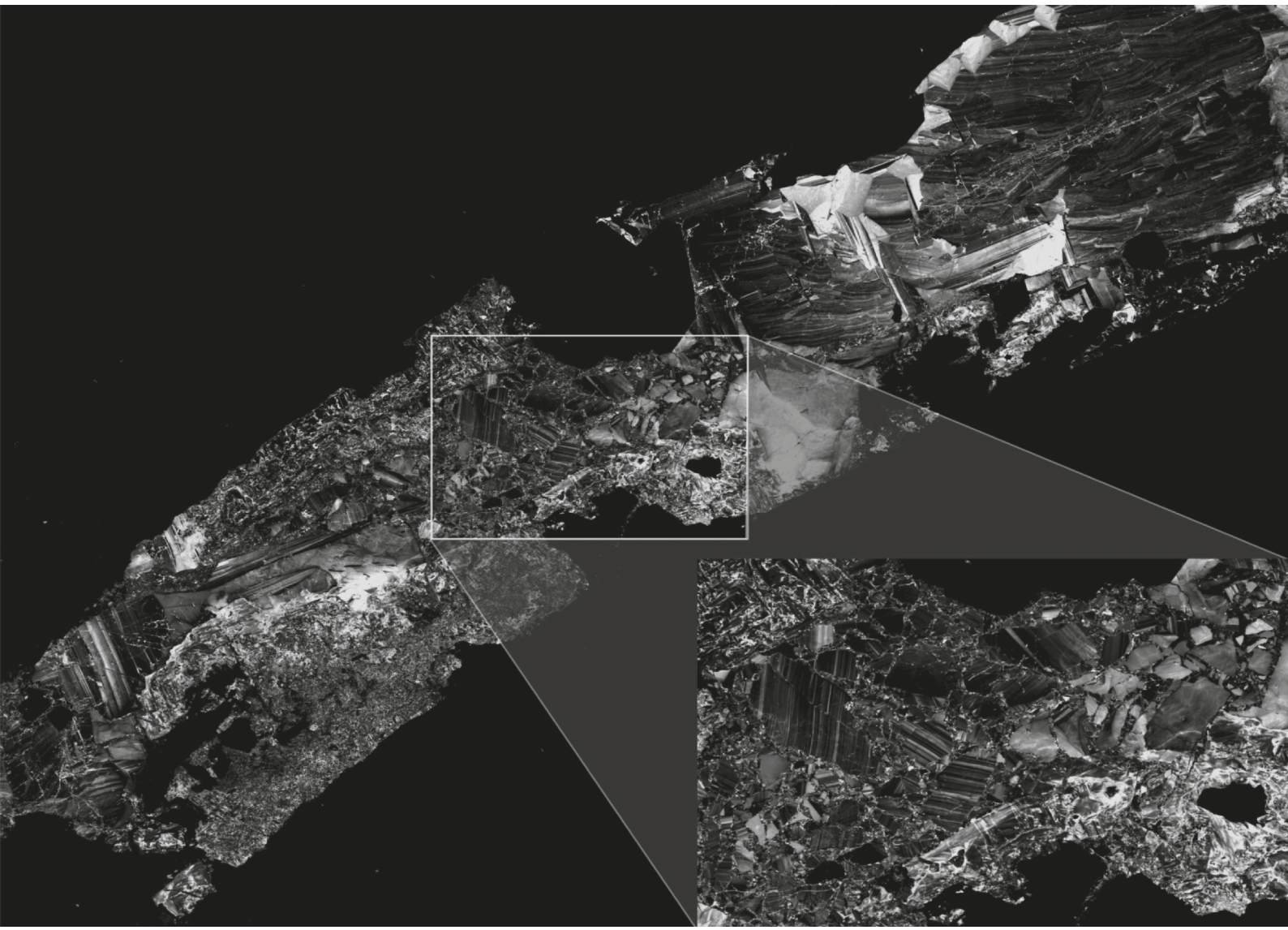
Application Note



Cathodoluminescence of Geological Samples: Fluorite Veins

ZEISS Scanning Electron Microscopes with Atlas

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Introduction

When an electron beam in a scanning electron microscope (SEM) interacts with a sample, multiple signals such as backscattered electrons (BSE), secondary electrons (SE), characteristic X-rays, and visible light are produced. Cathodoluminescence (CL) is a phenomenon causing the emission of light (a photon) as a sample that has been hit by an electron beam returns to a ground or lower energy state. The emission of photons in geological samples is a result of either trace elements contained within the crystal structure (e.g., rare earth elements, chemical elements such as manganese, etc.), of structural defects, and/or vacancies. The emission of these photons and detection by the CL detector in a scanning electron microscope (SEM) allows for the visualization of these defects, chemical zonation and growth zones, and internal crystalline structural changes.

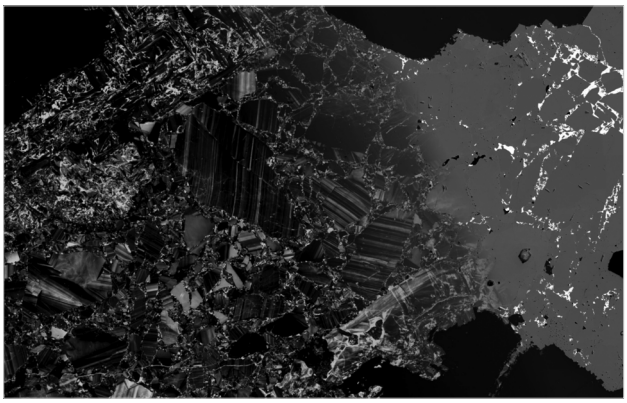

Figure 1 *Comparative image of a fluorite vein showing the overlay of the CL signal (left) over the BSD signal (right). The images were exported from an Atlas 5 large-area image mosaics that were acquired simultaneously both with the CL detector and the BSE detector. The blending of the CL image over the BSD image illustrates the additional information that can be obtained from the sample by using the CL detector in addition to the BSE detector.*

Advantages of CL

One of the key advantages of the CL detector is its ability to provide information on mineral grain boundaries in touching minerals of the same type, which are not visible when using the BSE detector since it relies on atomic number (Z) differences to distinguish contrast (Figure 1).

There have been numerous and wide-ranging applications in geosciences, particularly in sedimentary, igneous, metamorphic, and hydrothermally altered rock samples. The most common minerals that display CL signatures are zircon, diamond, corundum, quartz, calcite, apatite and fluorite.

ZEISS CL Detector

The ZEISS CL detector is a flexible and multipurpose detector that is based on the ZEISS variable pressure secondary electron detector (VPSE). This multipurpose detector, when operated in the high vacuum mode on a ZEISS SEM, is able to produce panchromatic CL images.

With a wavelength of 185 to 850 nm and the option to fit specific blue light filters to remove long-lived light and artifacts typically associated with carbonate samples, the ZEISS CL detector offers versatility and a complete range of detection for geoscience applications.

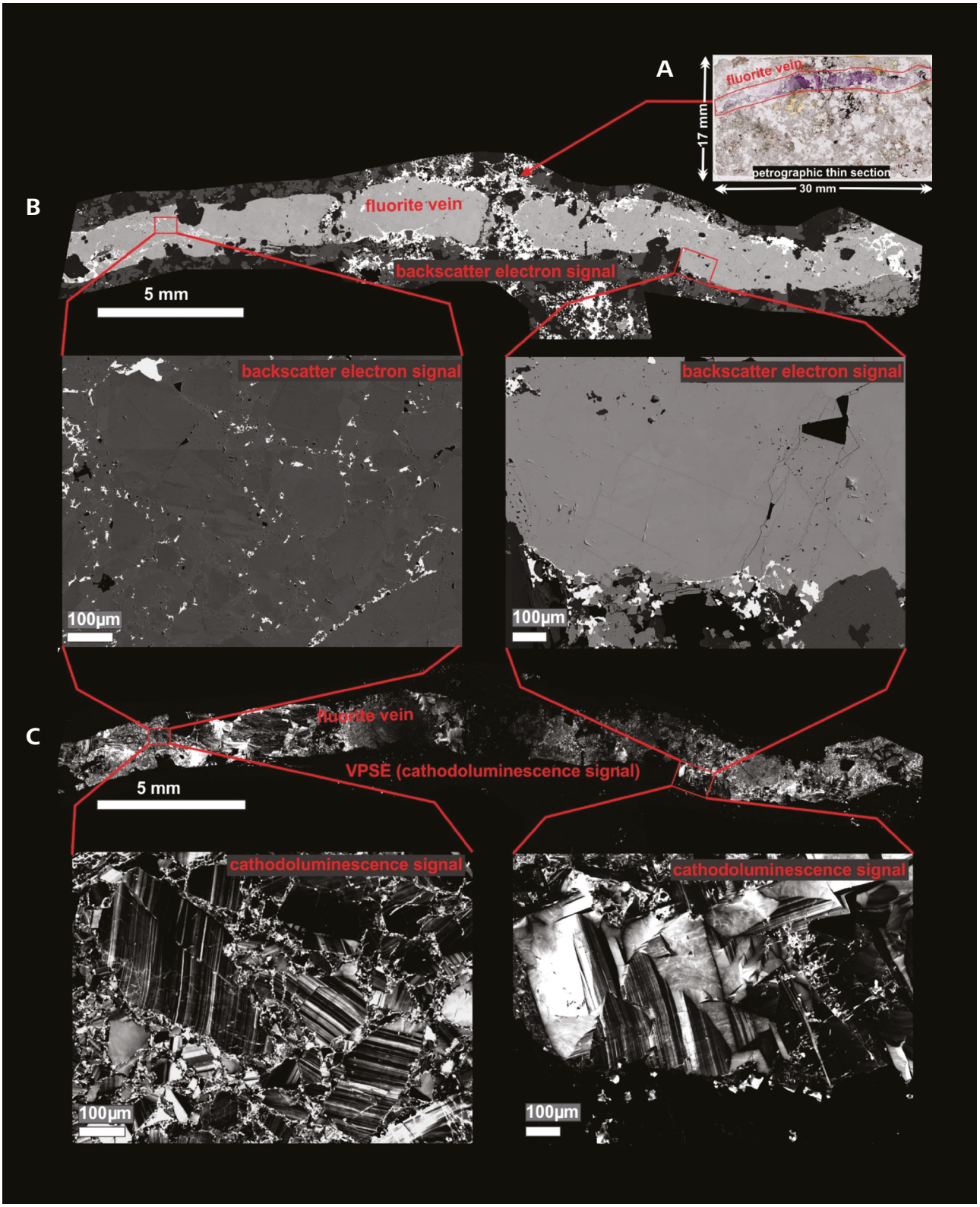

Figure 2 *Overview image mosaic of a fluorite vein crosscutting a peralkaline granite from the Strange Lake deposit, Northern Quebec. A) Overview image showing the light-microscopy image mosaic acquired with plane-polarized light. B) ZEISS Atlas 5 large area image mosaic of the fluorite vein showing the BSE signal. C) CL signal of the same image mosaic as shown in (B), acquired with the VPSE detector. The areas marked with red rectangles in the fluorite vein show the locations of the higher resolution BSE and CL images. The full Atlas 5 data set is available online at www.petapixelproject.com.*

This detector is compatible with the complete ZEISS SEM portfolio: conventional tungsten (W) and LaB6 EVO family, SIGMA Field Emission Gun (FEG) analytical SEM, GEMINI (FEG) high-resolution imaging SEM and Crossbeam Focused Ion Beam (FIB-) SEM.

CL Signals in a Hydrothermal Fluorite Vein

A petrographic thin section of a mineralized peralkaline granite from the Strange Lake REE-Zr-Nb deposit (north-eastern Quebec, Canada) was imaged with ZEISS Atlas 5 in the dual signal acquisition mode using ZEISS BSE and ZEISS CL detectors (Figure 2). The primary magmatic mineralogy consists of arfvedsonite, quartz, potassium feldspar, and albite that have been overprinted during Ca-F-metasomatism. The granite is crosscut by a hydro-thermal vein of zoned fluorite with mineralizations of REE-bearing minerals and hydrothermal zircons (displayed by the lighter zones in BSE images).

Typical CL activators in fluorite are REE, such as the heavy REE ytterbium (Yb), which was detected in this sample. Previous studies have also shown that the fluorite at Strange Lake is enriched in yttrium (Y). The CL images reveal a heterogeneous and complex fluorite vein, which was not obvious from the BSD signal alone. The vein is composed of multiple generations of fluorite forming micro-brecciated zones and healed fractures nicely recording the hydrothermal history of this part of the REE mineral deposit.

Modern, large-area and high-resolution Microscopy with ZEISS Atlas 5

ZEISS Atlas 5 is an automated large-area imaging solution allowing for rapid acquisition of large areas at high resolution using multiple detector signals (i.e., BSD and CL). A task-specific scan generator allows for acquisition of single images or image mosaics with image sizes up to 32k x 32k pixels, with each pixel having nanometer resolution. The GEMINI objective lens design used in the ZEISS FEG SEM product range combines an electrostatic and magnetic field to maximize optical performance and acquisitions of these high frame store images without distortions and aberrations. This lens design also minimizes the amount of stage movement and thus increases acquisition efficiency.

ZEISS Atlas 5 software allows for the acquisition of multiscale large-area image mosaics of the entire sample. Individual tiles, with nanometer resolution, are seamlessly stitched to produce the described image mosaic of the entire sample. This offers distinct advantages in not only producing high resolution imaging, but also preserving the full contextual setting of the imaged sample.

ZEISS Atlas 5 also provides the capability to correlate the acquired data with additional data sets from light micro-scopy, electron microscopy, automated mineralogy (Mineralogic) and X-ray microscopy (XRM). These data sets can then be loaded onto the worldwide web (www.petapixelproject.com) and shared.

Summary

ZEISS offers a flexible and multipurpose detector for fast and reliable CL imaging for a variety of geological samples. It is possible to combine and use additional modern-day software packages such as ZEISS Mineralogic and ZEISS Atlas 5 to drive the SEM for large-area imaging and chemical data acquisition.

Appendix:

Title Page Image

Selected image is of the fluorite vein from the sample collected at the Strange Lake deposits. The image shows a large area, high-resolution Atlas 5 image mosaic of the fluorite vein which cross cuts the sample. More detailed images of the vein can be observed in Figure 1 and Figure 2.

Peta Pixel Project (http://www.petapixelproject.com/)

Online resource were datasets acquired by Atlas 5 are stored and can be viewed. The online data set from Strange Lake deposit can be found using the above link.

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