American Mineralogist, Volume 89, pages 1304–1312, 2004

Nondestructive three-dimensional element-concentration mapping of a Cs-doped partially molten granite by X-ray computed tomography using synchrotron radiation

SUSUMU IKEDA,[1,*] TSUKASA NAKANO,[2] AKIRA TSUCHIYAMA,[3] KENTARO UESUGI,[4] YOSHIO SUZUKI,[4] KO-ICHI NAKAMURA,[2] YOSHITO NAKASHIMA,[2] AND HIDETO YOSHIDA[5]

[1]Department of Complexity Science and Engineering, Graduate School of Frontier Sciences, The University of Tokyo, Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8561, Japan
[2]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8567, Japan
[3]Department of Earth and Space Science, Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan
[4]Japan Synchrotron Radiation Research Institute (JASRI/SPring-8), Mikazuki, Hyogo 679-5198, Japan
[5]Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, Bunkyo-ku, Tokyo 113-0033, Japan

ABSTRACT

Nondestructive, three-dimensional (3-D) element-concentration mapping was performed and high spatial resolution and quantitative applicability were demonstrated. X-ray computed tomography using synchrotron radiation developed at SPring-8 (SP-μCT) enabled us to acquire high-resolution tomographic images with X-ray energies just above and below the absorption edge of an element. Concentration of the element could be calculated from the difference of these images with a correction using standard material. A 3-D Cs concentration map of a partially molten granite was obtained by this technique and compared with a 2-D element map produced by an electron-probe X-ray micro-analyzer (EPMA), with respect to spatial and compositional resolution. A spatial resolution of about 20 μm was achieved by SP-μCT. The compositional resolution of ±2.5 wt% was achieved using the following two calibration processes of linear attenuation coefficients (LAC): (1) calibration based on the empirical relationship between theoretical LACs and observed CT values, and (2) the calibration of spatial variation of observed mass attenuation coefficients (MAC) due to X-ray energy shift using a standard material (Cs-bearing solution). Using the Cs_2O map obtained by SP-μCT, 3-D image analysis was demonstrated, for example, connectivity of melt was calculated and it was found that 88 vol% of melt was connected in three dimensions in the sample. Furthermore, the possibility of 3-D diffusion studies by SP-μCT was discussed based on the spatial and compositional resolutions. This "nondestructive" and "3-D" mapping technique can reveal the internal compositional distribution of precious samples such as extraterrestrial materials and cultural assets, and can solve many 3-D issues such as material transport in geological and industrial materials.