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Multiphotonic Confocal Microscopy 3D imaging: Application to mantle sulfides in sub-arc environment (Avacha Volcano, Kamchatka)

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Petrogenetic relations in igneous rocks are usually studied in natural samples using classical optical microscopy and subsequent geochemical data acquisition. Multiphotonic Laser Scanning Confocal Microscopy (MLSCM) can be a powerful tool to section geological materials optically with sub-micrometric resolution and then generate a three-dimensional (3D) reconstruction (ca. 106 µm3 stack). MLSCM is used here to investigate textural relations of Monosulfide Solid Solution (MSS) with silicate phases in fresh spinel harzburgite xenoliths from the andesitic Avacha volcano (Kamchatka, Russia). The xenoliths contain MSS disseminated in olivine and orthopyroxene (opx) neoblasts as well as MSS-rich quenched magmatic opx veins [1]. First, Reflection Mode (RM) was tested on vein sulfides in resin-impregnated thick (120 µm) polished rock sections. Then we used a combination of Differential Interference Contrast (DIC) with a transmitted light detector, two photons-excited fluorescence (2PEF) and Second Harmonic Generation (SHG). Sequential imaging feature of the Leica TCS-SP2 software was applied. The excitation laser used for 2PEF was a COHERENT MIRA 900 with a 76Hz repetition rate and 800nm wavelength. Image stacks were analysed using ImageJ software [2]. The aim of the tests was to try to discriminate sulfides in silicate matrix as a tool for a better assessment of equilibrium conditions between the two phases.
Preliminary results show that Fe-Ni rich MSS from vein and host rock have a strong auto-fluorescence in the Near UV-VIS domain (392-715 nm) whereas silicate matrix is only revealed through DIC. SHG is obtained only from dense nanocentrosymmetrical structures such as embedded medium (organic matter like glue and resin). The three images were recorded sequentially enabling efficient discrimination between the different components of the rock slices. RM permits reconstruction of the complete 3D structure of the rock slice. High resolution (ca. 0.2 µm along X-Y axis vs. 0.4 along Z axis) 2PEF enables analysis of 3D textural relations of tiny individual MSS globules ($\sim$10 µm) in their various habitus. Statistical microgeometric descriptions can be derived from volumetric image data.
These results may permit refinement of models concerning (re-) crystallisation kinetics and miscibility conditions of sulphur species in various media likely to act in different mantle environments: silicate melt, fluid-rich silicate melt, silicate-rich fluid. Furthermore, this study provides 3D images with improved resolution of several components (silicate phases, sulfides, silicate glass) over the full thickness (>100 µm) of rock slices which cannot be done with classical methods. Besides 3D imaging of ‘hidden’ phases in mantle rocks, it opens up new possibilities for other domains in geosciences like crystallography or petrophysics.

[1] Bénard & Ionov (2010) GRA, this volume
[2] Abramoff, M.D., Magelhaes, P.J. & Ram, S.J. (2004) Image processing with ImageJ. Biophoton. Int., 11, 36-42