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Microchemical and structural characterization of replacement symplectites

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Symplectite microstructures generated from a homogeneous precursor phase are frequently observed in many magmatic and metamorphic rocks. Symplectite formation may be induced by changes in temperature, pressure and composition, thus providing a possible geothermobarometer. The aim of this study is to parameterize experimentally symplectite formation as a function of temperature and to investigate in detail the microstructure through the application of analytical techniques with high spatial resolution.

Synthetic monticellite (Mtc) crystals with a forsterite (Fo) component of about 8 mole% were annealed in a piston-cylinder apparatus at 1.2 GPa, 950 - 1100°C, run durations of 5min - 24h and water contents of 0 - 2.0 wt.% H_2O using BN and Al_2O_3 as a pressure medium. At these conditions Mtc breaks down into two types of fine-grained symplectite microstructures.

Both microstructures were investigated by high resolution scanning electron microscopy (SEM) combined with the focused ion beam (FIB) technique. Compositional zoning within the symplectite and across the phase boundaries was measured on TEM foils. For the investigation of compositional gradients within the reaction front, line scans were carried out, employing EELS analysis using scanning transmission electron microscopy (STEM) mode. The three-dimensional geometries of the symplectite microstructures were reconstructed by BSE images taken on serial sections using a SEM with a field emission gun and FIB technique. The lateral resolution of the images is about 50 to 100 nm, the step size for the material sputtered from the frontal surface of the sample before the acquisition of each image was 50 nm. The focus on analytical methods with high spatial resolution as well as 3D access to the microstructure enables us to refine conceptual models about symplectite formation [1] and improve experimental parameterization.

The composition and the geometry of the symplectites reveal that they were formed by two types of cellular segregation reactions: (a) The Mtc precursor phase (Mtc I) is replaced by a symplectite (type I) consisting of Fo rods in a Mtc matrix without excess Fo component (Mtc II). (b) A symplectite (type II) consisting of a lamellar intergrowth of merwinite (Mw) and Fo is formed. In both cases replacement of the Mtc precursor phase by the symplectite implies chemical diffusion within the advancing reaction front.

The characteristic wavelengths of both symplectite types show strong temperature dependence. At identical run durations and at a temperature of 1000°C, the wavelength of the type I symplectite is on the order of 800 nm, whereas the lamellar spacing of the symplectite type II is about 300 nm. At 1100°C the characteristic wavelengths of both symplectite types are about two times larger, showing the strong influence of temperature on formation and growth of symplectite microstructures.

[1] Abart R, Petrishcheva E, Joachim B. (2012) Thermodynamic model for growth of cellular reaction rims, *American Mineralogist*, 97, 231-240, DOI: 10.2138/am.2011.3820