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Assessing mechanisms and timing in magma-sediment interaction in the subseafloor: True 3-D microfabric observations provide insights into shallow sill emplacement processes

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Magma emplacement in basin sediments at shallow levels initiates a plethora of processes, proceeding both simultaneously and sequential, and on variable length scales. On the grain scale, uptake and heating of sediment and pore fluids during magma emplacement, as well as the fractionation of a highly mobile fluid phase upon crystallization induce distinct rock microfabrics.

IODP Expedition 385 drilled through the shallow sills emplaced in the active rift of the Guaymas Basin, Gulf of California. Here we present first results of a high-resolution X-ray µ-CT survey on drill core material recovered from Hole U1546, covering a shallow basaltic sill emplaced within 300 m below the seafloor. Comprising sample material from just a few meters from top and bottom contacts, from the center of the ca. 75 m thick sill, and a distinctly gabbroic region in the upper third of the sill, several characteristic features of the rock microfabric have been observed. In general, 3D quantitative digital image analysis of the porosity matches the trend determined by onboard moisture and density analyses. Detailed size and shape analysis reveal a bimodal distribution of the pores near the sill margins: Near the top contact, porosity is constituted by small interstitial pores and large spherical vesicles; Near the bottom contact, scarce pores comprise minute interstitial voids and dendritic cavities within granular concretions. While in the center layer of the sill pores are minuscule, porosity within the gabbroic region occurs as almost mm-sized interstitial cavities. The spherically-shaped large vesicles near the top contact feature a complex history: Ductile environment is required in the course of formation, and subsequent precipitation of zeolite or/and calcite can be observed. In places, iron sulfide is present near or at the vesicle walls. In addition, consideration of the grain phase allows further constraints. While plagioclase phenocrysts are abundant throughout the entire sill thickness, grain sizes of matrix pyroxenes and plagioclase near the center are larger than near the contact. In the gabbroic region the presence of hornblende is indicative of a water content of 2 to 3 wt.%. The induced lowering of the solidus temperatures in this region explains why very large crystal sizes are allowed to develop morphologies of pyroxene and plagioclase intergrowth resulting in a coarser gabbroic texture.