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Microstructural and chemical investigation of magma-sediment mingling in natural and laboratory samples

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Magma emplacement and the mingling of sediment with magma (forming peperite facies) in unconsolidated, near-surface basin sediments have been described in fossil systems but have not been reported in active settings. The IODP Expedition 385 drilled through the soft sediment (first 500 m) of the Guaymas Basin, a young marginal rift basin in the Gulf of California. This basin is characterized by an unusually high spatial density of sill intrusions emplaced off-axis. One of the drilled sills, inferring an emplacement within 200 m depth below the seafloor (Site U1547), displays an extraordinarily high porosity (12–20%) in the form of large spherical vesicles. Despite being cold and crystallized, this sill is at the root of an active ring of hydrothermal system that outlines the edges of the sill at depth. Here we explore the hypothesis that this high porosity originates from the magma-sediment mingling process occurring during the magma emplacement. Understanding this process has direct implications for better constraining the different stages of epithermal activity in the Guaymas Basin and will provide clues to possible mass transfers and longevity of the hydrothermal system.

To test the above hypothesis, we performed laboratory experiments in a gas-mixing furnace to determine how the primary porosity is affected by the liberation of thermogenic gas at high temperature from the organic-rich sediment. Experiments were conducted at 1200 ℃ and fO_2 corresponding to -8 (QFM). We quantified element segregation associated with textural variations using scanning electron microscopy and electron microprobe analysis and compared the results with observations in samples from IODP Expedition 385. Our results show that large vesicles form when the magma mix with organic-rich sediments. Natural samples from Site U1547 display increasing porosity towards the top of the sill consistent with an immiscibility process of the thermogenic free gas similar to that demonstrated in the laboratory experiments. Additionally, the

absence of shear forces applied to the large vesicles (perfectly spherical) most likely reflect an initial increasing amount of sediment uptake into the magma towards the top contact. This suggests that the sediment uptake during the emplacement process is reflected and pre-condition the final porosity profile of the sill. Calcite precipitation in some of the vesicles and iron sulfide presence near or at the vesicle walls are good support of a sediment-derived origin of the vesicles.

Our investigation demonstrates the process by which large porosity forms and develops in the post-emplacement phase of a sill. This occurs through a seeding process associated with magma-sediment mingling resulting in the assimilation of wet and organic-rich sediment during the emplacement phase. A numerical simulation of the regional setting of Guaymas Basin will show how gas accumulation might have been encountered during the emplacement phase, thereby considerably enhancing the porosity growth potential inside the sill. We propose that the high porosity of the sill could be instrumental in driving the current hydrothermal stage of the system, as it enables channelling of deeply sourced geothermal fluids along and through the existing magma plumbing system.