

Pore-scale coupling of dissolution, diffusion, and crystallization forces during alteration of vesicular lavas

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Time-progressive infilling of vesicular pore space by secondary minerals is a common textural feature of zeolite facies metabasalts. For instance, individual vesicles are often rimmed by one or more generations of mafic phyllosilicates and silica phases, with later infillings of one or more generations of zeolites and other silicates. Infilling of pore space is due to formation of secondary mineral phases that are considerably less dense than the basalt. Digital analysis of pore geometries and mineral parageneses at the thin section scale show that the thickness of phyllosilicate linings is independent of pore size within a sample leading to an increased percentage of phyllosilicate occlusion of porosity as pore size decreases. However, the preservation of residual pore space after alteration is a function of pore size, with larger pores being more likely to retain porosity after alteration. In rare instances, alteration aureoles are observed around pores. We propose a model to explain these observations that involves coupled diffusion of water into the matrix of the lavas and ions into the vesicle that is governed by the amount of available open volume necessary to accommodate new mineral formation. Mass balance calculations indicate that the volume of mafic phyllosilicates formed during alteration is smaller than that of the lava dissolved. However, reaction path modeling indicates that at low degrees of reaction, mafic phyllosilicates form first with an early net gain in solid volume. Further reaction leads to stabilization of zeolites along with mafic phyllosilicates, which leads to a dramatic increase in total solid volume of up to ~30 % for complete reaction of the lava. Paragenetically late infilling of vesicles by zeolites without phyllosilicates suggests that phyllosilicate formation during zeolitization is restricted to pseudomorphic replacement of primary phases, consistent with petrographic observations. The fact that the progressive infilling textures are consistent from vesicle to vesicle, and that mineral volumes are not averaged between vesicles, indicates that these processes are controlled by local scale diffusion and volume availability at the scale of individual pores. Temporal variations in mineral stability and net volume changes during reaction thus drive net transport of components between vesicles and the lava matrix in response to restrictions on the space necessary for authigenic mineral formation.

Dissolution-precipitation creep under cyclic stress

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Dissolution-precipitation creep (DPC) is one of the main deformation mechanisms in natural systems. Common models for DPC assume a steady state process in a closed system consisting of three steps: i) dissolution at the grain-to-grain interfaces of non-hydrostatically stressed surfaces, ii) transport of the solute in interfaces, iii) precipitation at grain-to-pore interfaces or at hydrostatically stressed crystals.

The deformation is ultimately driven by the potential energy of the system (Weyl, 1959) and the kinetics of DPC is assumed to be transport controlled. However, recent investigations (He et al., 2003; Lohkämper et al., 2003) show that open systems, capillary forces, or temperature variations can significantly affect the rate of DPC. Here, we investigate the influence of cyclic stress on the deformation rate of halite crystals in contact with silica. In low stress periods, transport within the interface is noticeably enhanced in comparison to high stress periods. Therefore during low stress periods, material, which was plastically deformed in previous high stress periods, can be quickly removed and transported out of the interface.

Regardless of the interface morphology, reducing the load enhances material transport. Therefore, cyclic variations of stress provide an efficient deformation mechanism by permanently increasing the internal energy of the crystal via plastic deformation in high stress periods and reducing the energy via dissolution and transport in low stress periods.

As evident from seismic activities, cyclic variations of stress are common in geological systems. Therefore, we expect from our results that cyclic build up and release of stress can become key factors for fluid assisted deformation of rocks.

References

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