Development of layering during rock deformation: a pressure solution self-organized process

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Abstract

Natural deformation of rocks is commonly associated with development of mineralogical layering, leading to irreversible transformations of their microstructure. The mechanisms of such chemical differentiation processes during diagenesis, tectonics, metamorphism, or fault differentiation remain poorly understood, as they are difficult to reproduce experimentally due to the very slow kinetics involved. This paper shows that development of differentiated layering, similar to that observed in natural deformation, is stress driven and can be obtained from indenter experiments. Samples of (1) gypsum plaster mixed with clay, and (2) natural diatomite loosely interbedded with volcanic ash, saturated with aqueous solutions in equilibrium, were subjected to loading for several months at 40 °C and 150 °C, respectively. X-ray microtomography and scanning electron microscopy observations show that layering develops by a self-organized pressure solution process. Stress-driven dissolution of the soluble minerals (either gypsum or silica) is initiated in the areas initially richer in insoluble species (clay or volcanic ash), as diffusive mass transfer along the interface between soluble and insoluble minerals is much faster than along the healed boundaries of the soluble minerals. The passive concentration of the insoluble minerals amplifies the dissolution along layers oriented perpendicularly to the maximum compressive stress. Conversely, in areas with an initial low content of insoluble minerals and clustered soluble minerals, dissolution is slower. Consequently, these areas are less deformed; they host the re-deposition of the soluble species and act as rigid objects that concentrate both stress and dissolution near their boundaries, thus amplifying the differentiation and the development of layered microstructures.