

Linking evolution of preferential flow paths, transport self-organization and chemical weathering in porous media using non-equilibrium thermodynamics

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We apply non-equilibrium thermodynamic framework to analyze the coupled reaction-transport interaction of reversible dissolution-precipitation of calcite, characteristic to the emergence of preferential flowpaths in subsurface geophysical systems. The reaction-transport interaction is modeled on a Darcy-scale using Lagrangian particle tracking, capable of capturing the multiscale heterogeneity phenomena. Dissolution-precipitation of calcite is driven by the injection of an acid compound into the porous matrix, initially saturated with resident fluid. We analyze the entropy production attributed to various dissipative processes in the field to describe evolution of preferential flowpaths and the accompanying dissipative dynamics within the non-equilibrium thermodynamic framework.

The reactive-transport interaction enhances the emerging preferential flowpaths, leading to transport channelization, as attested by the Shannon entropy, and a decline in the normalized entropy production due to percolation and chemical reaction, signifying the decrease in reaction intensity and frictional dissipation. This is attributed to the intensification of transport channelization in the field due to the bounding of reaction within these paths, thus providing conductive channels for the flow which are preferable energetically. The flip side of transport channelization is the decline in the mixing of reactive species, corresponding to intensification of concentration gradients.

This allows the interpretation of results as the evolution of a non-equilibrium system towards a stationary state under the applied constraint of influx of reactive species. This asymptotic stationary state corresponds to complete channelization of the medium, thus minimizing the mixing of reactive species, reducing the ensuing chemical reaction and providing energetically preferable conductive paths for the flow.

Article currently under review [1]. Relevant references include [2], [3].

[1] Shavelzon, Zehe & Edery (2024), DOI: 10.22541/essoar.173687429.91307309/v1

[2] Shavelzon and Edery (2024), *HESS* 28/8, 1803-2024

[3] Zehe et al (2021), *HESS*, 25/10, 5337–5353

