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Effects of evaporation-induced aquifer scale mixing on mineral precipitation.

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Reactive transport is fundamentally involved in many challenges for the future as it is strictly linked with the progressive climate change. For example, CO2 sequestration can be achieved by mineralization of this gas and precipitation of salts in the surface soil leads to a severe reduction in land fertility and desertification. These processes are frequently observed in arid zones, where the evaporation plays a key role in the evolution of the environment. In particular, evaporation can control the groundwater flow, lead to mineral precipitation and trigger variable-density flow in the aquifer after reconcentration of solutes. This study aims at investigating the interplay between mineral precipitation and mixing by means numerical simulations of variable-density flow, transport of aqueous species and reactions in a salt lake-aquifer system representative of many real cases. A fixed evaporation rate and recharge, with the same chemistry of the aquifer, is imposed at different portions of the aquifer surface to maintain saturated conditions, while the flow driven toward the surface by evaporation involves the entire domain. The simulations' results show the formation of a surface saline layer where minerals can precipitate in equilibrium with saturated water and density differences can trigger the formation of fingers that grow, migrate and sink in deeper portions of the aquifer, eventually evolve in a convective regime. The entire system shows a strong sensitiveness to evaporation rate and permeability, which are two factors that show a certain variability in nature. In accordance with the theory, the saline layer becomes more unstable as the evaporation rate decreases and permeability increases, resulting in a higher frequency at which the fingers form and sink and the system evolves. These features have direct consequences on mineral precipitation patterns observed at the surface portions of the aquifer subjected to evaporation, in terms of mineralogic association, the spatial distribution and amount of minerals. In addition, the convective mixing drives the aquifer to a characteristic stratification where the recharge freshwater flow is limited to a progressively narrow surface layer in contact with saline water, resulting in a moving mixing zone where geochemical reactions can occur.