

SLAC Groundwater Quality SFA: Simulations of Anoxic Lenses as Exporters of Reactivity in Alluvial Sediments

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Project Abstract: Understanding the development of mixing zones between contrasting hydrogeological facies is critical to predict the transfer and mobilization/retention of contaminants. This is the case for gravel bed alluvial aquifers in the intermountain West, which often exhibit both complex sedimentary structures and contamination derived from human activity or geogenic sources. The juxtaposition of fine-grained, organic matter enriched sediments with more permeable aquifer material is an important property in these systems and has been observed to profoundly alter the mobility of redox-sensitive elements such as O₂, Fe and S. In spite of the importance of those interfaces to water quality, quantitative process representations of the various physical and biogeochemical processes involved do not exist, and the characterization of how their coupling modulates groundwater geochemistry remains as an ongoing challenge.

Here we calibrate a reactive transport model on a series of column experiments using sediments from a field site at Riverton, WY, where low-permeability, organic-rich reducing lenses (Naturally Reduced Zones, NRZs) are embedded in coarser-grained aquifer material. Simulations are carried out in water-saturated conditions using the numerical reactive transport code CrunchFlow. They explicitly account for C, O₂, Fe and S cycling at the interface between NRZs and the aquifer. Simulation results highlight the role of NRZs not only as sources or sinks for redox-sensitive species, but also as exporters of reactivity. By releasing large amounts of organic carbon into the surrounding aquifer, NRZs drive the development of secondary reduction zones, or "halos", in their vicinity, characterized by high microbial activity (e.g. sulfate reduction) and the accumulation of reduced reaction products (e.g. iron sulfide mineral). Because those secondary reduction zones are hydraulically connected to the aquifer, they are susceptible to changes in hydrologic conditions, for instance oxygen pulses associated with seasonal snowmelt. Our results also emphasize the limitations of relying solely on aqueous species measurements to inform reactivity in such systems: high precipitation rates of iron sulfide minerals (mackinawite) combined with sizeable transport of organic carbon presumably in colloidal form lead to a limited signature of reactivity in the dissolved phase.