ANOMALOUS TRANSPORT OF STRONTIUM IN REACTIVE POROUS MEDIA

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Anomalous transport of contaminants in the groundwater has been observed in numerous cases associated with the migration of heavy metals, organic compounds, and radionuclides. Even in the absence of the well-known fast migration pathways, associated with fractures and colloids, anomalous transport arises in numerical simulations of reactive flow and it is due to the presence of highly pH-dependent adsorption and the broadening of the concentration front by hydrodynamic dispersion. It is characterized by the emergence of an isolated pulse or wave of a contaminant traveling at the interstitial flow velocity ahead of the retarded main contamination front. The wave is considered anomalous because it is not predicted by classical chromatography theory, unlike the retardation of the main contamination front.
We used chromatography theory to study a simple pH dependent surface complexation model to derive the mathematical framework for the anomalous transport. We model incompressible one-dimensional flow through a reactive porous medium for a fluid containing four aqueous species: Sr2+, H+, Na+, and Cl-. The mathematical problem reduces to a strictly hyperbolic 2x2 system of conservation laws for effective anions and Sr2+, coupled through a competitive Langmuir isotherm. The complete set of analytical solutions to the Riemann problem which comprises only three combinations of rarefaction, shock, and shock-rarefaction was compared with numerical solutions. We show that the numerical solutions follow the analytic solutions in all cases except under the conditions which determine the formation of a pulse traveling at the interstitial flow velocity ahead of the strontium front (anomalous wave) shown in Figure 1. N umerical solutions computed using PFLOTRAN were used to study the eect of a complex aqueous chemistry and of the heterogeneity in the case of a three-dimensional flow. Under increasing complexity of the solution chemistry and in the presence of CO2, the anomalous wave is still present but its magnitude is diminished by the formation of aqueous complexes particularly favored at basic pH. On the contrary, in an high heterogeneous media, hydrodynamic dispersion magnifies leading to a larger anomalous wave.