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ABSTRACT TITLE: Colloid Deposit Morphology and Permeability of Porous Media

ABSTRACT: Subsurface remediation and materials transport through soils depend on flow in porous media. Darcy’s law states that such flow is proportional to permeability, which depends in part on porosity. However, when colloidal materials (such as clays, precipitates, or microbes) form deposits, the resulting permeability cannot be accurately predicted from porosity. This is a major challenge for subsurface remediation, casting doubt on models linking biological, geological, and chemical processes. It has been hypothesized that the morphology of colloid deposits—specifically, their fractal dimension—could be a critical aspect relating deposition and permeability. Until now, determining colloid deposit morphology within porous media at the relevant spatial scale is an unsolved problem. To address this issue, we have developed a unique extension of static light scattering to measure the fractal dimension of colloid deposits within refractive index matched (i.e., transparent) porous media. The media in our flow column is Nafion, a synthetic material that becomes essentially transparent when saturated by a solution of isopropanol and water. We are studying the aggregation and deposition of colloidal polystyrene microspheres. Laser light scatters from the deposited colloids, but not from the transparent Nafion, such that the intensity of scattered light as a function of scattering angle indicates the fractal dimension.

While neither the solid nor fluid phase components are taken from natural environments, this system will permit us to study the relationship between deposit fractal dimension and flow within saturated columns under well characterized flow conditions. Currently, we are measuring how deposit fractal dimension varies with ionic strength, and how fluid velocity (i.e., shear stress) dynamically changes deposit morphology.

In complementary research aimed at generalizing these laboratory results to field settings, we are also measuring the fractal dimension of suspended colloids in groundwater collected from the Old Rifle Integrated Field Research Challenge (IFRC) site in western Colorado. Other samples, to be analyzed in Summer 2013, will provide fractal dimension of mineral precipitates and microbial biofilms collected from laboratory models prepared in collaboration with Lawrence Berkeley National Laboratory. The ultimate goal of this research is to create a clogging model linking environmental variables and colloidal phenomena to soil permeability, in order to reduce the associated uncertainty in models for subsurface remediation and materials transport.