Multi-Method High-Resolution Characterization of Contaminant Distributions in Sedimentary versus Igneous Rock Settings

Steven Chapman (schapman@g360group.org) and Beth Parker (G360 Institute for Groundwater Research, University of Guelph, Guelph, Ontario, Canada)
Seth Pitkin (Cascade Technical Services, Montpelier, Vermont, USA)
Thomas Imbrigiotta and Dan Goode (US Geological Survey, Lawrenceville, New Jersey, USA)
Lars Davidsson (WSP Environmental, Halmstad, Sweden)

Background/Objectives. Characterization of contaminant distribution in fractured rock is a pervasive and challenging problem. It is well known that mass transfer between groundwater flowing in fractures and the immobile water in the rock matrix strongly affect contaminant plume behavior and remedial efficacy. In fractured rock systems, nearly all groundwater flow and contaminant transport occurs in the interconnected secondary porosity of the fracture network. However, the rock matrix typically has higher primary porosity by orders of magnitude in sedimentary bedrock (e.g., sandstone, mudstone), where contaminants may be adsorbed or entrapped in dead-end pore spaces. In metamorphic and igneous bedrock (e.g., granite) the porosity of the matrix can be much lower, however, still appreciable relative to fracture porosity, and may be enhanced by micro-fractures. Contaminant degradation by biotic and/or abiotic processes can also occur in the matrix. Inward diffusion from fractures to the matrix causes retardation of plume fronts and attenuation of plume concentrations, which can be a positive effect reducing plume migration rates and mass transport to receptors. However, matrix storage also impedes remediation due to back diffusion, so that plumes may persist for extended periods even if sources become depleted or remediated. Understanding contaminant mass distribution between mobile groundwater in fractures and immobile groundwater and sorbed mass in the matrix is key to assessing plume attenuation, remediation effectiveness, and risks.

Approach/Activities. This presentation will focus on intensive field characterization using boreholes at two fractured bedrock sites with chlorinated solvent contamination, at the former Naval Air Warfare Center (NAWC) site in New Jersey where bedrock is primarily mudstone, and at a former metals fabrication site in Sweden where bedrock is granite. Comprehensive field investigations, using the 'Discrete Fracture Network – Matrix' (DFN-M) field approach, have been applied to characterize the contaminant mass distributions and flow systems in detail at these sites. Continuous rock coring with high resolution rock core subsampling adjacent to fractures and in the matrix just above or below the fractures provide the most comprehensive assessment of the contaminant mass distribution, avoiding or minimizing the possibility of biased results from cross-contamination. Several other techniques were also applied to compare the characterized contaminant mass distribution results, including the recently developed FLUTe FACT™ technique, novel geophysical tools, a new porewater sampling device, and groundwater sampling using multilevel systems. Boreholes were also subjected to geophysical and hydrophysical logging techniques, including FLUTe transmissivity profiling and Active Line Source (ALS) testing to assess groundwater flow in the fracture network.

Results/Lessons Learned. The various high-resolution datasets provide exceptional insights into the contaminant mass distribution in the rock matrix relative to the hydraulically active fractures and flow system. The presentation will discuss results from the various techniques, such as differences in mass distribution related to geological settings (mudstone versus granite), potential for bias such as effects of open hole cross-connection and best practices. It will also discuss how these techniques, when applied in a complementary manner, can contribute to improved site conceptual models, remediation design and site decision making.