Nano-related potential projects,
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1. Transport of nano-particles in fractures and heterogeneous porous media.
2. Nano fabrication of surface roughness and flow channels in fracture simulator for exploring the dynamics of flow and transport processes.

1. Nanoparticles comprise a broad range of inorganic materials, but the main classes are carbonbased (e.g., fullerenes/C60) and metal-based (e.g., metals, metal oxides). During their production, delivery, and use, nanoparticles will inevitably be released into the environment. Of particular concern is the release of nanoparticles into groundwater reservoirs, during wastewater disposal from industry, either during production and/or following application of nanoparticles. Moreover, in addition to health concerns, nanoparticles may influence a variety of geochemical interactions in the subsurface environment; nanoparticles possess unique chemical properties which are often quite different – generally far more reactive – than those of corresponding bulk materials. Conventional wastewater treatment methods are, presumably, incapable of removing nanomaterials from water, but even this issue has not been addressed systematically. Moreover, in the context of using nanoparticles to purify water contaminated by a range of chemical compounds, Savage and Diallo (2005) mention the toxicity of carbon nanotubes and fullerenes, and their low solubility in water.

In terms of groundwater systems, limited studies on nanoparticles have concentrated mostly on qualitative analyses. At this stage, very little is known about nanoparticle transport, capture and mobilization in groundwater systems, and especially their interactions with soil and aquifer materials in groundwater (Maynard et al. 2006). It is known that some nanoparticles such as fullerenes are not soluble in water; therefore their mobility is expected to be low. Other studies mention that the aggregation products of fullerenes are much more soluble (Cheng et al. 2005a).

There has been similarly little study of the effect of inorganic constituents in groundwater on nanoscale metal reactivity, longevity, and transport. The rapid agglomeration of nanoparticles and the resulting loss of reactivity and mobility is a

recognized problem (or advantage), although migration distances of the order of several meters have been reported in the field (Elliott and Zhang 2001).
To date, only a handful of studies have measured, or attempted to measure – quantitatively transport of nanoparticles in porous media. To the best of our knowledge, there is practically no work done on transport of nanoparticles in fractures and heterogeneous porous media under unsaturated conditions. In my laboratory we worked a lot in the last five years on transport of colloidal particles in fractures and heterogeneous systems (e.g., Zvikelsky end Weisbrod, 2006; Zvikelsky et al., 2008, Tang and Weisbrod, 2009, Mishurov et al., 2008). In the near future, we are considering initiating a research to explore transport of nanoparticles in these environments.

2. In the last decade it became well-accepted that flow within fractures is influenced by surface roughness and internal fracture structure (flow channels). In natural systems fractures are very far from the ideal "parallel plate model". Nevertheless, this simple model, that is the basic assumption for the "cubic low", is still being used to quantify flow through fractures in most cases. Although the impact of flow channels and roughness on fracture flow is investigated extensively in theory, there are very few studies that explore these issues experimentally. The internal fracture structure is typically a "black box" and knowledge about its properties are either unknown or explored after flow experiments – in a way that the experiment cannot be repeated. The advanced options of nano fabrication open a new window into exploration of these issues experimentally. I believe that with the assistance of the nano fabrication experts we can create several "fracture replicates" in which the impact of specific internal fracture structure will be explored. These systems will enable us to shed a new light on the link between the internal fracture properties and the breakthrough of solutes and colloids through them, under controlled conditions. Moreover, these controlled systems will enable the exploration of the of internal flow system dynamics over time. For example, particle deposition and salt precipitation can vary the internal fracture structure. However, it is unclear where these processes happen within the complex flow domain and how the processes evolve with time. We believe that with a nano-scale controlled channels and roughness in fracture simulators, prepared according to predetermined criteria, very valuable information could be achieved.