

Repeat turbidity surveys can help assess the effectiveness of restoration efforts. Analysis of the temporal and spatial patterns of turbidity can suggest the location of sources and transportation pathways of undesirable material that enters the lake.

H42H MC: 130 Thursday 1610h

A Strategy for the Advancement of Hydrologic Science III (joint with ED)

Presiding: R C Bales, University of Arizona

H42H-01 0830h

A Strategy for the Advancement of Hydrologic Science III

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There is no abstract for this presentation.

H51A MC: Hall D Friday 0830h

Gas and Vapor Transport Processes in Porous and Fractured Media I

Presiding: D Wildenschild, Technical University of Denmark

H51A-0299 0830h POSTER

Coupled Gas-Liquid Diffusion in Porous Media Using the Dusty Gas Model

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Numerous problems involve the simultaneous diffusion of chemical species in both aqueous and gaseous phases. Applications include diffusion of non-condensable gases including carbon sequestration, volatile organic compounds (VOCs), and chemicals from buried landmines. Diffusion in the unsaturated zone involves simultaneous transport in the aqueous and gaseous pathways. Calculation of diffusion in the individual phases is straightforward. However, for simultaneous diffusion in both phases, simply adding diffusive fluxes in gas and liquid phases will in general not be correct. Proper treatment of diffusion in multiphase conditions must take into account the coupling between diffusion and phase partitioning.

Coupled gas-liquid diffusion was previously considered using Ficks law for both aqueous and gaseous diffusion. The diffusive strength term was harmonically weighted at the interface to enforce mass conservation. Results showed that the coupling effects are significant, and that uncoupled results can seriously underestimate diffusion across a capillary fringe. In the present work, the Dusty Gas Model (DGM) has been used to model gas diffusion. The DGM is a more fundamentally sound model for gas diffusion than Ficks law. However, the formulation of multiphase diffusion coupled with gas-liquid phase partitioning becomes considerably more complicated, and mass conservation must be explicitly imposed on each component through solution for the appropriate interface conditions.

For higher permeability and trace gas conditions, the two models (Ficks law and DGM) give similar results as expected. However, for lower permeability media and non-trace gas conditions, significant differences exist.

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H51A-0300 0830h POSTER

Vertical Mixing of CO₂ and CH₄ with Gravity Effects

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Numerical simulations of mixing of carbon dioxide (CO₂) and methane (CH₄) in a gravitationally stable configuration have been carried out using the multicomponent flow and transport simulator TOUGH2. The configuration is relevant to carbon sequestration in depleted natural gas reservoirs, where injected CO₂ will migrate quickly to low levels of the reservoir by buoyancy flow due to its large density. Once a gravitationally stable configuration is attained, mixing will continue on a longer time scale by molecular diffusion. However, diffusive mixing of real gas components CO₂ and CH₄ can give rise to pressure gradients that can induce pressurization and flow that may affect the mixing process. Understanding this coupled response of diffusion and flow to concentration gradients is important for the prediction of mixing times in stratified gas reservoirs used for carbon sequestration. We have implemented the Dusty Gas Model (DGM) as an alternative to the standard Advective Diffusive Model (ADM) in our multiphase flow simulator TOUGH2. A new equation of state module (EOS7C) that handles water, brine, CO₂, gas tracer, and CH₄ was developed in which gas properties for mixtures in the system water, CO₂, and CH₄ are calculated using the Peng-Robinson real gas mixture model. Comparisons of vertical mixing results for low permeability and high permeability systems using the DGM and ADM will be presented.

Support for this work was provided by the Assistant Secretary for Fossil Energy, Office of Coal and Power Systems through the National Energy Technology Laboratory under U. S. Department of Energy Contract No. DE-AC03-76SF00098.

URL: <http://esd.lbl.gov/GEOSQ/code/index.html>

H51A-0301 0830h POSTER

Effects of Reynolds Number on Mixing and Dispersion

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The lattice Boltzmann (LB) method was used to estimate the effects of Reynolds number (Re), and sidewall boundaries, on dispersion of gases in fractured and porous media. The systems studied ranged from idealized channels with parallel grooves and honeycomb structures, to casts of natural fractures and aggregates of sedimented, quasi-spherical particles.

For specific configurations of rough, intersecting fractures, Re variation from 0 to 100 causes only a factor 2 variation in the mixing ratio C₂/(C₁+C₂), where C₁ and C₂ are the concentrations of solute in the outlet legs of the fracture intersection. However, slight changes in the intersection alignment yield up to factor 5 range in the mixing ratio, for the geometries studied. For both individual fractures and fracture intersections, sidewall boundary effects tend to be overwhelmed by velocity variations within the fracture planes.

LB simulations for porous aggregates give good agreement with experimental studies. However, in random aggregates at high Re, it becomes impractical to obtain dispersion coefficients by LB and the method of moments. Alternative LB methods are discussed.

H51A-0302 0830h POSTER

Gas Diffusion in Unsaturated Porous Media: Pore Connectivity, Hysteresis and Power Law

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We found that some soil reveals conspicuous hysteresis in gas diffusion coefficient between wetting and drying processes, that diffusion coefficient goes to zero as the gas saturation approaches the residual saturation and that the model assuming a power law around the residual saturation agreed well with the experimental results. A new apparatus enabling to measure low gaseous diffusion coefficient was developed and gaseous diffusion coefficients of unsaturated porous media were measured. For soil materials, we used soil from an agricultural field and sieved fractions of sand. The agricultural field soil contains some organic matter and has wide pore size distribution, and did not revealed hysteresis in gas diffusion. On the other hand, sieved fractions of sand have narrow grain size distribution, and conspicuous hystereses were observed both in retention curves and gaseous diffusion. Only primary/main imbibition and main drainage processes was investigated (we did not investigate the primary drainage processes because this process would rarely happen in natural vadose zone), and thus gas saturation never became lower than residual saturation, due to the trapping of the air. In imbibition processes, as the gas saturation approaches to the residual saturation, measured effective gas diffusion rate dropped sharply. This means that the residual saturation will act as a kind of threshold. We fitted the experimental data to power-law-around-residual-saturation model, and model and experimental results agreed well. Also, we investigated the relationship between the exponent of the power law and the Brooks-Corey's lambda parameter. It seems that wider the pore size distribution, larger is the exponent of the power law.

H51A-0303 0830h POSTER

Anisotropy of Pore Structure and Permeability in Granite: Preliminary Results

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The permeability of rocks is sensitive to pore structures. In fault zones where brittle deformation dominates, connectivity of cracks is perhaps the most important factor to control the fluid permeability. The relationship between microstructure, porosity-pore structures and permeability were investigated, using drill core samples from the Toki Granite in Gifu Prefecture, Central Japan. Core samples taken from a borehole penetrating a fault strand of the Tsukiyoshi Fault at the depth of 700 m were used for analysis and measurements. The Toki Granite shows textural variations. For example, away from the fault zone, the granite is fresh, massive biotite granite. Toward the fault the granitic texture is largely destroyed, reflecting deformation due to fault movement, with extensive fracturing and development of calcite veins. The central part of the fault zone constitutes foliated ultra-cataclasis with a fine grained matrix. Microstructural observations indicate that fragmentation of crystals is the cause of grain size reduction in the fault zone and anisotropy in micro-crack development. The effective porosity of bulk samples measured by Helium pycnometer varies from 0.54% for unaltered fresh granite to over 5.4% for foliated cataclasis from the central part of the fault zone. The pore structures of the granite samples were visualized by the Laser Scanning Microscope (LSM). The samples were impregnated with low viscosity fluorescent resin under vacuum condition, and then observed by the LSM. Quasi 3-D images of pore structures were constructed from optical slices (confocal images) of thick sections. Micro-cracks in granites were successfully filled with the fluorescent resin. Micro-cracks were mainly observed at grain boundaries, and the intra and inter granular fractures. Permeability measurements were performed by a High Pressure Temperature (HPT) gas apparatus using the pore oscillation technique. Confining pressure was increased and then decreased in the range of 25- 200 MPa, with pore pressure kept around 20 MPa. Preliminary results indicate relatively high permeability for undeformed biotite granite, about 10⁻¹⁶ m² at the initial confining pressure (Pc=30MPa), and with a gradual decrease to 10⁻¹⁷ m² at the highest Pc(=198MPa). The fractured