Abstract for **CMG2004**

**Anomalous transport in geological formations**

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The observation of anomalous or non-Gaussian transport in heterogeneous geological formations is ubiquitous. The motion and spreading of chemical plumes are characterized by distinct temporal scaling. A theoretical basis has been developed that accounts for this time behavior of chemical (solute) transport in heterogeneous media in field, laboratory and numerical experiments. The transport is described by a spatially biased (non-Markovian) continuous time random walk (CTRW) governed by $\psi(s, t)$, the joint probability density for a transition with displacement $s$ and time $t$ (e.g., these can be transitions through fracture fragments of a random fracture network RFN). The $\psi(s, t)$ is determined by the spectrum of transition rates generated by the complex flow field in the RFN and/or permeability variations in heterogeneous porous media. Breakthrough curves are calculated and shown to be agreement with those measured in both field and laboratory experiments.

Recent innovations have allowed a general solution of the CTRW for any well-posed $\psi(s, t)$ and boundary conditions in 1—3 spatial dimensions. Results are presented detailing the time dependence for the resident and flux solute concentrations, including the evolution from anomalous to normal behavior when the plume moves a distance large compared to the spatial scale of heterogeneities. One solution is applied to the case of a flux entering a stream from a point injection of tracer in a catchment. These 2d results are discussed as an independent test of our model of fractal stream chemistry in catchments.

The transport model has been incorporated into a unified framework that treats non-stationary systems in that it takes into account the different levels of uncertainty often associated with characterizing heterogeneities at different spatial scales. It treats the unresolved, small-scale heterogeneities (residues) probabilistically using CTRW and the large-scale heterogeneity variations (trends) deterministically. This formulation leads to a Fokker-Planck equation with a memory term and a generalized concentration flux term. The calculations demonstrate long tailing (anomalous behavior) arising (principally) from the memory term, and the effects on arrival times that are controlled largely by the generalized concentration flux term. This transport framework is compatible with large-scale numerical programs and can increase their effectiveness in accounting for field observations.