CENTER FOR NUCLEAR WASTE REGULATORY ANALYSES

TRIP REPORT

SUBJECT: Geological Society of America 1999 Annual Meeting (20.01402.861)

DATE/PLACE: October 25-28, 1999
Denver, Colorado

AUTHORS: David Farrell and Scott Painter

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PERSONS PRESENT:

David Farrell, Scott Painter, and the general scientific public

BACKGROUND AND PURPOSE OF TRIP:

This trip report presents a summary of the presentations at the 1999 Annual Meeting of the Geological Society of America (GSA). The presentations attended were predominantly hydrogeologic in nature, however, discussions related to geosciences and the legal system, and landscape evolution modeling were also attended.

SUMMARY OF PERTINENT POINTS:

Landscape Evolution Modeling

The session on Landscape Evolution Modeling was well attended and there were several interesting presentations which generated considerable discussion. From the presentations it is clear that this area of research is still in its infancy; conceptual approaches to modeling erosion are only now being developed. The following summarizes some of the discussions.

G. Tucker et al. presented preliminary applications of the CHILD model to geo-archeological work being carried out in the Central Great Plains. The central idea behind this work is that an understanding of floodplain dynamics can help target areas for archeological work. In the presentation, Tucker demonstrated some features of the CHILD model as it pertains to floodplain development, e.g., migrating meanders and multiple terrace development. The simulated floodplain development produced terraces that appeared qualitatively consistent with field observations. However, as discussed in the presentation, robust verification of the model is limited by the lack of data.

G. Olyphant presented results based on a new model (now in the developmental stage) for studying the response of alluvial channel networks to varying inflows of water and sediment. The numerical aspects of the model are based on the Saint Venant equation for flow routing, and the sediment transport equation. This model appears to be applicable only to small scale drainage basins. Like most models in this field, the numerical approach is based on a finite difference formulation. Simulations demonstrated that rates of incision and deposition were strongly influenced by time-dependent run-off and sediment inflow to headwater tributaries, and the existing landscape.

J. Pelletier proposed a two-scale model to simulate the evolution of alluvial drainage basins and floodplains. In his presentation he pointed out two limitations of Tucker's CHILD model that pertain to alluvial drainage basin and floodplain evolution: (1) the fixed mesh used in CHILD may not be the most appropriate approach for modeling migrating meandering systems, and (2) there exists a junction angle problem in CHILD which appears to imposes constraints on the way channels intersect. The first appears to require multigrid algorithms, while the second appears to have been resolved in Pelletier's model. Pelletier also suggested that current simulation models treat channels as single grid points without resolving channels in cross-section and that this is a significant limitation of existing models. It is noteworthy that Pelletier also discussed some shortcomings commonly observed in cross-sections produced by existing fluvial erosion and sediment deposition simulation models. These problems do not appear obvious to non-experts in the field. He argued that his model, which is unconventional and still in the developmental stage, resolves some of these issues. Pelletier described his model as a two-stage model that represents hillslopes and stable upstream channels as single grid points with a discharge-dependent width but explicitly models channel cross-section and flow structure in down stream channels where floodplains form and channels can meander, braid, and form alluvial terraces.

D. Mitchell et al. presented work aimed at critically examining the stream power incision law which is commonly applied in hydrology and is considered important for landscape evolution modeling among other applications. The work consisted of estimating stream incision rates along a number of rivers in New Mexico (incising differing geologic materials) and then comparing the observed incision rates with those predicted based on the stream power law model. The comparison showed that for mountain streams in regions of arid climate that are subjected to moderate tectonic activity the stream power law model does not accurately predict field observed incision rates. The presenters also indicated that stream power law models derived from field-based estimates, including discharge and slope, differed from estimates based on drainage area and slope inferred from topographic maps. Finally, the authors suggested better agreement between field observed incision rates and those predicted by applying field observed parameters to the stream power law may be possible by normalizing the results based on the stream power law by channel and valley widths.

D. Furbish et al. presented novel work in the field of landscape evolution modeling using the Master Equation which appears to be a more formal presentation of the Conservation Equation. Their approach essentially involved applying the Fokker-Planck formulation to the Master Equation and performing particle tracking (virtually identical to particle tracking in hydrogeology). Then they explored various aspects of the formulation, in particular the diffusion term. The formulation was used to examine particle movement along a slope due to "rain splash".

Two other presentations of interest were made by L. Smith et al. who discussed gully development on US military bases, and W. Chromec et al. who discussed the use of Watershed Erosion Prediction Project Model (WEPP) and the Hydrologic Efficiency Code 6T (HEC 6T) to examine soil erosion and subsequent actinide transport via surface waters at Rocky Flats. Smith's presentation was qualitative and discussed the fact that gullying is a poorly understood and a poorly modeled process. Smith suggested that research in the following areas is important to understanding gully evolution, (1) processes influencing gully initiation and growth, (2) the influence of soil type, groundwater, climate and topography on accelerating gully development, (3) improved modeling techniques, and (4) the interaction between gullying, erosion and landscape evolution.

Geoscientists in the Legal System: the Challenge for the Next Century

Two of the presentations focused on the Woburn, MA, site and the associated legal activities (Jerome Facher and John Guswa). Jerome Facher discussed the role of the defense attorney in the case while John Guswa (HSI Geotrans) discussed the view of the courtroom from the perspective of a defendant's expert. Gushwa basically summarized the steps a geoscientist should take when approached to be an expert witness. The steps are summarized as follows:

1. Preliminary Contact Phase:

* Introduction to the client
* Identify technical issues
* Review the big picture
* Identify extraordinary issues which may impact the problem

2. Detailed Technical Evaluation Phase:

* Develop a good interaction/working relationship with the client
* Perform topical analysis
* Build a story (involves developing a conceptual model and a site history, however, it is important to note that the plaintiff establishes the ground rules at this point, since he/she present his/her view first)

3. Expert Discovery

* Involves interaction with opposing counsel
* Explores opinions and basis
* Based on a Q & A format
* May involve interactions with opposing experts through opposing counsel

4. Trial Preparation

* Respond to plaintiff's story
* Present own story plus "appendices" based on plaintiff's story
* Simplify arguments

5. Trial

* Involves judge/jury and the audience
* Direct testimony phase
* Cross examination phase
* Redirect examination phase
* Recross examination phase
* Rebuttal phase

Duane Miller presented the perspective of the plaintiff's counsel and presented case studies related to (1) heavy metal poisoning of children prior to birth which produced deafness and (2) city of Fresno's litigation case against farmers accused of contaminating drinking water supplies with DDCP. Miller pointed out that a key aspect of such cases is how to demonstrate causation and that the job of the expert witness is to help the lawyer demonstrate this. He suggested that the data should be presented in a piecemeal fashion since too much data all at once confuses the jury. He also suggested that during the deposition the expert witness should always pay attention to the questions posed and ask for clarification when questions appear unclear.

Thomas Prickett presented a discussion on the geologist as an expert witness. He pointed out that details should always be presented at a level that members of the jury can understand. Prickett summarized the litigative approach as:

* Preliminary interview with the client and attorney
* Case preparation
* Data exchange between the expert witness and the client
* Analysis and reporting
* Deposition
* Negotiations and preparation for court
* Decision to settle or resolve in court

Prickett listed the following as being good characteristics of expert witnesses

* Extremely well prepared, both scientifically and legally
* Ability to simplify concepts
* Non-combative and honest
* Relatively clean career

Finally, Prickett suggested the following as recommended reading for persons who may be called to provide expert testimony:

* *The Last Ranch, A Colorado Community and the Coming Desert* by Sam Bingham (ISBN: 0156005395)
* *The Terrible Truth About Lawyers: How Lawyers Really Work and How to Deal with Them* by Mark H. McCormack (ASIN: 0380706520)

Measurement and Description of Flow and Transport in Highly Heterogeneous Aquifers

This session was well attended and generated considerable discussion. Of particular interest were the talks on by A. Geldon, W. Barrash et al., G. Weissmann et al., L. Lemke et al., S. Painter and D. Farrell *(invited)*, G. Fogg et al., F. Molz et al., and R. Schumer et al..

Geldon presented a discussion on an 18-month pump test conducted at the C-Holes complex at Yucca Mountain. Part of the presentation involved presentation of borehole geologic and geophysical data, as well as pump test data. General observation presented were (1) rocks closest to faults have highest K; (2) most of the drawdowns (and fluctuations) observed at pumping locations were due to well losses; (3) conductive fractures along and adjacent to boreholes allowed water to move around installed packers. Drawdown data were fitted with Fisher and Theis curves, with the Theis curve appearing to fit all of the data. General findings were (1) transmissivity increased in a SE direction; (2) hydraulic conductivity appeared to be scale dependent; (3) Miocene tuffs appear to act as one continuous hydraulic unit so that no sub-divisions are required.

Painter and Farrell presented an invited talk on using non-Gaussian random fields to model aquifer heterogeneity. This talk presented results from an SwRI-funded internal research and development project. Painter emphasized that the complex, highly variable nature of the subsurface is inconsistent with classical statistical models that are widely used in subsurface hydrology. Painter described new models based on fractal concepts, which are able to reproduce statistical features of subsurface data. Examples of conditional simulations based on fractal random-field models were discussed, including a large-scale simulation of a producing petroleum reservoir.

Barrash et al. presented a discussion on hierarchial geostatistics of porosity derived from neutron logs at the Boise Hydrogeophysical Site. Different data analysis techniques were employed such as variograms plots, frequency histogram plots etc allowing the development of a geostatistical model describing the spatial variability of porosity.

Weissmann et al. described an approach based on transitional probabilities and Markov chains, to model stream dominated alluvial fan aquifer systems. The authors discussed its application to the Kings River alluvial fan located in California. The approach presented is identical to that presented in Weissmann et al. (1999), and Thompson et al. (1999). They then showed the potential application of the method to contaminant transport.

Lemke et al. presented work on the use of sequence stratigraphic concepts to characterize and predict the distribution of local-scale spatial trends and heterogeneities within glacial sediments by restricting interpretation of facies assemblages to genetically related units bounded by chronostratigraphically significant surfaces. This approach allows construction of facies-keyed stochastic distributions of hydraulic conductivity within a deterministic stratigraphic architecture defined by the geometry of the chronostratigraphic bounding surfaces. The method was applied to the study of flow and contaminant transport at the Pall-Gelman Sciences, Inc. site in southeast Michigan.

Fogg et al. argued the case for a connected network model of subsurface heterogeneity, in which the connected network could be based on such things as buried stream channels. The authors presented simulated pumptest data that demonstrated the plausibility of the network approach, although not confirming the presence of the network. The presenters also showed that decreasing K of the aquitard facies resulted in increased drawdown in regions which appear to be isolated from the pumped network. The presenters argued that this arises from the complexity of the network and is contrary to commonly held views on pumptest analyses. Finally, the presenter showed that the evolving plumes demonstrated characteristic features which differed considerably from those commonly predicted by standard stochastic approaches.

Molz et al. presented a discussion of the connectivity of high hydraulic conductivity zones in hydraulic conductivity fields generated using multi-fractal and mono-fractal approaches and data from the MADE site. The analysis showed poor connectivity between zones of high hydraulic conductivity. The presenters suggested that this appears to be unrealistic and that future development of such models should aim to incorporate varying degrees of connectivity.

Schumer et al. presented work on a more generalized formulation of the advection-dispersion equation which incorporated fractional derivatives. They showed that under this formulation commonly observed "tail heaviness" in contaminated plumes can be easily reproduced.

Dynamics of Mass Transport in Fractured Rocks and Fine Grained Sediments

Notable contributions to this session included E. Sudicky, M. Helmke, L. McKay, M. Landrum, S. Altman, S. van der Hoven, G. Bussod, H. Turin, and H. Zhang.

Sudicky documented the history of efforts to model fracture flow and mass transport in fractured rock under variable saturation. He pointed out that based on the work of Way and Narasimham (1985), fractures may act as barriers to flow. He noted that numerical simulation work at the University of Waterloo indicated there is no apparent correlation between fracture spacing and plume dispersivity, however, there does appear to be a correlation between fracture aperture and dispersivity. Sudicky pointed out that these results are consistent with some recent findings of S. Neuman. Sudicky also discussed whether it is possible to obtain a representative concentration sample in a fractured rock. His numerical simulation work indicates that this may not be possible because the presence of the well modifies the concentration field in the sample region prior to sampling. Finally, Sudicky presented findings based on numerical simulations that suggested the generally accepted notion that DNAPLs will only reside within the fractures of a fractured rock system may be incorrect. His numerical simulations indicate that depending on the air-entry pressure DNAPLs may invade the matrix. When this occurs, migration of the DNAPL may be "retarded".

M. Nicoll and R. Glass presented the results of an infiltration test performed near Fran Ridge at Yucca Mountain. Their infiltration experiment consisted of ponding dyed water at the surface and allowing it to infiltrate into the subsurface fracture network. The site was then excavated and the migration path of the infiltrating water mapped. The results indicated a strong tendency for preferential flow along both vertical and sub-horizontal fractures with very few fractures participating in the tracer migration.

Bussod et al., and Turin et al. both presented results for the tracer tests conducted at Busted Butte by the DOE. Bussod et al. suggested that the observations from the first tracer test indicated strong capillary flows within the matrix, insignificant fracture flows, and flow along unit contacts. Asymmetry in plume crossections were apparent in the data presented, which appears contrary to commonly observed plume geometries. This may indicate heterogeneity within the geology. On the basis of these observations Bussod et al. concluded that (1) the fractured non-welded tuff appears to behave like a "simple porous medium" so that equivalent continuum models may be used, (2) fractures appear to play a minor role in transport, and (3) matrix processes dominate transport. Turin et al. provided a description of the second tracer test that is currently ongoing at Busted Butte and presented some preliminary results. They indicated that over 9000 samples have been collected to date. They pointed out that the data from electrical resistivity tomography and ground penetrating radar tomography which are currently being used to monitor the plumes appear in most cases to be qualitatively consistent. They also indicated that neutron logging is being performed in the bore holes.

Altman et al. presented work in support of the Japanese nuclear waste program geared towards visualization and quantification of diffusion rates in the vicinity of fractures in the Karihashi granodiorite using x-ray adsorption imaging. Their work consisted of injecting potassium iodide into fractures in the samples and then x-raying the samples periodically along with a control sample. The images are then analyzed to determine potassium iodide concentration in the sample. Diffusion rates are then determined from the temporal concentration data using analytical and numerical methods.

Helmke et al. presented the results of a study designed to predict solute transport through fractured Wisconsin till. As part of the study, five tracers (Br, PFBA, PIPES, NO^{3}-N and atrazine) were used in a radial diffusion cell experiment to obtain independent estimates of their effective diffusion coefficients (D*). The tracers were then used to conduct tracer experiments in a column of fractured Wisconsin till. Two approaches were used to interpret the tracer data (1) the continuum mobile-immobile model, and (2) the parallel plate discrete fracture model. Interpretations of the tracer data using both methods indicated that when D* was treated as a fitting parameter to the data, the estimated D* overstated the measured D* by an order of magnitude. This suggests that accurate modeling of solute transport in fractured Wisconsin till requires a robust estimate of D*.

McKay et al. and, later, van der Hoven discussed work aimed at developing a conceptual model of groundwater flow and mass transport in mudrock saprolite located at Oak Ridge, Tennessee. The first part of this work by McKay et al. involved an indepth investigation of site lithology, and laboratory studies of pore structure (both primary and secondary), with particular interest to factors deemed important to flow and mass transport processes. van der Hoven et al. used the field data to design numerical experiments to assess flow and transport at the site under variably saturated conditions. An interesting finding of this study is that during wetting cycles, mass moved from the fractures into the matrix. During drying cycles, only a fraction of the mass migrated back into the fractures. van der Hoven suggested that this may be of potential value to the nuclear waste disposal industry because it indicates that the unsaturated zone can be used as a potential reservoir for radionucles with short half lives.

Landrum et al. presented details of a study designed to examine the importance of fracture skin on flow and mass transport processes in the Topopah Spring Tuff. Analyses showed the fracture skin to be composed of calcite and rock fragments. The diffusivity of the fracture skin was determined using an electrical resistivity methodology in which the resistivity of the rock sample (plus fracture skin) was determined. Later the fracture skin was removed from the sample and the resistivity of the sample reanalyzed. The change in resistivity was then used to determine the diffusivity of the fracture skin using a correlation function. Because the work still appears to be in its infancy, the primary focus of the work appeared to be on methodology.

Zhang presented a study of the factors affecting solute transport in fractured tufts of the saturated zone at Yucca Mountain based on laboratory and field data. Values of fracture spacing, fracture and matrix porosities, diffusivity, distribution coefficient, and dispersivities of the various units were perturbed around their experimental determinations and their impacts on flow and mass transport noted. The results of those analyses were then compared to the results from models based on effective continuum and parallel fracture approaches. Breakthrough curves based on the fracture model were found to be more conservative than those based on the parallel plate model. As a result, the authors concluded that the effective continuum approach implemented in the DOE's total system performance assessment calculations was conservative in estimating the risk associated with radionuclide contamination.

CONCLUSIONS:

Overall, the meeting was well attended and sessions were very informative in both an academic and a practical sense. In many of the sessions, ideas were presented which are applicable to many problems encountered at Yucca Mountain. Participation in this meeting should continue to be encouraged.

REFERENCES

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PROBLEMS ENCOUNTERED:

PENDING ACTIONS:

RECOMMENDATIONS:

SIGNATURES:

David A. Farrell — Date: 11/24/99
Geohydrology and Geochemistry

Scott Painter — Date: 11/24/99
Geohydrology and Geochemistry

CONCURRENCE:

English C. Pearcy, Manager — Date: 11/24/99
Geohydrology and Geochemistry

Budhi Sagar — Date: 11/24/99
Technical Director