tivity of electrical measurements to reduction in reactive iron performance, measurements were made over a three month period of ageing and correlated with geochemical indicators (pH, Eh, electrical conductivity, iron concentrations) of Fe surface oxidation and precipitation. We find that induced polarization (IP) parameters are highly sensitive to Fe0 surface area whereas conduction parameters measured with the resistivity method are insensitive to Fe0 concentration over the investigated range. Polarization at the iron-electrolyte interface shows a power law relationship with electrolyte activity for all solutions and is consistent with Warburg impedance theory. Power-law exponents are slightly higher than that predicted for the active ion species based on Warburg impedance theory. Polarization magnitude depends on ionic composition of the electrolyte with the magnitude following the order CaCl2: NaCl: NaNO3. Conduction parameters are insensitive to ionic composition at constant electrolyte activity. Electrolyte activity exerts a strong control on the polarization relaxation length-scale, with time constant of the relaxation decreasing with increasing electrolyte activity. Polarization parameters measured during three months of ageing are clearly correlated with time and suggest that electrical measurements are sensitive to reduction in reactive iron performance.

H12H-07 1510h INVITED

Resolving the Impact of Biological Processes on DNAPL Transport in Unsaturated Porous Media Through Nuclear Magnetic Resonance Relaxation Time Measurements

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This research leads to a better understanding of how physical and biological properties of porous media influence water and dense non-aqueous phase liquid (DNAPL) distributions under saturated and unsaturated conditions. Knowing how environmental properties affect DNAPL solvent flow in the subsurface is essential for developing models of flow and transport needed for designing remediation and long-term stewardship strategies. We investigate the capability and limitations of low-field nuclear magnetic resonance (NMR) relaxation decay-rate measurements for determining environmental properties affecting DNAPL solvent flow in the subsurface. For in-situ subsurface environmental applications, low-field proton NMR measurements are preferred to conventional high-field techniques commonly used to obtain chemical shift data, because low field measurements are much less degraded by magnetic susceptibility variations between rock grains and pore fluids that significantly interfere with high-field NMR measurements. The research scope includes discriminating DNAPLs in water-wet or solvent-wet environments and the impact of biological processes on their transport mechanisms in porous media. Knowledge of the in situ flow properties and pore distributions of organic contaminants are critical to understanding where and when these fluids will enter subsurface aquifers. Experiments determined that commonly found subsurface DNAPLs containing hydrogen, such as trichloroethylene and dichloroethylene, are detectable and distinguished from water in soils. Related experiments concern the effects of bacterial accumulation in saturated and unsaturated porous media on water and DNAPL pore-size distributions. These include synthetic bio-film matrix as a surrogate bio-film and sand, biological agents to grow biofilms, and multiple pore sizes to determine if bio-films prefer certain pore-size ranges. NMR microscopy focused on imaging a single biofilm in a 1 mm capillary reactor. This system serves as a model for a single large anisotropic pore of a porous media and allows for determination of T2, spin-spin magnetic relaxation behavior within the biofilm. Measurement and analysis protocols along with packing and saturating protocols are evaluated. The anticipated outcome of this research will establish the utility of proton NMR laboratory and field measurements for elucidating flow properties in different porous media, detecting microbiological influence on DNAPLs, and DNAPL pore-fluid partitions under saturated and unsaturated conditions.

H12H-08 1525h

Clay in Contact Zones: NMR and Ultrasonic Effects

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Presence of clay minerals in soils can affect acoustic impedance considerably. Clay in the contact area lowers the micro- and macrostructural impedance of the formations. We have investigated changes in acoustic properties as the clay dries and changes from a damping to a cementing agent. The study is aimed at understanding the role of clay minerals in saturated to partially saturated soils. METHODS: Acoustic waves were propagated through two discs in contact. The contact zone between the discs was filled with thin layers of dry clay, clay slurry that was allowed to dry slowly, and air. We monitored water content by weighing. Pore size distribution was measured by NMR experiments. We report here waveforms of P- and S-wave signals transmitted through the air-coupled, dry clay-coupled, and cemented clay-coupled quartz discs. RESULTS: We find that the state of the clay changes the wave propagation characteristics in a very pronounced manner. Addition of a water saturated clay layer to quartz discs dampens waves significantly. Significant signal damping occurs after applying a 0.05 mm thick clay layer in the contact region between glass discs. The effect is more pronounced in the S-waves than in the P-waves. However, as the clay dries, it acts as a strong cementing agent and enhances wave propagation through the clay-cemented quartz discs. The NMR experiments allowed us to measure the pore size distributions corresponding to the acoustic measurements. As the average water content decreases, the average water layer thickness decreases from 600 nm in the wet slurry to 56 nm in the partially saturated clay, and 7 nm in the almost dry clay cement with most of the signal coming from capillary water.

URL: http://pangea.stanford.edu/~manika/AGU2003

H12I MCC: 3022 Monday 1600h

Designing a Network of Hydrologic Observatories *(joint with A, B)*

Presiding: **R P Hooper,** Consortium for the Advancement of Hydrologic Sciences, Inc. (CUAHSI)**; K Reckhow,** North Carolina State University

H12I-01 1600h INVITED

A University Consortium for the Advancement of Hydrologic Research

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Seventy-six research universities across the United States have joined to form the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI), a non-profit corporation. With support from the National Science Foundation, CUAHSI has embarked upon the design and development of programs to enable hydrologic research at larger spatial scales over longer time periods than has been within the grasp of individual investigators. The guiding principle of this design has been an embracing of the entire hydrologic cycle to enable research at the interfaces among traditional hydrologic subdisciplines and between hydrologic science and allied disciplines in the earth and life sciences. To improve our predictive understanding of hydrologic phenomena, the fundamental approach that has been adopted is the development of multidisciplinary, coherent data sets to enable testing of hypotheses in different hydrologic settings across a range of spatial and temporal scales. Four mutually supportive program elements have been conceived: a network of hydrologic observatories (the subject of this special session) designed strategically to collect additional data at large scales (on the order of 10,000 km2) and to leverage existing investments in small-scale intensive studies and in larger scale monitoring activities; hydrologic information systems to develop a comprehensive data model for integrating disparate data types, to develop the cyberinfrastructure necessary for systematic data collection and dissemination and to support community models; hydrologic measurement technology facility to broker instrumentation services from existing sources, to provide cutting edge tools along with the necessary support to use them, and to develop new hydrologic instrumentation needed to advance the science; and hydrologic synthesis center to provide a venue for hydrologic sciences from a range of disciplines to work on topics ranging from inter-observatory comparison to evolving CUAHSI's science agenda. Each of these elements has a dual role. They contribute towards the development and dissemination of the multidisciplinary data set to be collected at observatories that lies at the heart of CUAHSI activities. However, they also serve individual scientists to advance their own research by providing, respectively, access to data, a generic data model and modeling tool box, access to instrumentation at low or no cost, and access to a venue to pursue collaborative research. In this manner, CUAHSI strives to advance both its stated research agenda and to support research of individuals.

URL: http://www.cuahsi.org

H12I-02 1615h INVITED

Hydrologic Observatories: Design, Operation, and the Neuse Basin Prototype

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Hydrologic observatories are conceived as major research facilities that will be available to the full hydrologic community, to facilitate comprehensive, cross-disciplinary and multi-scale measurements necessary to address the current and next generation of critical science and management issues. A network of hydrologic observatories is proposed that both develop national comparable, multidisciplinary data sets and provide study areas to allow scientists, through their own creativity, to make scientific breakthroughs that would be impossible without the proposed observatories. The core objective of an observatory is to improve predictive understanding of the flow paths, fluxes, and residence times of water, sediment and nutrients (the "core data") across a range of spatial and temporal scales across interfaces'. To assess attainment of this objective, a benchmark will be established in the first year, and evaluated periodically. The benchmark should provide an estimate of prediction uncertainty at points in the stream across scale; the general principle is that predictive understanding must be demonstrated internal to the catchment as well as its outlet. The core data will be needed for practically any hydrologic study, yet absence of these data has been a barrier to larger scale studies in the past. However, advancement of hydrologic science facilitated by the network of hydrologic observatories is expected to focus on a set of science drivers, drawn from the major scientific questions posed by the set of NRC reports and refined into CUAHSI themes. These hypotheses will be tested at all observatories and will be used in the design to ensure the sufficiency of the data set. To make the observatories a national (and international) resource, a key aspect of the operation is the support of remote PI's. This support will include a resident staff of scientists and technicians on the order of 10 FTE's, availability of dormitory, laboratory, workshop space for all scientists, and the awarding of travel support out of observatory funds. The conflicting goals of support for a PI-designed observatory and a network of community-available observatories will be achieved by allocation of resources to assure both goals will be met. It is proposed that these resources be divided into three pools: • Core data pool. Data to be collected by the observatory PI's and staff, and where possible, augmented by existing (e.g., USGS) data collection. • Design pool. Available to support the designs of observatory PI's. • Community pool. Available to non-PI scientists to test cross-observatory hypotheses. Application of these design and operation concepts to the design of the Neuse basin prototype hydrologic observatory is briefly discussed.

H

H12I-03 1635h INVITED

Surface water, groundwater, and social science measurements in a prototype hydrologic observatory

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We convened in late April 2003 to begin work on the design for a "paper" prototype hydrologic observatory (HO) in the watershed of the Neuse estuary in North Carolina. This design example was to specify what would be measured in the HO, why, where, how, how often, and how much it would cost. This presentation focuses on aspects of the design related to stream and river measurements (discharge, water quality, fluvial geomorphology and sediment), groundwater measurements, and groundwater interaction with streams, rivers, and the estuary. Also considered is the collection of social sciences data to support multidisciplinary studies of land and water use and the consequences for flooding, water supply, and water quality. A second presentation in this session (Scanlon et al.) covers atmospheric and land surface aspects of the HO design, including recharge and ET. The design calls for measurements to quantify surface and subsurface hydrologic fluxes (water, solutes, sediment) into the Neuse estuary, and internally within the watershed at a wide range of spatial scales (about 5 orders of magnitude, roughly 0.1-10,000 square km). One hydrologic goal is to construct reliable water budgets for watersheds spanning this full range of scales, from the smallest to the full Neuse estuary watershed. A linked water quality goal is a strong quantitative characterization of the hydrologic storage and transport of nitrogen, a major water quality issue in this and many other large watersheds with major agricultural operations. Geomorphological observations will target the effects of physiographic and anthropogenic factors on rates of erosion, residence times of sediment in the fluvial system, and the role of wetlands and channel sources on the discharge of sediment and sorbed nutrients to the Neuse estuary during extreme events. Measurements will span the entire Neuse watershed but be more concentrated in a subset of 6 intermediate-size watersheds (averaging about 500 square km) that represent zones of different geology, land use, and topography within the larger watershed. We do not claim that the design is "optimal" in a rigorous statistical sense, but believe the reasoning used in the design is sound and applicable to other sites. The design and its staged implementation plan are flexible and allow the reasonably full coverage of the hydrologic cycle (and reasonable core) necessary to yield new insights and to make the HO an attractive site for individual studies.

H12I-04 1655h INVITED

Atmospheric and land surface measurements in a prototype hydrologic observatory

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Quantifying spatial and temporal variability in fluxes across interfaces and storage within reservoirs is critical for understanding the water cycle. The interfaces being considered in this presentation on the Neuse basin prototype hydrologic observatory (HO) include the land surface - atmosphere and land surface - groundwater. Critical fluxes include precipitation, infiltration, evapotranspiration and energy balance, and groundwater recharge; soil water storage in the unsaturated zone is an important determinant of flux partitioning at either interface. A companion presentation in this session (Genereux et al.) focuses on fluxes of water and solutes related to groundwater-surface water interfaces and surface water flow. The proposed measurement approach combines remote sensing and in-situ measurements to cover a wide range in spatial (1 m2 - 10,000 km2) scales. High-resolution precipitation maps will be provided by a combination of NEXRAD data and an enhanced ground-based network of rain gauges, disdrometers, and profilers. Evapotranspiration and energy balance fluxes will be monitored at several locations to characterize spatial patterns and process controls. Measurements of water content and matric potential will be co-located in the unsaturated zone to develop in situ water retention functions and to test existing pedotransfer functions for translating basic soils data to hydraulic parameters for modeling. Subsurface water fluxes in the unsaturated zone will also be estimated using newly developed fluxmeters. Co-located unsaturated and saturated zone instrumentation will be used to measure vertical and horizontal gradients to determine flux direction and to quantify fluxes using modeling. Fluxes in the unsaturated zone below the root zone may be equated to groundwater recharge. In addition, environmental tracers (tritium/helium and chlorofluorocarbons) will be measured in groundwater to estimate recharge rates. Ground-based measurements will be located in different microclimate, vegetation, land use, and soils regions to assess the relative importance of these parameters as controls on fluxes and to provide baseline data for predicting potential impacts of future climate and land use change on these fluxes. Critical parameters for hydrological modeling will be included in the measurement design. Although this prototype HO focuses on a porous media system in a humid environment, many of the design aspects are generic and should apply to HOs in other settings (fractured media, arid settings). Another goal of the program is to locate ground-based measurement stations to provide ground referencing for satellite systems. An example application is the use of satellite data (LandSat TM, AVHRR, and MODIS) to estimate ET with comparison to ground-based systems (Eddy Covariance/Bowen Ratio) and scintillometers. The use of Advanced Microwave Scanning Radiometer (AMSR-E) for monitoring soil moisture will also be evaluated using ground-based water content monitoring and field campaigns. Precipitation gauge clusters will be optimally located to evaluate NEXRAD and satellite precipitation data. Understanding the correlation between satellite and ground-based data is essential because spaceborne observations provide spatially and temporally distributed measurements and a framework for scaling local measurements to regional areas. The HO networks will provide valuable information on many aspects of the water cycle to advance our understanding on controls on spatial and temporal variability in fluxes across interfaces.

H12I-05 1715h INVITED

CUAHSI Hydrologic Information System and its role in hydrologic observatories

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The Hydrologic Information System component of CUAHSI focuses on building a hydrologic information system to support the advancement of hydrologic science. This system is intended to help with rapidly acquiring diverse geospatial and temporal hydrologic datasets, integrating them into a hydrologic data model or framework describing a region, and supporting analysis, modeling and visualization of the movement of water and the transport of constituents through that region. In addition, the system will feature interfaces for advanced technologies like knowledge discovery in databases (KDD) and also provide a comprehensive metadata description including a hydrologic ontology (HOW) for integration with the Semantic Web. The prototype region is the Neuse river basin in North Carolina. A "digital watershed" is to be built for this basin to help formulate and test the hydrologic data model at a range of spatial scales, from the scale of the whole basin down to the scale of individual experimental sites. This data model will be further developed and refined as additional hydrologic observatories are selected by CUAHSI. This will result in a consistent means for the characterization and comparison of processes in different geographic regions of the nation using a common data framework. The HIS will also provide a generalized digital library capability to manage collections of thematically-organized data from primary sources as well as derived analytical results in the form of data publications. The HIS will be designed from the beginning as an open federation of observatory-based collections that are interoperable with other data and digital library systems. The CUAHSI Hydrologic Information System project involves collaboration among several CUAHSI member institutions, with the San Diego Supercomputer Center serving as the technology partner to facilitate the development of a prototype system.

H12I-06 1730h INVITED

Implementing a Network of Hydrologic Observatories

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The Neuse prototyping effort will result in an implementation plan for a hydrologic observatory that will include • Design concepts to address both CUAHSI science drivers as well as local-interest hypotheses • The resulting data collection network, including an strategy for integration with existing activities within the basin • A coordination plan with local universities, various government agencies, and stakeholder groups (such as watershed associations to enable collection of data on private lands) • Detailed budget, including buildout strategies, capital, operating and staffing costs. • Plans to disseminate information to the community coordinated with the Hydrologic Information Science (HIS) committee, including contributions to the HIS concept of "Digital Watersheds" • Design of infrastructure to facilitate use of the observatories by individuals or groups of scientists by competitive proposal Two of the three data pools described by Reckhow et al. (this session) will be designed by this effort: the core data and the design data. Core data will be made public as soon as possible and will be subject to oversight by CUAHSI to achieve comparability of data among all observatories. The design data will be proprietary to the principal investigators for a reasonable period of time (e.g., 2 years) to permit interpretation and publication of results. The third data pool, the "network" pool, is data collected specifically to enable intersite comparisons to be made. The intersite studies will be awarded on a competitive basis once multiple observatories have been established. In the long run, we envision resources to be divided evenly among these three activities, although the proportions may shift in favor of the first two pools as observatories are being established. Once the Neuse plan has been reviewed by the community and comments have been received, CUAHSI will hold a competition to select approximately 10 additional groups to develop implementation plans at sites around the Nation. (The Neuse basin is not eligible for such an award.) Information gathered as part of these implementation plans will be used to develop additional "Digital Watersheds" in conjunction with the HIS group. This will extend and make further available detailed information on a set of regional watersheds to the hydrologic community. With the set of "Digital Watersheds" and implementation plans in hand, we envision a subsequent refinement of network objectives to enable a detailed description of how hydrologic observatories will advance hydrologic science. The entire network plan will be submitted to NSF for evaluation for possible funding in 2005.

H12J MCC: 3024 Monday 1600h

Geohydrological Modeling in Support of Litigation *(joint with PA)*

Presiding: **G F Pinder,** University of Vermont**; J F Sykes,** University of Waterloo

H12J-01 1605h INVITED

The Future of the Utility of Groundwater Models for Water Resources Management

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Groundwater models have become indispensable tools for water resources planning and management. After more than 30 years of study, however, the model calibration problem still is not resolved completely. Hydrogeologists may not have sufficient confidence in using their calibrated models for prediction and decision-making purposes. There are two major difficulties in groundwater modeling: (1) the geological structure of a real aquifer usually is very complex and unknown, and (2) the data that can be used for model calibration usually are very limited, in both quantity and quality. These two difficulties are closely interconnected during the model calibration process. A simple model structure may not be able to both fit the observed data and produce reliable predictions. On the other hand, a complex model structure may cause overparameterization when data are limited. If a model is over-parameterized, the reliability of model prediction will decrease rather than increase. It is well understood that a model that can fit the existing data well may not necessarily be a good model for prediction when it contains significant model error. This paper proposes methods that can be used to calculate the model structure error when a simplified model structure is used to replace a more complex model structure. We consider both the fitting residual as well as the model structure error for model calibration. We propose a generalized parameterization scheme for the distributed hydraulic conductivity field that can vary from a pure zone to a continuous distribution. We also suggest a method which can be used to identify a least complex model that is useful for prediction and decision-making.

H12J-02 1635h INVITED

Modeling in Support of Groundwater-Remediation Cost Allocation

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The allocation of costs for remediation among multiple potentially responsible parties (PRPs) can be addressed using a 'stand alone' method developed and applied initially to water supply problems. The variant of the stand alone approach used in an allocation case in the San Fernando Valley of California involves 1) the development of groundwater flow and transport models that reflect 1) the contributions of each of the PRPs individually and , 2) the combined effect of all parties. The allocation is then based upon the proportional impact of each PRP. The proportional cost is therefore established by taking the ratio of the plume size of each PRP divided by the overall plume size multiplied by the overall remediation costs.

H12J-03 1650h

The Toms River Childhood Cancer Cluster: Coupled Groundwater and Water Distribution System Modeling

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Toms River, New Jersey is the location of a statistically significant childhood cancer cluster. A 1995 cancer investigation indicated that relative to the state, the Toms River section of Dover Township had excess childhood cancer incidence for all malignant cancers combined, brain and central nervous system (CNS) cancers, and leukemia. Children under the age of five were found to have a seven-fold increase in brain and CNS cancer. The community's concern focused on the possibility that exposure to environmental contaminants may be related to the incidence of these childhood cancers. Two Superfund sites in Dover Township were implicated as having a possible impact on the local water supply. One of these, the Reich Farm site, is a source of contaminants to the aquifer that serves a major well field for Toms River. Contaminants in the aquifer include TCE, PCE and styrene-acrylonitrile (SAN) trimer. In 1997, the New Jersey Department of Health and Senior Services and the Agency for Toxic Substances and Disease Registry began an epidemiology study to evaluate the relationship between the environmental exposure pathways and the elevated childhood cancer incidence. Toxicity studies for the SAN trimer were also initiated. Groundwater modeling was undertaken to establish the historical relationship between the Reich Farm site and the municipal well field and to aid in the management and protection of the aquifer and well field to ensure both water quality and quantity. The modeling of the water distribution system for Toms River was also part of the study. Groundwater flow from the Reich Farm Superfund site to the municipal well field for Toms River was modeled for a thirty-year time period using MODFLOW. To account for the growth and development of the well field within the modeling domain, a transient model was constructed. The use of Geographic Information Systems (GIS) and databases to manage, maintain, and compile field observations for model input and calibration was an important part of the work. GIS and databases were important tools in assessing the quality of the data, discovering and correcting errors in the field data (including surveying inconsistencies), as well as providing an efficient and automated means to visualize the data. Model calibration exercises indicated that a more physically based spatial and temporally variable recharge was necessary to account for dramatic fluctuations in water levels due to seasonal variations. The accurate simulation of the transient groundwater flow system was essential for the subsequent prediction of contaminant migration from the superfund site to the municipal wells and then subsequently into the modeled water distribution system. The independent estimation of the adsorption parameters of the SAN trimer on the porous media of the aquifer was an important aspect of the determination of both the average travel time and the breakthrough of the chemical at the municipal well field. The modeling methodology included an uncertainty analysis of the estimated exposure concentration in the water distribution system given uncertain groundwater parameters. Distributed computing with a Monte Carlo analysis was used for this work. The results of the modeling study were used to assist in the definition of the temporal integration periods in the epidemiology study. The predicted historical breakthrough curve of the SAN trimer in the municipal wells correlates with the period with the excess childhood cancer incidence.

H12J-04 1705h

Groundwater Flow Model for Taos, New Mexico

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The New Mexico Office of the State Engineer - Hydrology Bureau (OSE) has developed a regional groundwater flow model for Taos, New Mexico. The MODFLOW 2000 model will serve as a tool to evaluate alternatives in settlement negotiations in an on-going water rights adjudication. If current settlement negotiations fail, it is conceivable that the model might be used in support of litigation. OSE produced the model in cooperation with technical representatives of the various parties to the adjudication. Regional hydrogeologic data including well records, aquifer test results, stream flow measurements and seepage studies have been shared relatively freely among the parties. A recent deep drilling program conducted in conjunction with the negotiation effort has added substantially to the hydrogeologic data set. Among the hydrologic processes simulated by the model are mountain front recharge; areal recharge from precipitation; evapotranspiration; discharge from springs; river and stream flow; accretions to groundwater from irrigation return flow, seepage from acequias, canals, and ditches, and deep percolation; and pumping by municipal entities and mutual domestic water users associations. The resulting model files are available for all parties to review and evaluate. Comments are assessed and many have resulted in significant improvements to the model. At this stage, however, it is unclear whether adopting this cooperative approach will increase the likelihood of model acceptance by the parties.

H12K MCC: 3020 Monday 1600h

Hydrogeophysics: Characterization and Monitoring of Soil Properties and Processes in the Laboratory II *(joint with NG, MR)*

Presiding: **M Prasad,** Stanford University**; X Comas,** Rutgers University

H

H12K-01 1600h

Intrinsic Anisotropy In Sediments And Its Sesimic Potential

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In this paper we present a study of intrinsic anisotropy focusing on stratification of poured sediments using Vp. We describe the experimental procedure to detect the intrinsic anisotropy with Vp in sand and glass bead samples. We then offer a method to determine textural anisotropy with the spatial autocorrelation function. In this method we use the spatial autocorrelation function and its variation with direction to characterize the stratification texture from images of the samples. To determine if there is a relation between Vp and the textural anisotropy, we compare velocity anisotropy and the spatial autocorrelation function. We find that velocity anisotropy reveals internal packing.

H12K-02 1615h

Near-Seafloor Overpressure in the Deepwater Gulf of Mexico Interpreted from Laboratory Experiments

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