SuperSting R8 marine resistivity instrument. To map coastal porewater conductivities, the EM instruments were adapted for use in shallow marine waters (< 1 meter). In such high-conductivity environments, interpretation of EM readings requires processing with layered models of terrain conductivity that include direct sampling data. Typically, nearby marine resistivity readings are necessary to distinguish between equivalent EM model solutions. Porewater conductivities estimated from the layered EM models and the resistivity-derived formation factors show very good agreement with measured pore water conductivities. The use of EM systems in very shallow waters has potential application in locating prospective submarine groundwater discharge in areas that are difficult to reach with conventional towed marine resistivity arrays. Electromagnetic and direct sampling data show that salt exclusion by mangroves significantly increases pore water conductivities, and hence terrain conductivity readings within 10m of a mangrove shoreline. Terrain conductivities fall off to background values within 15m of the mangrove shoreline. The marine EM-31 measurements were effective at sensing the magnitude and lateral extent of high and low salinity porewaters within wetlands and mangrove lined ditches and ponds, which may be useful for interdisciplinary studies of coastal ecosystems.

URL: http://gulfsci.usgs.gov/tampabay/index.html

NS31A-10 0830h POSTER

Re-evaluation of Spatial Sensitivity of Low-Induction-Number Frequency-Domain Electromagnetic-Induction Instruments: Implications for Improved Efficiency in Field Surveys

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A series of simulations were done using one-dimensional, forward numerical models to examine the sensitivity of two commonly used, low-induction-number, frequency-domain electromagnetic-induction instruments (Geonics Inc., EM31 and EM34) to spatial variations in electrical conductivity. In these simulations, a relatively thin layer whose electrical conductivity differed slightly from background was moved to successively greater depths in an otherwise homogeneous half-space. Inputs to the models reflected the fact that only certain combinations of transmitting frequency and intercoil separation are possible for each instrument. The calculated responses were converted into weighting functions, which indicate the proportion of the measured secondary electromagnetic field arising from different depth intervals. Comparisons of results from different frequency-intercoil separation combinations were made possible by normalizing the results with respect to intercoil separation. The results contradict the prevailing view of the spatial sensitivity of these instruments. Specifically, for a given electrical conductivity, the shape of the weighting function varies with the induction number. In other words, the proportion of the measured response contributed by different depths depends on the combinations of transmitting frequency and intercoil separation built into each instrument. There exist instruments in which frequency and intercoil separation can be varied more freely, and thus the vertical distribution of sensitivity can be altered to improve depth discrimination. In addition, weighting functions from horizontal and vertical magnetic dipole orientations are very similar, implying that each orientation is essentially equally sensitive to any given depth. Contrary to the previous view, the shape of both functions indicates that sensitivity peaks at the surface and declines exponentially with depth for both dipole orientations. Therefore, measurements using both orientations provide little additional information. As a result, using one dipole orientation in field surveys can yield significant savings of time and operating costs without compromising data quality and utility.

(The use of trade, product or firm names in this publication does not constitute endorsement by the U.S. Government.)

NS31A-11 0830h POSTER

Investigation of Water Migration Through the Vadose Zone of the Miami Oolite Using High-Resolution 4D Ground Penetrating Radar.

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Despite implications for groundwater vulnerability and aquifer recharge, the anatomy of vadose zone flowpaths and ponded water layers remains largely unknown. Data available at present rely either on interpolation between point measurements, or broad brush geophysical methods which lack the resolution to exactly define how or where moisture pulses migrate to the water table. Ground Penetrating Radar (GPR) has the capacity to image aquifer structure and dynamics at a sub-meter scale. However, its true potential has been restricted because conventional 2D and pseudo 3D GPR images are distorted by out-of-plane reflections and interpolation artefacts.

We present first field trials with a new full-resolution 3D radar system which allows the rapid acquisition of precisely located and repeatable radar grids, with cell size of 5-10 centimetres, over sites larger than a thousand square meters. These dense 3D volumes accurately image the complex sedimentary structure of the Miami Oolitic Limestone. Applying the new radar to hydrological investigation introduces the possibility of monitoring the migration of moisture pulses, as the system enables precise relocation of the radar antennae and repetition of surveys several times per day. As site geology remains constant, any variation in the 3D radar image is due to changes in water content. Porosity in the Miami Oolite ranges from 0.4 to over 0.6 and calculations using the Topp equation show that for this medium, radar velocities may easily halve as the moisture content approaches saturation. This gives rise to significant time-shifts even at lower saturations. In radar images, varying moisture contents are visible as both time-shifts and amplitude changes. The time-shift data indicate varying levels of rock saturation, and the amplitude changes show the locations of ponded water layers and active flow paths. Our results demonstrate that GPR is capable of monitoring both individual rainfall events and seasonal moisture variation within the Miami Oolite, at a resolution far greater than that allowed by alternative methods. Further development of this radar system and its application to groundwater investigations represents a significant advance in monitoring techniques and will lead to increased understanding of vadose zone flow.

NS33A CC: 220 C-E Wednesday 1330h

Near-Surface Geophyscis: General Session Posters *(joint with H, S, T, C, GC, PP, ED, MR)*

Presiding: **J J Daniels,** Ohio State University

NS33A-01 1330h POSTER

Exploration Depth of Multi-frequency Helicopter EM Systems

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Due to the high resolution of hilicopter electromagnetic (HEM) systems, they are being widely used for shallow earth resistivity mapping problems. The traditional investigation of the exploration depth of a HEM system is based on the model of a single-frequency coil array over a layered earth. In this paper we extend the study to the multi-frequency HEM systems. We first determine for each frequency channel of a HEM system the maximal depth of a target, beyond which it cannot be identified from the EM signal. This is mathemically realized by assuming that the abnormal signal from the target is three times larger than the noise level of the HEM channel. Since each frequency channel of an HEM system has a different noise level and for different frequency channel the EM field has different penetration depth, we choose the biggest value of these depths as the depth of exploration.

Different models are implemented in the study of this paper, including a layered earth model, a dipping plate or a dyke, a 3D ore body, etc. We use as example the Fugro DIGHEM system with three horizontal coplanar (HCP) coils (380 or 900, 7200, 56kHz) and two vertical coaxial (VCX) coils (900, 5500Hz). The following conclusions are obtained:

1. Except for a steeply dipping sheet, the HCP coil array has a larger depth of exploration than the VCX coil array;

2. The depth of exploration may be obtained from different frequency channels for different target geometries and different conductivity contrasts between the target and host rocks. This means that for a specific target geometry and conductivity contrast, we need to search such a frequency channel that offers the maximal value for depth of exploration;

3. Among the factors that influence the depth of exploration, the noise level of the HEM system is the key. The other factors include the geometry of the target and the conductivity contrast between the target and the host rocks, and the relative location between the HEM system and the target;

4. We have assumed in this paper three times the noise level as the threshold in defining the depth of exploration of a HEM system. If the HEM data have a high quality, e.g. with good system calibration and data processing, this factor might be reduced, so that the depth of exploration can be greatly improved.

NS33A-02 1330h POSTER

Effect of Electrode Position Errors on Electrical Resistivity Tomography Data

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The electrical resistivity tomography (ERT) method has proven to be a valuable geophysical tool for a variety of shallow subsurface imaging tasks such as contaminant monitoring, fracture detection and moisture content mapping. Inversion artifacts are features of the tomographic image that are not attributable to the actual subsurface material properties. Limitations of tomographic imaging arise due to the difficulty of quantifying the origin of these artifacts and, thus, the reliability of tomographic images. Environmental and engineering geophysical surveys are often such that target sizes or the scale of heterogeneity may be of the same order of scale as the experiment dimensions. At these small scales, errors in electrode positions may significantly contaminate ERT data and artifacts may populate large portions of the tomographic volume. Variations in the data due to errors in source and/or receiver coordinates may overwhelm variations in the data due to changes in material properties. The dependence of the data on electrode mislocations is characterized by the sensitivity of electrical potential to both source and receiver positions. Analytical sensitivities and synthetic forward models are used to investigate the effect of electrode position errors on ERT data. In the homogeneous case, the sensitivities of potential with respect to source/receiver positions are purely geometrical and dependent on the electrode-electrode separation according to a inverse squared-distance relationship. The homogeneous sensitivities illustrate the robustness with respect to position errors of different data types (pole vs. dipole) and different electrode geometries (cross-hole vs. common-hole). In the heterogeneous case, the sensitivities of potential with respect to source/receiver positions are described by scattering-type equations and thus, magnitudes of the sensitivities depend not only on electrode-electrode separation but also electrode-heterogeneity separation. Accordingly, for surveys in which electrodes may be close to the target, sensitivities to source/receiver positions can be high; corresponding data errors can significantly exceed measurement precision. Furthermore, for a given electrode pair, the sensitivities to source/receiver positions are asymmetrical and the sensitivity to receiver position is equal to the sensitivity to source position for the reciprocal electrode arrangement. The implication is that, in a inverse paradigm, only the relative source-receiver location error will be determined for a given electrode pair. Multiple electrode combinations may alleviate this problem. Finally, while results are specific to the ERT problem, the general methodology is applicable to other types of geophysical data that may be contaminated by source/receiver position errors.

NS33A-03 1330h POSTER

Characterization of Shallow Subsurface Electrical Conductivity Features and Heterogeneity Using Wavelet Analysis and Geostatistics

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Depositional and geochemical processes act on multiple spatial scales and time scales. As a result, variations in geological field properties are often non-stationary in space and scale. An adequate understand-

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ing of the behavior of this complex heterogeneity is critical when modeling or conducting site characterization, especially when analyzing field variables derived from experiments with different sample volumes.

An extensive geophysical field campaign was carried out at the St. Denis National Wildlife Area in order to characterize the heterogeneity in electrical conductivity near a small wetland. The near-surface geology at the wetlands within the St. Denis Wildlife Area typically shows evidence of salt-cycling as a result of depression-focused recharge. Salts beneath the wetlands are leached and are subsequently concentrated in the nearby uplands. Electrical conductivity data were collected using 3-D electrical resistivity imaging (ERI) and a series of 70 direct-push conductivity (DPC) profiles, collected along two perpendicular transects. The DPC profiling characterizes small-scale (cm^3-scale) electrical conductivity features while the ERI provides larger scale (m^3-scale) bulk measurements. We first explore the depth-scale properties of the electrical conductivity data by partitioning the variance in the DPC data by scale and location using wavelet analysis. We further explore how the DPC depth-scale components extracted by wavelet analysis can be related to the results obtained through ERI. Conventional geostatistics for both the ERI and DPC data sets are also examined to further characterize the local heterogeneity.

NS33A-04 1330h POSTER

Surface Conduction in Rock at Low Temperature

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Frozen rock exhibits anomalous conduction in that the conductivity is often greater than would be expected from simply substituting ice resistivity for pore water resistivity. Furthermore, the change in conductivity does not occur at 0^oC but may be spread out over several degree or tens of degree. Several different mechanisms are probably responsible for this behaviour. One that has often been proposed is that the electric double layer is prevented from freezing by the strong electric fields that are present within it. Thus, ion mobility in the electric double layer remains high and surface conduction still contributes to conductivity even if the bulk pore water is frozen. In this work, the Gouy-Chapman theory is used to show that, at least for minerals with high cation exchange capacity, the electric field near the pore wall is large enough to polarize water and that a threshold potential, or equivalently threshold cation exchange capacity, exists below which polarization is not possible. Critical questions are; Can the threshold potential be confirmed by measurement? Is there evidence that polarization can inhibit freezing? Is there a critical temperature below which electrical polarization is not effective in preventing freezing? Experimental work with frozen electrodes confirms the existence of a threshold potential and suggests that the electric double layer can remain unfrozen for at least a few degrees below 0^oC.

NS33A-05 1330h POSTER

Geophysical Investigation of Lateral Spread Features at Crowley's Ridge, Helena, Arkansas

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Geophysical investigations were conducted along suspected lateral spread features in the southern portion of Crowley's Ridge near Helena, Arkansas. The ridge was affected by a series of earthquakes that occurred along the New Madrid Seismic Zone (NMSZ) in southeastern Missouri from December 1811 through early 1812. Due to the sparse population density in the vicinity of Crowley's Ridge in the early 1800s, the geomorphologic effects of these earthquakes on the ridge are widely unknown. Population density and the number of larger structures near the NMSZ have greatly increased in the past 100 years. Understanding geomorphologic processes caused by the 1811 and 1812 earthquakes is key to assessing risk and safety for the current structures and population that may be affected by the recurrence of seismic activities. The purpose of the geophysical investigation was to confirm the presence of lateral spread features identified from previous geomorphologic mapping.

The geophysical data were able to image the contacts between surficial loess, underlain by discontinuous sand and gravel, underlain by clay. The discontinuity of the sand and gravel layer is consistent with past lateral spread studies that suggest that the sand and gravel liquefied and rafted the loess overburden.

The existence of lateral spread features along a smaller ridge such as Crowley's Ridge shows that these features occur on a much smaller scale than previously suggested. Using geophysics to locate and delineate these spread features will aid in the understanding of lateral spreads, and may assist in predicting where future spreads may occur.

NS33A-06 1330h POSTER

2-D Traveltime Inversion of Near Surface Refractions and Reflections in Support of Hydrological Studies: Utikuma Lake Region, Northern Alberta

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In July 2001 two seismic refraction lines (720 meters and 216 meters, respectively) were acquired in the Utikuma Lake region, northern Alberta in support of a hydrological study. of the groundwater flow between several small lakes. Shallow wellbores were drilled to depths of 20 m but aside from missing deeper formations were not sufficiently dense to provide for good measures of stratigraphic continuity over the site. A weight drop source was used to activate a static array of 240 14-Hz geophone singles spaced at 3-metres. Standard seismic reflection processing (filtering, static corrections, velocity analysis, depth migration) was not able to provide detailed structural information about the first 100 meters although below this depth the bedrock stratigraphy is apparent to 500 ms. Consequently, a travel-time inversion technique was employed to provide additional structural information. First break times and up to four distinct reflector times were picked and inverted using a well-known ray-based inversion method. In the main line, 19608 clean travel-times were picked from the 56 high quality shot gathers for use in the inversion. The final inverted model consists of 5 layers. The surface is represented by the x,z coordinates of the 56 shot locations (spacing 12 m) The weathering layer varies in thickness between 2 and 10 meters, and velocity changes horizontally between 0.25 and 0.47 km/s. The second layer required that velocity decrease with depth from 1.85 km/s to 1.55 km/s, this agrees well with the saturated horizon, this information allowed the hydrological models to be updated for simulations. Layer 3 is 8 m in thickness and consists of till (1.65 km/s). The model further required two additional layers with thicknesses of 16 m and 10 m and velocities of 1.8 km/s and 2.0 km/s, respectively. The bedrock appears to be at approx. 65 meters depth in agreement with additional information for this area.

NS33A-07 1330h POSTER

Electrical Conductivity Imaging Using Controlled Source Electromagnetics for Subsurface Characterization

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Controlled Source Audio-Frequency Magnetotellurics (CSAMT) is a frequency domain electromagnetic (EM) sounding technique. CSAMT typically uses a grounded horizontal electric dipole approximately one to two kilometers in length as a source. Measurements of electric and magnetic field components are made at stations located ideally at least four skin depths away from the transmitter to approximate plane wave characteristics of the source. Data are acquired in a broad band frequency range that is sampled logarithmically from 0.1 Hz to 10 kHz.

The usefulness of CSAMT soundings is to detect and map resistivity contrasts in the top two to three km of the Earth's surface. Some practical applications that CSAMT soundings have been used for include mapping ground water resources; mineral/precious metals exploration; geothermal reservoir mapping and monitoring; petroleum exploration; and geotechnical investigations. Higher frequency data can be used to image shallow features and lower frequency data are sensitive to deeper structures.

We have a 3D CSAMT data set consisting of phase and amplitude measurements of the Ex and Hy components of the electric and magnetic fields respectively. The survey area is approximately 3 X 5 km. Receiver stations are situated 50 meters apart along a total of 13 lines with 8 lines bearing approximately N60E and the remainder of the lines oriented orthogonal to these 8 lines. We use an unconstrained Gauss-Newton method with positivity to invert the data. Inversion results will consist of conductivity versus depth profiles beneath each receiver station. These 1D profiles will be combined into a 3D subsurface conductivity image. We will include our interpretation of the subsurface conductivity structure and quantify the uncertainties associated with this interpretation.

NS33A-08 1330h POSTER

Natural Methane and Carbon Dioxide Hydrates in the Earth System

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Both CH4 and CO2 are abundant volatiles in the earth's crust. Methane hydrates occur in permafrost regions and continental slopes of oceans. It is currently estimated that the energy stored in CH4 hydrate reserves totals more than twice the global reserves of all conventional oil, gas, and coal deposits combined. This means that methane hydrate could prove to be a very important source of energy in the future. Pressure versus temperature phase diagrams for methane and carbon dioxide define characteristic stability fields for gas, fluid and hydrates states.

Sequestration of carbon dioxide in the earths crust and production of methane hydrate reservoirs are critically dependent on knowledge of the in situ elastic moduli of natural hydrates. The physical properties of simple methane and carbon dioxide hydrates are similar [1]. Our compilation of experimental data confirms high compressional wave velocities and elastic moduli for CH4 and CO2 hydrates and low compressional wave velocities for the fluid and gas phases. As methane and carbon dioxide hydrates are stable over similar pressure-temperature ranges, the two types of hydrates form in similar settings in the earth's crust. For example, temperature and pressure conditions in deepwater marine environments require both CO2 and CH4 to be in hydrate phase. However, not much is known about the origin, distribution and total volume of natural carbon dioxide hydrates stored in the earth's crust. For a number of tectonic/geological settings, CO2-rich fluids from deep crustal reservoirs must be considered: rifted margins, volcanic arcs, deepwater vents [2], mud volcanoes and mud diapirs [3]. Both methane and carbon dioxide hydrates work to cement sea floors in similar ways. Slope failure, a phenomenon usually taken as a hallmark of the presence of methane hydrate, could also be attributed to the existence of carbon dioxide hydrates. Perhaps most critically, many of the estimations of the amounts of methane hydrates are based on seismic imaging. However, since carbon dioxide hydrate can also form gas traps and subsequently bottom simulating reflections (a prime indicator of methane hydrate reserves), we speculate that some of the global estimated methane hydrate may in fact be natural carbon dioxide hydrate.

References: [1] Sivaraman, R., Gas TIPS, 9, 4-7, 2003;[2] Sakai, H. et al., Science, 248, 1093-1096, 1990; [3] Mueller, C. et al., World Oil, 222, 60-67, 2001

NS33A-09 1330h POSTER

Monitoring Groundwater Aquifer by Geoelectrical Prospecting

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An advanced geoelectrical technique has been developed for monitoring groundwater aquifer with increase demands for groundwater in coastal areas. Three geoelectrical methods of monitoring groundwater resources has been developed to evaluate contamination of aquifers against sea water intrusion. The transion zone from the fresh groundwater to sea water were evaluated by a sharp boundary as salt-water wedges from the resistivity sections derived from the two-dimensional inversion and three dimensional subsurface structures in a coastal plane. Results of transient

electromahnetic mathod was also compared with verical electric soundings with Schlumberger array. It is concluded that VES survey are a quite effective geophysical method for both a long-term and a short-term monitoring of groundwater contamination. It was also confirmed that 4-D geoelectrical techniques using a personal computer that the fluid-flow behaviour in a groundwater auifer could be continuously imaged with a function of time using a time series data of streaming potential measurement.

URL: http://www.agu.org

NS33A-10 1330h POSTER

Fault Activity Investigations in the Lower Tagus Valley (Portugal) With Seismic and Geoelectric Methods

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The Lower Tagus River Valley is located in Central Portugal, and includes a large portion of the densely populated area of Lisbon. It is sited in the Lower Tagus Cenozoic Basin, a tectonic depression where up to 2,000 m of Cenozoic sediments are preserved, which was developed in the Neogene as a compressive foredeep basin related to tectonic inversion of former Mesozoic extensional structures. It is only a few hundred kilometers distant from the Eurasia-Africa plate boundary, and is characterized by a moderate seismicity presenting a diffuse pattern, with historical earthquakes having caused serious damage, loss of lives and economical problems.

It has therefore been the target of several seismic hazard studies in which extensive geological and geophysical research was carried out on several geological structures. This work focuses on the application of seismic and geoelectric methods to investigate an important NW-SE trending normal fault detected on deep oil-industry seismic reflection profiles in the Tagus Cenozoic Basin. In these seismic sections this fault clearly offsets horizons that are ascribed to the Upper Miocene. However, due to the poor near surface resolution of the seismic data and the fact that the fault is hidden under the recent alluvial cover of the Tagus River, it was not clear whether it displaced the upper sediments of Holocene age.

In order to constrain the fault geometry and kinematics and to evaluate its recent tectonic activity, a few high-resolution seismic reflection profiles were acquired and refraction interpretation of the reflection data was performed. Some vertical electrical soundings were also carried out. A complex fault system was detected, apparently with normal and reverse faulting. The collected data strongly supports the possibility that one of the detected faults affects the uppermost Neogene sediments and very probably the Holocene alluvial sediments of the Tagus River. The evidence of recent activity on this fault, its length (at least 10 km), location in an area with significant historical seismicity, and proximity to Lisbon and other small towns, all indicate that it represents a serious hazard to the study region and so should be considered in the regional seismic hazard evalution.

NS33A-11 1330h POSTER

Prediction of Strong Earthquake Ground Motion for the M=7.4 and M=7.2 1999, Turkey Earthquakes based upon Geological Structure Modeling and Local Earthquake Recordings

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We test a means to predict strong ground motion using the Mw=7.4 and Mw=7.2 1999 Izmit and Duzce, Turkey earthquakes. We generate 100 rupture scenarios for each earthquake, constrained by a prior knowledge, and use these to synthesize strong ground motion and make the prediction. Ground motion is synthesized with the representation relation using impulsive point source Green's functions and synthetic source models. We synthesize the earthquakes from DC to 25 Hz. We demonstrate how to incorporate this approach into standard probabilistic seismic hazard analyses (PSHA).

The synthesis of earthquakes is based upon analysis of over 3,000 aftershocks recorded by several seismic networks. The analysis provides source parameters of the aftershocks; records available for use as empirical Green's functions; and a three-dimensional velocity structure from tomographic inversion. The velocity model is linked to a finite difference wave propagation code (E3D, Larsen 1998) to generate synthetic Green's functions (DC $< f <$ 0.5 Hz). We performed the simultaneous inversion for hypocenter locations and three-dimensional P-wave velocity structure of the Marmara region using SIMULPS14 along with 2,500 events. We also obtained source moment and corner frequency and individual station attenuation parameter estimates for over 500 events by performing a simultaneous inversion to fit these parameters with a Brune source model. We used the results of the source inversion to deconvolve out a Brune model from small to moderate size earthquake (M<4.0) recordings to obtain empirical Green's functions for the higher frequency range of ground motion (0.5 $< f <$ 25.0 Hz).

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NS33A-12 1330h POSTER

Artificial Neural Network Prediction of Soil Swelling/Shrinking

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An artificial neural network (ANN) is used to predict structural movement at a specific site using available soil data at the site and in the vicinity. ANNs are data-driven computational tools that map data inputs, such as moisture content and shrink/swell properties of soils, to desired outputs, such as soil displacement. The performance of the ANN is evaluated by comparing its predictions to observed structural movement. Although the back-propagation algorithm is the most commonly used training technique for ANNs, it is not always the most efficient. Other ANN architechtures, based on generalized regression and counter-propagation algorithms are more efficient for some problems, and are tested for this problem.

NS33A-13 1330h POSTER

Delimitation of Superficial Cracking Risk Zones Using Gravity Data and Finite Element Modeling in the Quertaro Graben, Mxico

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At the beginning of the 80s it was observed soil cracking and fissuring in the Valley of Queretaro damaging civil constructions and buildings along its path. Since then the phenomenon has evolved into three main fissure systems distributed in an area of nearly 40 km2. The surge of soil cracks is associated to the intense extraction regime of ground water occurring in the basin, where the saturated soil mass has a high consolidation potential and is sitting on top of an irregular non-compressible unit with low consolidation potential.

In urban areas, soil fissuring is responsible of extended damage to paved roads, houses and in general to civil infrastructure. As soil faulting is related to differential consolidation rates between two adjacent blocks with uneven thickness, buried fuel pipelines are also prone to suffer damage across fissure zones with the consequent hazard for the environment including ground water pollution.

In principle, soil fissures increase the efficiency of rainwater infiltration, which is of benefit for aquifer recharge. However, in urban areas, soil fissures are potentially hazardous zones as these may work as conduits carrying pollutants towards local aquifer systems when domestic and industrial waste water are directly discharged into them. Also, in many cases large fissures surrounding urban zones are used as solid waste dumps. The infiltrated fluids that result from the chemical decomposition of solid waste rapidly percolates to water table depths through more permeable fissured ground reducing the residence time and therefore carrying more pollutants directly to the ground water.

For these reasons it is important not only to make a catalogue of the existing fissuring zones within the valley but also to develop appropriate tools to predict accurately the zones where future soil faulting may occur under actual ground water extraction regimes. This is required to evaluate critical hazardous points for environmental purposes as well as for planning new urban developments to minimize the risk of damaging houses and buildings. Some ground fissure systems outside the urban area could even be used to stabilize the ongoing depletion of the aquifer system through artificial recharge for which it is important to understand the process that generate them.

In this research work we show the usefulness of micro-gravity studies to define zones where the ground is under tensional forces by means of the inversion of field curves and through the analysis of their horizontal gradient. Then a stress analysis is implemented using finite element approach to identify zones of maximum horizontal tension fed with geological sections interpreted from gravity and well data. Maximum gravity gradients correlate with anomalous large tensional stresses, which allow us to locate zones of ground weakness, i.e. zones where no ground fissures have yet appeared but that are prone to develop.

NS33A-14 1330h POSTER

3D Seismic and Magnetic characterization of the Borax Lake Hydrothermal System in the Alvord Desert, southeastern Oregon.

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As part of an interdisciplinary project aiming to study the link between the physical characteristics of hydrothermal systems and biota that occupy those systems, we are conducting a detailed geophysical characterization of an active hydrothermal system. The Borax Lake Hydrothermal System (BLHS), consisting of Borax Lake and the surrounding hot springs. BLHS is located near the center of the Alvord Basin in southeastern Oregon. The Alvord Basin is a north-south trending graben in the Northern Great Basin bounded by the Steens Mountains to the west and the Trout Creek Mountains to the east. We conducted a 2D seismic survey to characterize the geologic structure of the basin, a high-resolution 3D seismic survey to characterize the geologic structure of the BLHS, and a high-resolution 3D magnetic survey to characterize any lineaments in the bedrock that might control fluid flow in the BLHS. Previous results from the 2D seismic survey show a mid-basin basement high aligned approximately with the hot springs. In this study we present the results from the high-resolution 3D seismic and magnetic survey of the BLHS. We acquired the 3D seismic data using an SKS rifle and 240 channel recording system. The seismic survey covers approximately 90,000 sq. m with a maximum inline offset aperture of 225 m, crossline aperture of 75 m, and 360 degree azimuthal coverage. The coincidental magnetic survey was collected using a Geometrics 858G cesium vapor magnetometer. We designed both surveys to span nearly 100 active hydrothermal springs, including an approximately 50 m stepover in the trend of the surface expression of the hot springs.

After preliminary processing, the 3D seismic data show continuous reflections up to 300 ms (480 m). The initial interpretation of features seen in the 3D data cube include: normal faults dipping to the east and west, near-surface disturbances that are consistent with the trend of the hot springs, and significant near surface velocity anomalies throughout the survey area. Time slices through the 3D seismic cube show evidence of semi-continuous linear features consistent with the trend of the hot springs. A large scale inversion has been performed on the magnetic data. The fit to the observed data is good given the noise assumption of 3

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nT. After more extensive processing, we will compare structures in the inverted magnetic model with features in the seismic data and explore the connection between the subsurface geology and the surface geometry of the hot springs.

NS33A-15 1330h POSTER

Economical 3D Resistivity Surveys with Non-Linear Configurations and Neural Networks

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Electrical resistivity surveys traditionally have been conducted with linear arrays, with electrodes evenly spaced. Three-dimensional surveys require the placement of parallel lines. Large-scale surveys of this type are costly to conduct in the field and to interpret. Often, it would be desirable to place electrodes in non-linear configurations, with the geometry customized to the situation in the field. For instance, a circular depression or object could be surveyed with a circular electrode configuration. Non-linear configurations pose special problems in interpretation. However, with the use of neural networks, these difficulties may be overcome, offering three-dimensional resistivity profiles at lower cost than is possible with traditional methods.

NS41A CC: 516 B Thursday 0830h

Near-Surface Geophysics: Evaluation and Management of Water Resources II *(joint with H, GC, PP, ED)*

Presiding: **R Knight,** Stanford University**; C Darnault,** Environmental Engineering and Technology, Inc.

NS41A-01 0830h

An integrated hydrogeological and hydrogeophysical characterization of potential saltwater intrusion pathways in a fractured aquifer

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Fractures and fracture zones exert strong controls on groundwater flow regimes. Fractures are often more hydraulically conductive than the surrounding host rock; however, not all fractures are open to fluid flow. The hydraulic properties of fractured media differ with fracture aperture, intensity, orientation, connectivity and infill material. The interrelationship of any or all of these factors often causes fractured systems to be hydraulically anisotropic. Moreover, the scale of fracture flow varies from the local scale of individual fractures to the regional fracture zone scale. Characterization of fractured systems is both critical and difficult because flow and transport paths are complex. In this study, 2-D electrical resistivity imaging (ERI), 3-D ERI, fracture mapping and hydrogeological results were integrated to characterize a fracture system on Saturna Island, British Columbia, Canada. Bedrock consists of sandstone-dominant and mudstone-dominant formations with interbedded zones of mudstone and sandstone at formation boundaries. The presence of bedding plane fractures, joints, and faults suggest fracturing at a variety of scales. The geophysical results are consistent with local (outcrop) geology and previous (hydrostratigraphic and hydrostructural) conceptualizations. The images show a distinction between overburden, sandstone-dominant and mudstone-dominant units and the presence of fractured zones. However, discrete fractures were not identified using ERI. Consequently, under some geologic conditions it is possible to use ERI to constrain the aquifer architecture for groundwater models at a regional and sub-regional scale. In this particular fractured setting, ERI may be useful for identifying permeable pathways for saltwater intrusion, which may be associated with fracture zones.

NS41A-02 0835h

The use of electrical resistivity methods to investigate anisotropy in a fractured groundwater system

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The hydraulic properties of fractured media differ with fracture aperture, intensity, orientation, connectivity and infill material. The interrelationship of any or all of these factors often causes fractured systems to be anisotropic. That is, the hydraulic properties of the system differ with orientation. Electrical resistivity, azimuthal and square array techniques have been used to characterize and quantify the electrical anisotropy. Often, the principal direction of electrical anisotropy is interpreted to be coincident with the principal direction of hydraulic anisotropy because of the similarity between Ohms law and Darcys law (Watson and Barker, 1999); however, a quantitative relationship between the two has not yet been developed. In this study, azimuthal and square array resistivity surveys were conducted to investigate the electrical anisotropy in a fractured aquifer on Saturna Island, British Columbia, Canada. The results of a 3-D resistivity survey produced a 3-D resistivity model of the subsurface. Offset error analysis and forward resistivity modeling were used to investigate if the anisotropic response was the result of fracturing or heterogeneities. Both offset error analyses and forward modeling indicated that the anisotropic response could be explained by relatively simple subsurface heterogeneities associated with the geology in the vicinity of a fault. If electrical anisotropy due to the fracture system orientation exists, it appears to play a secondary role in the azimuthal array response compared to geologic structure. In this geologic setting, if offset error analyses and forward modeling were not completed the electric and hydraulic anisotropy could have been incorrectly interpreted. Therefore, anisotropy results should not be interpreted without considering variations in resistivity due to subsurface heterogeneities.

Watson, K.A. and Barker, R.D. (1999). "Differentiating anisotropy and lateral effects using azimuthal resistivity offset Wenner soundings." Geophysics 64(3): 739-745.

NS41A-03 0840h

Groundwater depletion in a heavily irrigated watershed in southern India: detailed assessment using MRS and ERT (CEFIPRA Project 2700-W1)

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The stress on groundwater resources due to the pumping of large quantities of water threatens the sustainability of agricultural development. This is a main issue for hot and dry areas such as central and southern India. In this fractured crystalline context, the aquifer is shared between a capacitive part corresponding to the weathered cover and a transmissive part corresponding to fractures in the basement. At the 60 km2 Maheshwaram catchment, (Andhra Pradesh, India); since 1985, irrigated surfaces have been increased by a factor of 3, from 0.7 to 2 km2 out of a total cultivated area of 18 km2, the number of pumping wells have increased from 10 to almost 800, and the mean ground water table level have deepened by about 8m drying up the entire capacitive part of the aquifer. Computations of the groundwater balance at watershed scale between 2001 and 2002 still showed a depletion of an average of 1.2m in spite of a regular monsoon (600 mm of rainfalls).

Electrical resistivity tomography (ERT) and magnetic resonance soundings (MRS) were undertaken in a heavily irrigated area in order to characterize the water content in the subsurface. The present study compares the findings of investigations carried out in November 1999 and December 2003. Both periods belong to post monsoon season when the water level is high. The free water content estimated by MRS in 1999 was about 5% in the capacitive part of the aquifer. In 2003, no free water is detected (NMR signal level is less than the instrumental noise of 5 nV). Comparisons between ERT inverted 2D sections located at the same place shows a significant 10 to 30% mean increase of resistivity in the 5-15 m depth range. Laboratory tests of resistivity variations versus water content on small weathered material cores indicates that such variations correspond to a drastic de-saturation of the porous network. Furthermore, the resistivity variations in this capacitive part of the aquifer are inhomogeneous; the larger variations may indicate sandy bodies of the weathered materials and so drying of interesting water bearing structures. Sub-vertical anomalies through the crystalline basement, interpreted as infiltration structures, have also become more resistive indicating a high drying up and a major modification of their hydraulic behaviour.

The combined interpretation of ERT and MRS methods allows to assess in detail groundwater depletion. In the Maheshwaram case presented here, it shows that at the end of the rainy season, the capacitive part of the aquifer, i.e the weathered zone, does not present any significant recharge. As a matter of fact, the sustainability of the agricultural development in this area is threatened by clear over exploitation of the groundwater resources.

NS41A-04 0845h

A Laboratory Study of Heterogeneity and Scaling in Geologic Media

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In rocks and soils, the bulk geophysical and transport properties of the matrix and of fracture systems are determined by the juxtaposition of geometric features at many length scales. For sedimentary materials the length scales are: the pore scale (irregularities in grain surface roughness and cementation), the scale of grain packing faults (and the resulting correlated porosity structures), the scale dominated by sorting or winnowing due to depositional processes, and the scale of geomorphology at the time of deposition.

We are studying the heterogeneity and anisotropy in geometry, permeability, and geophysical response from the pore (microscopic), laboratory (mesoscopic), and backyard field (macroscopic) scales. In turn these data are being described and synthesized for development of mathematical models. Eventually, we will perform parameter studies to explore these models in the context of transport in the vadose and saturated zones.

We have developed a multi-probe physical properties scanner which allows for the mapping of geophysical properties on a slabbed sample or core. This device allows for detailed study of heterogeneity at those length scales most difficult to quantify using standard field and laboratory practices. The measurement head consists of a variety of probes designed to make local measurements of various properties, including: gas permeability, acoustic velocities (compressional and shear), complex electrical impedance (4 electrode, wide frequency coverage), and ultrasonic reflection (ultrasonic impedance and permeability). We can thus routinely generate detailed geophysical maps of a particular sample. We are testing and modifying these probes as necessary for use on soil samples.

As a baseline study we have been characterizing the heterogeneity of a bench-size Berea sandstone block. Berea Sandstone has long been regarded as a laboratory standard in rock properties studies, owing to its uniformity and "typical" physical properties. We find that both permeability and velocity exhibit complex heterogeneity at the centimeter scale. While some correlation with the outcropping of the bedding is apparent, much of the heterogeneity is not clearly associated with visual features.

For the study of soil heterogeneity at a wide range of scales, we are focusing on a local glacial deposit. This deposit is a glacial kame terrace of fluvial origin with multi-scale sedimentary structures comprised of unconsolidated sands, clays, and gravels. There are also many joints and faults in the unconsolidated sediments, allowing study of these as potential fluid flow conduits or barriers. We have obtained undisturbed soil samples from this site, allowing detailed laboratory study using similar methods to those described for the sandstone block.