seismic compressional wave impedances between zones saturated with ice, with liquid brine, and with free gas can be significant. Local variations in saturation may provide the impedance differences necessary to produce these small scale seismic bright spots.

URL: http://www-geo.phys.ualberta.ca/~doug

NS14A-05 1630h

High-Resolution Seismic Imaging of the Chesapeake Bay Impact Inner Crater Rim Stratigraphy

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Results from a high-resolution seismic reflection experiment across the inner crater rim of the Chesapeake Bay Impact Crater (CBIC) will be presented. This crater is the seventh largest impact crater on Earth, formed during the Late Eocene when a meteorite struck the eastern continental shelf of North America. Although the impact structure is exceptionally well preserved, it is buried by about 500 m of post-impact deposits and cannot therefore be studied directly. The objective of this project was to image the transition from the inner to outer crater of the CBIC and to study the effect of the impact on the pre-impact stratigraphy and post-impact deposition on the continental shelf.

About 3.4 km of seismic reflection data were collected in 3 profiles near Exmore, Virginia. One profile was acquired using a 120-geophone array at 5 m spacing. The other 2 profiles were collected using 24 channels at 10 m spacing. The source was a Betsy seisgun and sensors were 40-Hz geophones. Data were processed using Globe Claritas software. The resulting seismic sections show continuous and strong reflections down to 400-500 ms. These reflections show the post-impact stratigraphy, with a strong reflection from the top of the Chickahominy Formation at about 400 ms. Reflections from the syn-impact section are discontinous with significant scattering. Processing, as yet, has been unable to bring out any basement reflections.

NS14A-06 1645h

Integrating High-Resolution Geophysical Technologies with a GIS-Based Decision Support System into Evaluation and Management of Wetlands

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Wetlands perform many ecological functions and provide numerous societal benefits such as providing unique wildlife habitats, natural mechanisms for water purification, flood storage, recreational opportunities and natural resources. Geophysical technologies are increasingly used on land for environmental assessment. However, geophysical evaluation of wetlands has received minimal attention. The problems associated with conventional direct sampling of subsurface properties are exasperated in shallow water wetlands due to the logistical constraints imposed by these environments. Growing interest in wetlands highlights a need for high-resolution, non-invasive methods for evaluating and managing wetland water resources.

We have developed an integrated geophysical-GIS approach to investigating shallow water wetlands. Rapid geophysical data acquisition in shallow water (less than 2 ft) is achieved using a plastic paddle-boat modified as a research vessel for conducting high-resolution geophysical surveys. The vessel is designed for reconnaissance electromagnetic terrain conductivity (TC), reconnaissance gradiometer and 2D/3D continuous electrical resistivity imaging. A buoyant 12-electrode array, using non-polarizing Pb-PbCl2 junctions, is pulled behind the boat with simultaneous measurement of 10 resistances at two-second intervals using a SYSCAL PRO acquisition system. All instrumentation was tested and modified to ensure removal of artifacts caused by the metal steering mechanism. A multi-purpose surface water quality probe simultaneously records water depth, surface water conductivity, salinity, temperature, pH, turbidity, and dissolved oxygen content. All instruments are set to take a multi parameter measurement every two seconds while paddling. Decimeter scale location of all measurements is obtained at the instant of acquisition using precision differential GPS unit. We are typically able to survey an average of 8 km in one day, producing over 6,000 measurements.

A GIS framework is used as a database for visualization. The system manages raster images, satellite and aerial photos, land use zonation, topography and spatial data. We have initiated wetland geophysical studies in the Hackensack Meadowlands of northern New Jersey. Our first study focused on Kearny Marsh, a unique freshwater wetland ecosystem situated within a highly industrialized part of the Hackensack Meadowlands of northern New Jersey, connected to the New York Harbor. Surface water quality and ecosystem health are threatened by runoff from landfills, runoff from industrial facilities and major highways, as well as a tidal connection to brackish water. Extensive geophysical surveys show that (1) the tidal connection to brackish water located east of the marsh exerts the primary control on water quality and (2) degradation of surface water quality from peripheral landfills is not as problematic as previously inferred from spatially limited direct sampling strategies.

NS22A CC: 516 B Tuesday 1030h

Near-Surface Geophysics: General Session *(joint with G, GP, H, S, T, C, GC, PP, MR)*

Presiding: **K Holliger,** Swiss Federal Institute of Technology**; J Ajo-Franklyn,** Stanford University

NS22A-01 1030h

New geological and geophysical antecedents at the Monturaqui Impact Crater, Chile

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Impact structures are a common and important landform on planetary surfaces. Currently there are 168 confirmed impact structures in the Earth [1]. Out of those, the Monturaqui crater (<400 m diameter, 0.1 Ma [2]), located in the north of Chile, represents a grand opportunity for a detailed study of simple impact craters: it is accessible, well preserved and exposed. In December 2003 a field expedition accomplished detailed geological and geophysical mapping on it. The geology of the Monturaqui area is characterized by a basement of Paleozoic granites overlain by Pliocene ignimbrite units [3]. The granite outcrops mostly at the higher terrain in the crater rim, while the ignimbrites outcrop at lower levels filling the crater. Gravity, magnetic, differential GPS surveying and geological mapping built a detailed dataset of the crater. From the DGPS survey, its dimensions are 370 m EW, 350 m NS, and ~34 m deep. In the centre it has an uplift of 3 m approx, coincident with lime sediments. The northern edge of the crater exhibits magnetic anomalies with inverted polarization, presumably due to magnetic remanence. This could have been caused by post-impact alteration [4]. The Bouguer gravity anomaly shows a negative anomaly of ~1mGal at the centre, associated with fracturing and brecciation of the target rocks. Due to its lower competence than the granite, the shock wave fractured the ignimbrite instead of deforming it, building the regolith that presently fills the crater. Then the shock wave melted the basement locally. Breccia and melt were ejected hundreds of metres around the crater, and excavation raised the edges of the ignimbrite strata and granite. Late erosion was controlled mainly by mechanical weathering due to the extreme arid conditions of the area since the mid-Miocene [5].

References: [1] Earth Impact Database, www.unb.ca/passc/ImpactDatabase/, 2003; [2] Buchwald V. F. Handbook of Iron meteorites. University of California Press, v3, 1975; [3] Ramrez, C. y Gardeweg, M. Carta Geolgica de Chile, Hoja Toconao. SERNAGEOMIN, 1982; [4] Ugalde, H. et. al., in GSA Special Volume, 2004 (Submitted); [5] Alpers, C. N. and G.H. Brimhall, Geolog. Soc. Of Am. Bull. 100, 1640-1656, 1988.

NS22A-02 1045h

Nonlinear Programming shallow tomography improves deep structure imaging

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In areas with strong variations in topography or near-surface lithology, conventional seismic data processing methods do not produce clear images, neither shallow nor deep. The conventional reflection data processing methods do not resolve stacking velocities at very shallow depth; however, refraction tomography can be used to obtain the near-surface velocities. We use Nonlinear Programming (NP) via known velocity and depth in points from shallow boreholes and outcrop as well as derivation of slowness as constraint conditions to gain accurate shallow velocities.

We apply this method to a 2D reflection survey shot across the Flame Mountain, a typical mountain with high gas reserve volume in Western China, by PetroChina and BGP in 1990s. The area has a highly rugged topography with strong variations of lithology near the surface. Over its hillside, the quality of reflection data is very good, but on the mountain ridge, reflection quality is poorer. Because of strong noise, only the first breaks are clear in the records, with velocities varying by more than 3 times in the near offsets. Because this region contains a steep cliff and an overthrust fold, it is very difficult to find a standard refraction horizon, therefore, GLI refractive statics conventional field and residual statics do not result in a good image.

Our processing approach includes: 1) The Herglotz-Wiechert method to derive a starting velocity model which is better than horizontal velocity model; 2) using shallow boreholes and geological data, construct smoothness constraints on the velocity field as well as; 3) perform tomographic velocity inversion by NP algorithm; 4) by using the resulting accurate shallow velocities, derive the statics to correct the seismic data for the complex near-surface velocity variations. The result indicates that shallow refraction tomography can greatly improve deep seismic images in complex surface conditions.

NS22A-03 1100h

Inversion of Airborne Electromagnetic Data: Application to Oil Sands Exploration

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In general, three-dimensional inversion of airborne electromagnetic data for models of the conductivity variation in the Earth is currently impractical because of the large amount of computation time that it requires. At the other extreme, one-dimensional imaging techniques based on transforming the observed data as a function of measurement time or frequency at each location to values of conductivity as a function of depth are very fast. Such techniques can provide an image that, in many circumstances, is a fair, qualitative representation of the subsurface. However, this is not the same as a model that is known to reproduce the observations to a level considered appropriate for the noise in the data. This makes it hard to assess the quality and reliability of the images produced by the transform techniques until other information such as borehole logs is obtained. A compromise between these two interpretation strategies is to retain the approximation of a one-dimensional variation of conductivity beneath each observation location, but to invert the corresponding data as functions of time or frequency, taking advantage of all available aspects of inversion methodology. For example, using an automatic method such as the GCV or L-curve criteria for determining how well to fit a set of data when the actual amount of noise is not known, even when there are clear multi-dimensional effects in the data; using something other than a sum-of-squares measure for the misfit, for example the Huber M-measure, which affords a robust fit to data that contain non-Gaussian noise; and using an l_1-norm or similar measure of model structure that enables piecewise constant, blocky models to be constructed. These features, as well as the basic concepts of minimum-structure inversion, result in a flexible and powerful interpretation procedure that, because of the one-dimensional approximation, is sufficiently rapid to be a viable alternative to the imaging techniques presently in use.

We provide an example that involves the interpretation of an airborne time-domain electromagnetic dataset from an oil sands exploration project in Alberta. The target is the layer that potentially contains oil sands. This layer is relatively resistive, with its resistivity increasing with increasing hydrocarbon content, and is sandwiched between two more conductive layers. This is quite different from the classical electromagnetic geophysics scenario of looking for a conductive mineral deposit in resistive shield rocks. However, inverting the data enabled the depth, thickness and resistivity of the target layer to be well determined. As a consequence, it is concluded that airborne electromagnetic surveys, when combined with inversion procedures, can be a very cost-effective way of mapping even fairly subtle conductivity variations over large areas.

NS22A-04 1115h

An Algorithm for Detecting Feature Lines in Potential-Field Maps

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Areomagnetic or gravity features are vector elements that correspond with local maxima of the horizontal gradient for the respective fields. These features often reflect the boundaries of anomalies, fault zones or other structures. We propose an algorithm based on contour-map to extract areomagnetic or gravitational features automatically. In the case of closed contours, based on the K-L transform,this algorithm also calculates the long-axis direction. The effectiveness of our method is illustrated using several real-data examples. Whereas the original gridded aeromagnetic or gravity data are either in raster format or contours, the set of feature lines as vectors produced by our algorithm can be imported easily into a GIS package as sparse vector elements, facilitating comparison with other types of data.

NS22A-05 1130h

Numerical and Physical Modeling of the Effects of Temperature Change on Ground Penetrating Radar Signals

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Ground-penetrating radar (GPR) is widely used for subsurface characterization in environmental contaminant remediation studies. GPR can be used to detect the extent of the contaminant plume and monitor the remediation process as contaminants are removed. Thermal remediation methods, such as steam injection, are used to mobilize non-aqueous phase liquids (NAPLs) for vapor extraction; these methods cause a temperature change in earth materials, which subsequently causes variations in GPR signal response. When using GPR to monitor a remediation process, it is critical to account for all possible factors that affect GPR signatures for better definition and delineation of contaminant flow and transport. Numerical and physical models were used to quantify the effects of temperature changes and fluid phase changes in a porous medium. The numerical modeling shows that when a porous media is heated, the GPR signal will show both a decrease in traveltime and an increase in amplitude from a reflector. A simplified numerical model of the GPR signal response to a steam injection, characteristic of some thermal remediation methods, was made by comparing GPR signal responses to a water-filled layer and an air-filled (steam) layer within the saturated porous medium. The polarity of the reflected GPR signal is opposite for the water- and air-filled layers. The results from physical experiments conducted in a laboratory-scale sand tank confirm the results obtained from the numerical models.

NS22A-06 1145h

Investigating the Hydrostratigraphy of an Unconsolidated Aquifer using Crosswell Seismic Traveltime Tomography

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Subsurface geologic structure such as sedimentary architecture can have a great influence on the movement of groundwater. For coarse braided stream deposits, computer modeling of contaminant transport has shown that the outcome is largely controlled by the distribution of facies and sedimentary structures (and their associated hydraulic parameters). One method that can be used to image this type of geologic variation in the subsurface is seismic traveltime tomography. Hydrogeologists can either use the resulting velocity image to define aquifer geometry or use the velocities themselves to estimate the values of hydrogeological properties. Seismic tomography can produce useful images in situations where surface seismic reflection has failed. The resolution of crosswell seismic tomography is limited by angular coverage. Synthetic studies have shown that including traveltimes from borehole sources to surface geophones improves angular coverage, and therefore the resolution. In field studies, however, including borehole-to-surface traveltimes has resulted in significant artifacts, such as lateral velocity variations. We have used crosswell seismic traveltime tomography to determine the hydrostratigraphic structure between wells at the Boise Hydrogeophysical Research Site (BHRS), a research wellfield in a coarse alluvial aquifer. We found that we could successfully include borehole-to-surface traveltimes in the tomography by using a reference model that included a large velocity contrast at the water table and weighting the borehole-to-surface data less heavily than the crosswell data. The inclusion of borehole-to-surface data eliminates the X shaped artifact common in crosswell tomograms. The final seismic velocity image agrees well with the existing hydrostratigraphic interpretation of the site.

NS23A CC: 220 C-E Tuesday 1330h

Near-Surface Geophysics: Contaminants II Posters *(joint with H)*

Presiding: **E A Atekwana,** University of Missouri at Rolla**; S S Hubbard,** Lawrence Berkeley National Laboratory

NS23A-01 1330h POSTER

Analysis of the Geoelectrical Stratigraphy of a Controlled LNAPL Release

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Various electrical and electromagnetic techniques are being used to geophysically characterize LNAPL impacted sites. This characterization is dependent on our understanding of the relationship between the geoelectrical stratigraphy and spatial distribution of pore fluids. A numerical model for the geoelectrical stratigraphy of an LNAPL impacted site was constructed using a modified version of the Lenhard and Parker method to predict vertical fluid distributions; Archie's Law and Topp's Equation were used to generate the corresponding electrical conductivity and dielectric permittivity profiles. Both the van Genuchten and Brooks-Corey equations for the fluid content-hydraulic head relationship were considered in the modeling.

The modeling results were compared with geoelectrical data collected during a controlled LNAPL release in a large test cell (3 meter diameter, 1.7 meters depth) containing repacked Borden sand. There are significant differences between the predicted and actual electrical conductivity profiles for both the clean and contaminated cases. The commonly assumed value of 2 for the Archie saturation exponent is too high; a value of 1.6 is more appropriate for matching the low- and high-saturation resistivity data. Furthermore, the Archie saturation exponent varies in a systematic manner over the intermediate saturations for this data set. The predicted and actual dielectric permittivity profiles show some differences for the clean case; however, better agreement is obtained for the contaminated case.

NS23A-02 1330h POSTER

Physical Model Experiment to Test the Sensitivity of GPR to the Presence of Gasoline

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Ground penetrating radar (GPR) measurements were made on a 3-D grid on the surface of a tank filled with sand to measure changes in the vadose zone at three stages during the introduction of water and gasoline. The fluids were introduced into the bottom of the tank, and water table fluctuations were simulated by adding and removing water.

Results from this experiment show the sensitivity of GPR to moisture content and its effectiveness for monitoring small changes in the water table and the capillary fringe. A decrease in reflection amplitudes within the vadose zone occurred as a function of time, after the injection of gasoline into the tank and prior to water table fluctuations. One interpretation of these results is that increasing hydrocarbon vapor pressure displaced redistributed interstitial moisture in the vadose zone, which led to this observed change in the GPR response. The experiment also shows that the GPR response from the water table can be enhanced when residual gasoline is present in the vadose zone. This effect can be interpreted as the result of less attenuation through the medium after the introduction of gasoline into the system.

NS23A-03 1330h POSTER

Characterizing the Hydraulic Components of a Contaminated Basalt Aquifer using Borehole Geophysical and Hydrologic Methods

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Groundwater flow and contaminant transport in basalt aquifers occurs primarily through high permeable interflow rubble zones and interconnected fracture zones. These zones are difficult to identify and characterize because they occupy a small percentage of the aquifer volume and exhibit complex patterns of spatial connectivity. We attempt to characterize these preferential flow zones by integrating information from borehole geophysical logs, optical televiewer (OTV) images, crosswell radar and seismic tomography, hydraulic tests, flowmeter logs, and chemical analysis of water samples. We demonstrate the effectiveness of this integration using data collected in two wells located at the Idaho National Engineering and Environmental Laboratory. The wells are 10 to 15 m apart (varies with depth) and penetrate a saturated 60 m thick sequence of interlayered and fractured basalt within the Snake River Plane Aquifer (64-128 m below the surface). The wells also intersect a trichloroethelene (TCE) plume that is undergoing bioremediation. Caliper logs, neutron logs and OTV images help to identify interflow zones and basalt stratigraphy. The OTV images also provide information about the location, orientation and aperture of fractures that intersect the boreholes. Staining around some fractures is a direct indicator of groundwater flow. Borehole flowmeter logging and hydraulic tests in packed off zones are used to estimate the hydraulic conductivity of different zones. Radar velocity and attenuation tomograms provide information about the continuity between the wells. Zones characterized by low radar and seismic velocities, and high radar and seismic attenuations, tend to be highly permeable zones. Six high permeability