NS13A-05 1430h

Differential Surface Wave Analysis: a Technique to Mmonitor Changes in Fluid Flow in Shallow Aquifers.

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The objective of differential surface-wave analysis is to identify temporal perturbations in the shear-wave velocity, and hence monitor in time the degree of water saturation and/or water pressure in shallow soils. We are testing a new analysis technique to directly measure perturbations in velocity by a direct comparison of seismic traces obtained before and after a change in the water saturation. Perturbations in phase velocity are measured by computing the Fourier transform of the difference of normalized traces. The perturbed structure can then be computed relative to a reference structure that need only approximate the actual structure. In effect, the perturbations of surface-wave group or phase velocity are inverted directly to velocity perturbations instead of inverting the dispersion curve for shear-wave structure. The test site is the Panola Mountain Research Watershed, a small controlled watershed where a thin (1-5m) soil overburden lies above granite. The water level varies significantly between times of rain and drought. Typically rain events are followed by a decayed runoff, indicating significant variations in water saturation in the soils.

NS13A-06 1445h

Magnetic Mapping and Classification of Contaminant Impact Levels in Lake Sediments

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Magnetic property measurements of Hamilton Harbour cores show that concentrations of hydrocarbons (PAH) and some heavy metals (Pb, Zn, Fe) in an upper contaminated sediment layer are strongly correlated with magnetic susceptibility. The magnetic contrast between contaminated and clean pre-colonial sediments is sufficient to generate a total field anomaly (ca. 2-20 nT) that can be measured with a magnetometer towed above the lake bottom. Systematic magnetic surveying ($>$ 500 line km) of the harbour using an Overhauser marine magnetometer clearly identifies a number of localized magnetic anomalies that coincide with known accumulations of contaminated sediments on the harbour bottom.

Apparent susceptibility maps calculated from the total field data provide a further attribute for classifying contaminant impact levels, as susceptibility is directly linked to pollutant levels. Magnetic detection of near-surface anomalies requires a closely-spaced survey grid and careful post-cruise processing to remove diurnal, regional and water-depth related variations in the magnetic field intensity. These results demonstrate the potential of lake-based magnetic surveying as a rapid reconnaissance method for mapping large areas of bottom contamination prior to detailed coring work.

NS14A CC: 516 B Monday 1530h

Near-Surface Geophysics: Climate Change and Earths Surficial Processes *(joint with H, GC, PP)*

Presiding: **S McGeary,** University of Delaware**; J J Daniels,** Ohio State University

NS14A-01 1530h

Internal Structure and Development of an Active Parabolic Sand Dune Determined with Ground-Penetrating Radar

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Ground-penetrating radar data were used to investigate the internal structure and development of an active parabolic sand dune in the Bigstick Sand Hills of southwestern Saskatchewan, Canada. This study is part of a broader investigation into the morphodynamics of parabolic sand dunes on the Canadian prairies. The study dune is up to 9 m high and has been migrating eastwards during the last 70 years at an average rate of about 2 ma-1. The radar survey was conducted in a grid configuration using a Sensors and Software Inc. Noggin Plus (250 MHz). Radar profiles oriented downwind reveal a variety of high- and low-angled dipping reflectors which are interpreted as cross-stratification and bounding surfaces. Well defined sets of grainflow cross-stratification along profiles near the central downwind axis were used to resolve former slipface positions and compared with historical aerial photographs. Radar profiles orthogonal to the prevailing wind direction were characterized by convex-up and concave-up cross-stratification along the dune head which are interpreted to be the result of scour and fill processes and migration of superimposed bedforms. Radar profiles over the trailing arms revealed an arrangement of stratification similar to the profiles oriented along the main downwind axis. Observations of exposed surface stratigraphy following extensive wind erosion lend support to the interpretations made from the GPR data. Taken together, the results provide a basis for a tentative model of the stratigraphic development of parabolic dunes.

NS14A-02 1545h

Temporal Variations in Glacier retreat and Bed Characteristics Derived From Ground-penetrating Radar Data

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Temporal Variation in Glacier Retreat and Bed Characteristics Derived From GPR Data Stagnation Glacier on Bylot Island in the eastern Canadian Arctic (72°N 78°W) has been rapidly retreating over the last 50 years. Over 40 km of ground-penetrating radar (GPR) surveys were conducted in the ablation area of the glacier in 1993, 1994, 1999, and 2002 to examine its hydrological, structural and bed characteristics. This polythermal glacier has exhibited a dramatically varying hydrological regime over the period of this study that is thought to result from the changing subsurface thermal structure. The GPR surveys have recorded changes in the bed characteristics that are interpreted to be a function of changes to the thermal structure of the glacier. The radar signature of the glacier and its bed have been observed to change over the study period on a seasonal and inter-annual basis. The results presented demonstrate how GPR can be utilized to monitor that changing internal physical, thermal and hydrological structure of a polythermal glacier.

NS14A-03 1600h

Resolving Large Pre-glacial Valleys Buried by Glacial Sediment Using Electric Resistivity Imaging (ERI)

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Two-dimensional electric resistivity imaging (ERI) is the most exciting and promising geological tool in geomorphology and stratigraphy since development of ground-penetrating radar. Recent innovations in 2-D ERI provides a non-intrusive mean of efficiently resolving complex shallow subsurface structures under a number of different geological scenarios. In this paper, we test the capacity of ERI to image two large pre-late Wisconsinan-aged valley-fills in central Alberta and north-central Montana. Valley-fills record the history of pre-glacial and glacial sedimentary deposits. These fills are of considerable economical value as groundwater aquifers, aggregate resources (sand and gravel), placers (gold, diamond) and sometime gas reservoirs in Alberta. Although the approximate locations of preglacial valley-fills have been mapped, the scarcity of borehole (well log) information and sediment exposures make accurate reconstruction of their stratigraphy and cross-section profiles difficult. When coupled with borehole information, ERI successfully imaged three large pre-glacial valley-fills representing three contrasting geological settings. The Sand Coulee segment of the ancestral Missouri River, which has never been glaciated, is filled by electrically conductive pro-glacial lacustrine deposits over resistive sandstone bedrock. By comparison, the Big Sandy segment of the ancestral Missouri River valley has a complex valley-fill composed of till units interbedded with glaciofluvial gravel and varved clays over conductive shale. The fill is capped by floodplain, paludal and low alluvial fan deposits. The pre-glacial Onoway Valley (the ancestral North Saskatchewan River valley) is filled with thick, resistive fluvial gravel over conductive shale and capped with conductive till. The cross-sectional profile of each surveyed pre-glacial valley exhibits discrete benches (terraces) connected by steep drops, features that are hard to map using only boreholes. Best quality ERI results were obtained along the Sand Coulee and Onoway transects where the contrast between the bedrock and valley-fill was large and the surficial sediment was homogeneous. The effects of decreasing reliability with depth, 3-D anomalies, principles of equivalence and suppression, and surface inhomogeneity on the image quality are discussed.

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NS14A-04 1615h

Thick Permafrost: MacKenzie Delta, North West Territories, Canada

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A 2D seismic reflection profile and a corresponding pseudo-3D single fold volume were obtained at the ICDP Mallik gas-hydrate research well in the MacKenzie River Delta of the N.W.T., Canada in February 2002. While the main target of this work was to obtain seismic images of the gas-hydrate zones, the permafrost itself displayed numerous features. These data were simultaneously acquired over 240 14-Hz geophone singles using the Univ. of Alberta seismic vibrator sweeping from 12 to 180-Hz. Common midpoints were spaced at 2-m. The stratigraphy imaged, to about 1400-m depth, consists primarily of flat-lying Tertiary to Quarternary fluvial, deltaic, and glacial sediments. Both the stacked 2D profile and the minimally processed volume display short (50 to 100 m) discontinuous zones of high reflectivity and support earlier surveys conducted in the vicinity (Miller et al., USGS Open-File Report 2003-36). The source of these short variations in reflectivity remain unknown in part due to the lack of quality logs or core through the permafrost zone that extends to depths of about 640-m. However, the permafrost is not completely frozen and has a complex structure that includes i) zones saturated with unfrozen brines in which salts have been concentrated during the freezing process, and ii) zones of free gas saturation the source of which may be dissociation of gas hydrates or even methanogenic bacteria. The differences in the

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 $\sim$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 $\sim$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].

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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