# NSGG
# Student Geophysics Symposium 2014
# Tuesday 13 May 2014
# BGS Keyworth
Convenor: Oliver Kuras, BGS (oku@bgs.ac.uk)

## Programme

| Time | | |
|---|---|---|
| 09:00 | Arrival & registration | |
| 09:45 | Welcome & introduction | |
| **Soils, Cryosphere & Archaeology** | | |
| 10:00 | **Donna Carless**<br>Swansea University | *Ground Penetrating Radar (GPR) and 3D modelling : A key to improving estimates of peat volume for carbon quantification* |
| 10:20 | **Charlotte Axtell**<br>Swansea University | *Improved sensitivity analysis of cross-borehole radar velocity calculations* |
| 10:40 | **Christine Bunting**<br>Reading University | *Integrating geophysics and geoarchaeology for a heritage management toolkit in wetlands* |
| 11:00 | Tea & coffee | *Tea & coffee sponsored by RSK Geophysics* |
| **Marine Geophysics** | | |
| 11:30 | **Tim Hughes**<br>NOC Southampton | *Environmental controls on the thermal performance of high voltage cables buried under the seafloor* |
| 11:50 | **Bedanta Goswami**<br>NOC Southampton | *A controlled source electromagnetic study of gas hydrates at the Vestnesa Ridge, West Svalbard continental margin* |
| 12:10 | **Chinedu Emeana**<br>NOC Southampton | *Sediment thermal properties and heat flow implication on the performance of sub-seabed HV cables* |
| 12:30 | Buffet Lunch | *Lunch sponsored by NSGG* |
| **13:30** | **Keynote Lecture** | **Adam Booth, Imperial College London:**<br>***Geophysics in the freezer: Seismic properties of glacier ice*** |
| **Seismics & Geohazards** | | |
| 14:00 | **Will Firth**<br>NOC Southampton | *Multi-parameter inversion of decimetre resolution 3D seismic reflection data* |
| 14:20 | **Sarah Tallett-Williams**<br>Imperial College | *Development of Vs30 ground profiles for UK strong ground motion instrument sites* |
| 14:40 | **Henry Dick**<br>Keele University | *Environmental geophysical investigation of surface depressions, Plumley, Cheshire, UK* |
| 15:00 | Tea & coffee | *Tea & coffee sponsored by RSK Geophysics* |
| **Geoelectrics** | | |
| 15:30 | **Wil Ward**<br>Nottingham University | *A novel means of isolating boundaries in ERT models with quantifiable uncertainty* |
| 15:50 | **Sebastian Uhlemann**<br>ETH Zurich | *Geoelectrical imaging of hydrological processes in a wetland environment* |
| 16:10 | Evaluations | |
| 16:30 | **Best Paper Award** | *Award sponsored by Geomatrix Earth Science Ltd* |
| 17:00 | Meeting close | |

## Ground Penetrating Radar (GPR) and 3D modelling: A key to improving estimates of peat volume for carbon quantification

Donna Carless[1*], Bernd Kulessa[1], F. Alayne Street-Perrott[1], Siwan Davies[1], Paul Sinnadurai[2]
[1] Department of Geography, College of Science, Swansea University, Swansea, SA2 8PP.
[2] Brecon Beacons National Park Authority, Cambrian Way, Brecon, Powys, LD3 7HP.
*E-mail: D.CARLESS.147854@swansea.ac.uk

Historically regional peatland volume estimates have been obtained using aerial imagery, and manual probing techniques, to establish area/extent and depth, respectively; however, these conventional survey methods are time consuming and laborious and therefore impractical for detailed or large scale investigations. Uncertainty exists when averaged depth estimates are used, as these are not necessarily determined from systematic field measurements, and can disregard the heterogeneous subsurface conditions between measured points. The high water content and low mineralisation, of peat soils make them well suited for Ground-Penetrating Radar (GPR) investigations; peat is highly resistive, with low signal attenuation and high permittivity, resulting in low propagation velocity (typically 0.03m/ns). The result is high-density spatial data allowing accurate estimation of depth to be achieved, relative to manual probing.
This project combines the use of geophysical and proxy techniques to reconstruct variations in long-term carbon accumulation in 6 ombrotrophic peat bogs across the Brecon Beacons National Park ranging in area from 0.04 $km^2$ to 0.31 $km^2$. Several GPR common offset transects were collected following the long axis of each bog with additional transverse transects to provide appropriate coverage for volume estimations. Due to the surface conditions, a 100 MHz articulated rough terrain antenna was used. A strong reflector was observed across all transects, except some central regions where it is interpreted that the signal was attenuated by a thick clay layer; peat depths were calculated using a range of velocities. Some manual probing was completed for comparison.
Combining GPR derived depths with surface-elevation data from LiDAR imagery, 3D models are created representing estimates of the total peat volume. These estimates are used in combination with radiocarbon dating and palaeoenvironmental data to infer variations in carbon accumulation rates within and between sites thereby permitting the factors influencing carbon storage to be elucidated.

## Improved sensitivity analysis of cross-borehole radar velocity calculations

Charlotte Axtell[1*], Roger Clark[2], Tavi Murray[1], Bernd Kulessa[1], Alessio Gusmeroli[3]
[1] Glaciology Group, Swansea University, Singleton Park, Swansea, SA2 8PP, UK
[2] School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK
[3] International Arctic Research Center, University of Alaska Fairbanks, Fairbanks, AK, USA
*E-mail: C.AXTELL.607467@swansea.ac.uk

We develop a rigorous approach to quantify potential uncertainties in velocity calculations from Cross-Borehole Radar (XBH) data on glaciers, that rely on accurately measuring small-magnitude velocity variations (~0.003m/ns) to calculate micro-scale englacial properties, such as water or air content. XBH radar studies, although spatially limited, can accurately calculate velocity at depth, unlike surface surveys that rely on calculation of the overlying subsurface properties. Major sources of potential uncertainty include [1] instrument drift, [2] first break picking, and [3] borehole geometry. Of these, instrument drift is the most critical, leading to velocity estimation errors of up to ±0.003m/ns for only ±2ns time drift. Uncertainty from first break picking is dependent on the quantity and horizontal antenna separation of surface shots, in addition to the standard temporal sampling uncertainty. Borehole geometry is defined by the borehole inclination and width. Inclination is standardly measured during XBH surveys, and has little effect on velocity results until the borehole's dip is greater than the critical angle defined by the velocity contrast between the water and ice. Refraction at the borehole wall results in a distance uncertainty through the ice of almost ±2cm; the effect is amplified perpendicular to the dip azimuth. Every ±3cm of error in the width estimation of the borehole will result in a velocity uncertainty of ±0.001m/ns: any smaller-scale variation has negligible effect, as its dimensions are too small to be recognised at GPR wavelengths. These are serious magnitudes of uncertainty: ±0.004m/ns in the velocity model results in a significant ±0.5% error in the englacial water – the total micro-scale water content is typically <1% anyway. In a case study from the ablation area of the polythermal mountain glacier Storglaciären, Arctic Sweden, XBH velocity results show minimal evidence of polythermal structure, atypical for polythermal ice, and suggest large influences from air content.

## Integrating geophysics and geoarchaeology for a heritage management toolkit in wetlands

Christine Bunting*, N. Branch, S. Robinson, P. Johnes
School of Human and Environmental Sciences, University of Reading, Whiteknights, Reading, UK, RG6 6AB
*E-mail: c.j.bunting@pgr.reading.ac.uk; Telephone: +44 (0) 7843014221

The North West European lowland wetlands contain a wealth of information on cultural and environmental histories, providing a unique and well-preserved record of human settlement, resource exploitation, subsistence and ritual practises, which are vulnerable to a range of pressures relating to development and climate change. Understanding the heritage resource potential of lowland wetlands is critically important for the future management of cultural remains.
Ground Penetrating Radar (GPR) is the geophysical technique which shows the greatest potential for archaeological purposes in wetland environments and geochemistry has shown potential in dry land archaeological contexts for gleaning information about activity type. Here they are tested in a range of wetland environments to map sub-surface morphology of the wetland areas, and identify stratigraphy and anomalous material consistent with the presence of archaeological material. The main outcome of the project will be the development and dissemination of a scientifically rigorous, multi-proxy toolkit that allows the identification, characterisation and classification of buried remains within the landscape prior to the threat of change.

## Environmental controls on the thermal performance of high voltage cables buried under the seafloor

Tim Hughes
National Oceanography Centre, Southampton
E-mail: t.hughes@noc.soton.ac.uk

Submarine high voltage (HV) cables are becoming ever more crucial to modern power transmission strategies as initiatives like offshore wind farms and the European supergrid are developed. To ensure the continuous and efficient operation of these assets while maximising their lifespan, it is essential that certain cable components are maintained at temperatures below 90$^{o}$C. The thermal performance of HV cables is controlled by the effectiveness of heat transfer through the sediments in which they are buried. Numerous studies into the behaviour of terrestrial cable systems have been carried out. However, the performance of cables laid under the seafloor has not been extensively investigated despite several key differences between the two environments. We have developed 2D finite element method (FEM) simulations to assess how variation in environmental parameters affects the nature of the heat flow around HV cables. Both conductive and convective heat transfer is considered. The dependence of the thermal behaviour on the intrinsic permeability and thermal conductivity of the burial sediment, as well as the burial depth of the cable is assessed.

When buried in low permeability sediments, the transfer of heat away from HV cables is mainly by conduction. Hence, the thermal conductivity of the sediments and the cable burial depth are the dominant parameters in determining the temperature profile. Heat transfer is approximately isotropic, and temperatures in regions local to the cable can reach up to ~70$^{o}$C. This may have interesting geochemical and/or biological implications that have not yet been investigated. For highly permeable sediments, convection transfers most of the heat away from HV cables. In this case, the permeability is the most influential parameter in determining the heat transfer within the system; most of the heat is advected upwards directly out into the overlying seawater with minimal heating of the surrounding sediment.

## A controlled source electromagnetic study of gas hydrates at the Vestnesa Ridge, West Svalbard continental margin

Bedanta Goswami*, Karen Weitemeyer, Tim Minshull, Martin Sinha, Graham Westbrook
National Oceanography Centre, Southampton
*E-mail: Bedanta.Goswami@noc.soton.ac.uk

Vestnesa Ridge (1200-1350m water depth) is a sediment drift that marks the northern boundary of the West Svalbard continental margin gas hydrate province. Various geophysical surveys have reported active methane seeps at the Vestnesa Ridge, identified by numerous seafloor pockmarks in a region where the seabed is within the hydrate stability field. Excess pore pressure associated with topographically driven fluid flow and free gas accumulation below the ridge axis, below the gas hydrate stability zone (GHSZ) is thought to be one of the primary causes of the observed seeps. While seismic reflection data provide an excellent structural image of the subsurface, they fail to provide accurate sub-surface fluid saturations, especially in presence of free gas. Electrical resistivity obtained from controlled source electromagnetic (CSEM) data provides better constraints on sub-surface fluid saturations, while being relatively poor at resolving geological structure. Joint interpretation of seismic and CSEM data, therefore offers a potential for improved estimates of hydrate and free gas saturations at the Vestnesa Ridge. With the objective of joint interpretation, seismic reflection, seismic refraction and CSEM surveys were conducted on Vestnesa Ridge during 2011 and 2012. The CSEM survey was conducted over an active pockmark on the Vestnesa Ridge using a 100 m horizontal electric dipole source, 8 ocean bottom electric-field (OBE) receivers and a towed tri-axis electric-field receiver. Preliminary results from 2D inversion of CSEM data indicate high concentration of resistive pore fluid in the fluid migration pathways observed in seismic reflection data.

## Sediment thermal properties and heat flow implication on the performance of sub-seabed HV cables

Chinedu John Emeana[1*], J K Dix[1], T J Henstock[1], T M Gernon[1], J A Pilgrim[2] and C E L Thompson[1]
[1] University of Southampton, National Oceanography Centre Southampton
[2] University of Southampton, Electronics and Computer Science
*E-mail: C.J.Emeana@soton.ac.uk

Offshore windfarms and the potential for a European Mega-Grid are generating huge interest in the use of subsea electricity transmission High Voltage (HV) cables, typically buried 1-2 m beneath the seabed and within the wide range of sediments found on the continental shelf. Critical to the performance of these cables is the rate of heat transfer into the surrounding sediment particularly as sub-seabed HV cables surface temperature can be up to 90$^{o}$C. However, the thermal properties of seabed sediments are poorly understood as are the implications for changing seabed properties with such an anomalously high heat source in the near surface sediments.

Experimental results for the response of a saturated fine sand (mean grain size of 0.25mm and average water content of 37.4%) to a heat source generating a controlled stabilised surface temperature range of 30-90$^{0}$C measured with thermocouples (TCs) inserted in a custom built tank, shows a spatially uniform and mainly conductive heat flow pattern as the applied heat spreads through the fine sand sediments. This was demonstrated with generated time dependent heat flow surfaces using the acquired TC temperature time series data. The controlling sediment thermal properties: diffusivity of 0.98 ($\pm$ 0.15) x $10^{-6}$ $m^2s^{-1}$, conductivity of 2.84 ($\pm$ 0.44) $Wm^{-1}K^{-1}$ and volumetric heat capacity of 2.95 ($\pm$ 0.05) x $10^{6}$ $Jm^{-3}$ $K^{-1}$ were calculated. The thermal diffusivity estimates were similar for different heat inputs using the same fine sand sediments, thus confirming a conductive heat transfer mode.

The results further implies that with external cable temperature approaching 90$^{0}$C, the wide variability of the surrounding near surface sediments could exhibit varying impact on the heat flow, controlling sediment thermal properties and cable performance. Factors such as cable insulation degradation, pore-water convection and drying, grains movement, seabed erodibility and scour as well as geochemical and biological implications are currently not well understood.

## Multi-parameter inversion of decimetre resolution 3D seismic reflection data

William J. Firth* and Mark E. Vardy
School of Ocean and Earth Science, University of Southampton, European Way, Southampton, SO14 3ZH
* E-mail: wf1g10@soton.ac.uk

Quantitative analysis of shallow sedimentation through traditional extraction methods such as coring and CPTU's are low coverage and are not necessarily representative of in situ conditions, especially in heterogeneous environments. This is a large issue when trying to classify the strength of sediments for purposes such as geohazard mapping and offshore infrastructure development. Here we present a multi-parameter inversion of high-resolution chirp data for the remote in situ classification of near surface sediments. This work represents one of the first efforts to classify submarine facies and derive their properties using high-resolution seismic inversion. Combining post-stack acoustic impedance and acoustic quality factor (Q-factor) inversion provides an accurate and robust method of characterising sediments and quantifying key properties, including porosity, mean grain size, density and P-wave velocity, without the need for low coverage, coring methods. The inversion is performed post-stack using a convolutional forward model and genetic algorithm for optimization. The genetic algorithm is ideal for such multi-parameter inversions as it searches a broad range of parameter space and prevents focusing in on local minima. Q-factor filters are applied using the spectral ratio method after continuous wavelet transform, the high time resolution of which is well suited to the resolution of the seismic data. Combining the Q-factor with impedance further constrains the inversion by inherently integrating down trace attenuation, producing a more accurate subsurface acoustic impedance model as well as the additional Q-factor model. This affords improved constraint of key physical properties, particularly fluid and gas saturation, to which Q-factor is particularly sensitive due to the attenuating effects of oversaturated sediments. The result of the inversion is a strong quantitative understanding of shallow sedimentary facies, which, when combined with the high-resolution seismic imagery, gives a complete understanding of the near surface.

## Development of Vs30 ground profiles for UK strong ground motion instrument sites

Sarah Tallett-Williams
Imperial College London
E-mail: sarah.tallett-williams09@imperial.ac.uk

Detailed shear wave velocity profiles ($V_{s30}$) of the near-surface are vital for accurate site response analysis and development of ground motion prediction equations. The aim of this study is to produce $V_{s30}$ velocity profiles for the existing strong ground motion stations in the UK. This lack of information for UK sites has not previously been addressed, causing uncertainty regarding the accuracy of station records when used for seismic design. There are currently little or no site specific data on the ground conditions of these sites, frequently as a consequence of their necessary remoteness. Thus, a method was developed to produce as rigorous an understanding of the site geology as possible through evaluation of prior information and further site-specific reconnaissance investigations. These data were then used to establish a detailed, geological profile of the ground under each station. These were applied, in combination with shear wave velocity data, geophysical data and SPT 'N' values, when available, to categorise each station according to the National Earthquake Hazards Reduction Programme (NEHRP) site classes. The uncertainty of these results is captured in a $V_{s30}$ velocity range for each station. These ground profiles will lead to a better understanding of site response for UK ground conditions.

## Environmental geophysical investigation of surface depressions, Plumley, Cheshire, UK

Henry C. Dick
School of Physical Sciences & Geography, Keele University, ST5 5BG
E-mail: h.c.dick@keele.ac.uk

Emerging topographic depressions in rural farmland in Plumley, Cheshire were the focus of near-surface geophysical investigations to determine their source. Potential causes could be natural dissolution of the solution-prone bedrock, brine pumping activities nearby and/or relict Devensian glacial outwash heterogeneities. Electrical resistivity, micro-gravity and electromagnetic-induction techniques were used to survey two selected ground depressions. Survey results exhibited an approximately 70m wide of high conductivity zone in Northwest-Southeast orientation, a relatively low gravity anomaly at the depressions, approximately 0.06µGal compared to background values, and inconsistent resistivity responses which reveals the heterogeneous nature of the topsoil. A 2D schematic geological cross-section of the area, using borehole information, calibrated geophysical results. Euler deconvolution modelling of microgravity data evidenced a good clustering pattern with anomaly depths calculated at 12m-24m below ground level. Gravity 2D numerical modelling using available site data also confirmed the estimated anomaly depth. Micro-gravity was considered optimum for this scenario after comparing datasets.

### A novel means of isolating boundaries in ERT models with quantifiable uncertainty

Wil O. C. Ward
University of Nottingham
E-mail: psxwowa@nottingham.ac.uk

Using electrical resistivity tomography for subsurface imaging of mineral deposits provides rapid non-intrusive means of investigation. With the constraints required for the generation of models with such a technique, there is a degree of unknown in the resolution of boundaries between areas of contrasting resistivity. A challenge, then, is finding an accurate method for identifying the locations of such interfaces for the means of quantifying and characterising subsurface structures, including mineral deposits, bedrock overlay and saturated regions. The result of this research is an efficient and robust algorithm for segmenting notable regions, in both 2-D and 3-D data, with the added property of presenting a probabilistic measure of uncertainty about the detected edges. Additional features of the framework include fully unsupervised automation, as well as the potential for intermediate user interaction.

### Geoelectrical imaging of hydrological processes in a wetland environment

Sebastian Uhlemann
ETH Zurich and British Geological Survey
E-mail: suhl@bgs.ac.uk

The River Lambourn and the associated wetlands comprise some of the least impacted chalk river systems in Britain. The associated lowland wetlands, due to their hydrological characteristics, may form a key conduit for, or barrier to, aqueous fluxes between land, rivers and groundwater. At Boxford, Berkshire, UK, a research site has been monitored for a number of years to establish the degree of groundwater and surface water interaction. Recently, two geoelectric monitoring lines have been added and measurements have been repeated every month.

The imaging of shallow processes in a regime where moisture content is hardly changing generates an environment for time-lapse electrical resistivity (ERT) monitoring in which accurately modelling temperature effects and their correction is necessary to define changes caused by hydrological processes. We present the methodology of temperature correction, as well as the corrected resistivity models, which are compared to geotechnical data (i.e. moisture content, water level, soil temperature, bulk conductivity).

# Meeting Announcement

## For further information, please visit the NSGG website: www.nsgg.org.uk

## Recent Work in Archaeological Geophysics & Forensic Geoscience: Future Horizons

### Geological Society of London, Burlington House, Piccadilly, London
### 2nd and 3rd December 2014

#### 2nd December 2014: Recent Work in Archaeological Geophysics

The Near Surface Geophysics Group of the Geological Society of London (NSGG) is pleased to announce the eleventh in a succession of biennial day meetings devoted to archaeological geophysics. Near surface geophysical techniques have become increasingly established in archaeological research and evaluation over the past decade and are now routinely applied in archaeological investigations. This meeting offers a forum where contributors from the UK and further afield can present and debate the results of recent research and case studies. Suppliers of equipment and software also attend and the meeting therefore represents an invaluable opportunity for both archaeological and geophysical practitioners to exchange information about recent developments.

Convenor: Paul Linford, English Heritage, Fort Cumberland, Eastney, Portsmouth, PO4 9LD, UK; Tel.: +44 (0)23 9285 6749; Fax.: +44 (0)23 9285 6701, email: Paul.Linford@english-heritage.org.uk

#### 3rd December 2014: Forensic Geoscience: Future Horizons

This multidisciplinary meeting will capture shared interests between the geological, environmental science, forensic science, geophysics, engineering, geotechnical, mining and archaeological communities in assessing the future of forensic geoscience. Sessions will include quality assurance in forensic geoscience; geoforensic applications in serious crime and terrorism investigations; techniques at crime scenes; environmental crime; and the issues of interpretation of geological forensic evidence.

Convenor: Dr Ruth Morgan, UCL Centre for the Forensic Sciences, 35 Tavistock Square, London WC1H 9EZ, UK. Tel: +44 (0)20 3108 3062, email: ruth.morgan@ucl.ac.uk

It is anticipated that each meeting will attract 100 or more participants. As well as oral presentations, there will be space for commercial and poster displays. Those interested in contributing to either meeting are warmly encouraged to contact the respective convenors, and to submit abstracts of up to 1000 words in length, accompanied by suitable illustrative material, no later than the 31st August 2014. These will be collated and made available to all those attending.