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Abstract Book

Rain Rivers Reservoirs

Edinburgh Conference Centre, Heriot-Watt University, Edinburgh

27-30 September 2016

Convenors:

Patrick Corbett (Heriot-Watt University)
Diarmad Campbell (BGS Edinburgh/Lyell Centre)
Gareth Pender (Heriot-Watt University)
Adrian Hartley (Aberdeen University)
Hugh Sinclair (Edinburgh University)
Daniel Barreto (Napier University)
Arjan Reesink (Southampton University)
Chris Hackney (Southampton University)
Adebayo Adeloye (Heriot-Watt University)
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10.10	**Cambrian rivers and floodplains: the significance of microbial cementation, groundwater and Aeolian sediment transport** Arjan Reesink, University of Southampton
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15.50	**Insights in Fluvial Reservoir Architecture from Understanding the Myriad of Well Test Pressure Build-up Responses** Patrick Corbett, Heriot-Watt University
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ABSTRACTS
(in programme order)

Organization and Reorganization of Drainage and Sediment Routing Through Time: Examples from the Mississippi System, Geologic Past to Near Future

M. Blum, Department of Geology, University of Kansas. Lawrence, Kansas USA

The northern Gulf of Mexico continental margin is dominated by the Mississippi River sediment-dispersal system. Mississippi source terrain stretches from the Rocky Mountains in the western US to the Appalachian Cordillera in the east. Sediment is routed through the tributary system and main stem for ~5000 km to sinks in the well-known alluvial-deltaic plain of south Louisiana and the deep-water basin-floor fan. However, integration of a continental-scale Mississippi drainage is a Neocene phenomenon, and sediment routing to the Gulf of Mexico has changed significantly over time.

This presentation first illustrates large-scale change in sediment routing for the Gulf of Mexico and Mississippi system over the last 200 Myrs, when tectonic and geodynamic processes drove continental-scale drainage reorganization, and development of the Gulf of Mexico as a major depocenter. I then examine the last 200 Kyrs, where Milankovitch-scale climate and sea-level changes resulted in proglacial vs. interglacial modes in the Mississippi system, with corresponding high-frequency changes in water and sediment flux that shaped much of the US landscape. Last, I examine the 20th and 21st century Mississippi River and the subsiding delta, where human activities have greatly reduced the sediment supply at the same time that rates of global sea-level rise have accelerated. This convergence of events has changed sediment mass balance to the point where the delta region will drown by the year 2100.

NOTES

Cambrian rivers and floodplains: the significance of microbial cementation, groundwater and aeolian sediment transport

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J.L. Best - Departments of Geology, Geography and Geographic Information Science, Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, Champaign, 61820 Illinois, USA
J.T. Freiburg - Illinois State Geological Survey, Champaign, 61820 Illinois, USA
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Rivers that existed before land plants colonized the Earth are commonly considered to be unaffected by microbial activity on their floodplains, because the limited cementation produced by microbial activity is insufficient to stabilize the river banks. Although this assumption is likely correct, such emphasis on channel dynamics ignores the potential role of floodplain dynamics as an integral component of the river system.

Detailed analysis of cores from the Cambrian Mount Simon Sandstone, Illinois, suggests that a significant proportion of the terrestrial sequence is composed of flat-bedded ‘crinkly’ structures that provide evidence of cementation by soil crusts and microbial biofilms, and that promoted the adhesion of sediment to sticky surfaces. Wind ripples and local desert pavements were abundant. These findings highlight that sediment deposition on Cambrian floodplains was often dominated by wind in locations where the ground water table reached the surface, and was thus independent of sediment transport within the river channel. Erosion by wind would thus have been hindered by surface cementation and the formation of desert pavements. Such ground water control on deposition, and resistance to erosion by floodplain surface hardening, appear to have been the primary controls on Cambrian floodplain topography. Because floodplain topography poses a key control on channel and floodplain flow, these processes would likely have affected patterns of erosion and deposition, as well as reach-scale dynamics such as channel avulsions. The autonomous operation of wind-dominated floodplains makes pre-vegetated river systems strikingly different from those that occurred after the development of land plants.

NOTES

Using outcrop, subsurface and modern day analogues to predict basin-scale alluvial architecture

Adrian Hartley[1], Amanda Owen[1] & Gary Weissmann[2]

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Models for alluvial architecture are important in predicting reservoir presence, distribution, quality and connectivity in continental basins. However coherent predictive models remain elusive except at a very broad scale as a clear relationship has yet to be established between accommodation space generation, depositional lithology (mudstone or sandstone) and alluvial architecture. In fact recent work has suggested that it is unlikely that any such relationship should exist. The realisation that distributive fluvial systems form an important component of modem and ancient continental basins has helped to increase the understanding of facies distributions at a basin-scale, however studies of distributive fluvial systems often lack temporal constraints. Here we use a combination of outcrop, subsurface and modern data together with a review of published data to develop a series of models for alluvial architecture in different tectonic, and climatic settings with variable subsidence rates and sediment supply. We include key architectural elements which include distributive fluvial systems, axial fluvial systems, valley development and a range of terminal facies such as wetlands, lake, play and aeolian.

The data show that no clear relationship exists between subsidence rate and depositional lithology and subsidence rate and style of alluvial architecture when considered across all the studied basins. However when broken down by tectonic and climatic settings, clearer relationships can be established which can serve as predictive models for the subsurface. Models for rift and foreland basins will be discussed.

NOTES

Understanding fluid flow at a basin scale in fluvial reservoirs

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Understanding fluid flow pathways in fluvial deposits is crucial in the exploration and exploitation of a range of resources such as aquifers, oil and gas reserves, and mineral resources such as uranium and exotic copper. Facies distribution has a profound control on fluid flow as this controls sandstone connectivity, permeability, and porosity. To gain insights into basin scale fluid flow we document the relationship between facies distribution, alluvial architecture, and uranium emplacement within the Upper Jurassic Salt Wash distributive fluvial system, SW USA. Uranium distribution in sandstone hosted deposits is strongly influence by sandstone body connectivity, as uranium enriched groundwater preferentially flows through the more porous and permeable channel deposits, and can therefore be used as a proxy for fluid flow at a basin scale.

A clear relationship is evident when sandstone percentage, channel-belt percentage, fluvial architecture and uranium distribution are analysed in conjunction with one another. More than 90% of recorded uranium deposits are located where net sandstone represents 40-55% of the succession and where channel belts form 20-50% of the succession. Below the 40% sandstone and 20% channel belt cut-off levels, uranium deposits are rarely observed. A change in fluvial architecture is observed at the point in which the majority of uranium deposits are emplaced. The majority of the uranium is found in laterally extensive channel bodies that are distinctively separated by laterally extensive floodplain facies with limited vertical connectivity, which is typical of medial DFS facies. Downstream the channel bodies decrease in size and presence, with little to no amalgamation observed.

The documented relationships suggests that below the 40-55% sandstone and the 20-50% channel belt percentage contour lines effective connectivity of the channel belts is lost. This allows the enrichment and precipitation of uranium against internal permeability barriers, such as scroll bar deposits, when reducing conditions prevail. This rock record example allows valuable insights into the three-dimensional morphology of a fluvial reservoir to be gained.

NOTES

The complex shapes of fluvial meanders and the distribution of heterogeneity in point-bar deposits

C.E. Russell, N.P. Mountney, D.M. Hodgson, L. Colombera & R.E. Thomas

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Meander bends are dynamic features in fluvial systems that result in complicated and composite deposits. Determining the three-dimensional architecture of point-bar deposits from seismic data and at outcrop is challenging. The geomorphology of modern fluvial forms highlights the range of evolutionary behaviours. Quantification of these forms permits the development of predictive tools that can then be applied to field and subsurface settings to better interpret accumulated successions from known geomorphological details. The planform architecture of modern systems enables detailed reconstruction of palaeoflow and facies distributions, thereby enabling better constraint on the three-dimensional distribution of lithological heterogeneities.

This research uses an integrated GIS and quantitative sedimentological approach to better understand scroll-bar development and modes of meander-belt growth. This allows for geometric classification of the physiographic components of meandering fluvial systems from different modern sedimentary basins. To achieve this, a novel 'Intersection Shape Method' has been developed, which allows quantitative comparison of meanders with markedly differing morphologies.

Measurements of 35 morphometric parameters of 390 meander bends from 13 different rivers (13,650 in total) have been acquired using Google Earth Pro. Studied rivers were selected to isolate the effects of independent variables (e.g., climatic zone, valley slope and discharge). Systems strongly modified by anthropogenic activity have been avoided. Analyses of exhumed point-bar successions (Pennsylvanian, Wales; Jurassic, England) serve as test data sets for the reconstruction of meander morphology from preserved stratal architectures; distributions of 19 lithofacies and 2,500 palaeocurrent readings highlight subtle yet predictable variations in the growth histories of point-bar macroforms and their internal components.

Climatic regime exerts a primary control on meander morphology through its role in determining mean annual discharge, sediment supply (rate, calibre), hinterland geomorphology, vegetation type and density. This leads to variations in meander cut-off style, as well as variations in the direction and type of growth during meander expansion. Fluvial systems with different gradients, sediment calibres, channel sizes, accumulation rates and climate regime all exhibit different yet predictable trends in meander and scroll-bar development.

A classification scheme identifies end-member models, which can be used to interpret the origin of ancient point-bar accumulations from their internal heterogeneity and architecture. This method can be applied to high-resolution seismic time slices (e.g., Cretaceous McMurray Formation, Alberta, Canada; Triassic Mungaroo Formation, NW Shelf, Australia) to help infer palaeo-river characteristics and predict internal architectures and heterogeneity.

NOTES

A sedimentological analysis of a 3D point bar outcrop in a Jurassic distributive fluvial system outcrop, South West USA.

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Understanding the architecture of sandy point bars and the channel belts they construct is crucial in building accurate models of such systems. The key to understanding and identifying sandy, meandering fluvial systems in the rock record, lies in the use of remotely sensed imagery to recognise point bar complexes, as vertical sections with limited lateral extent display similar characteristics to those of braided fluvial deposits.

The Upper Jurassic Saltwash Formation represents a distributive fluvial system (DFS) which crops out in central Utah. The studied outcrop lies in the proximal/medial portion of the system and offers a well exposed, sand dominated point bar that forms part of a largely undeformed meander belt deposit which extends across 9000 km^2. High resolution satellite imagery and ground based photo panels from the internal and external perimeter were combined with seven sedimentary logs to build a full 3D understanding of the point bar and its associated deposits. The dimensions of the outcrop vary from 8-10 m in height, 30-45 m in width at the widest point and around 300 m in length. The dimensions can give an approximation of the width and depth of the channel - likely 6m minimum depth and a width of between 60-120m.

Interpretation of the satellite imagery shows that the bar form has an arcuate geometry that clearly represent a point bar composed of a number of different scroll bars in a meandering river system. The ‘classic meander profile’ of a fining upwards sequence with gravel lags at the base and ripple cross-lamination at the top is only present at one location across the outcrop – the apex of the point bar. This section is also where lateral accretion is observed and is likely the most commonly described section of a point bar. Elsewhere, poorly sorted trough cross-bedding is commonly found at the base of the point bar with gravel lags randomly distributed throughout. Lateral accretion surfaces are less common than expected and are only present in the middle section of the point bar, whereas downstream accretion dominates the upstream and downstream sections.

The observed deposits would typically be interpreted as the deposits of braided fluvial systems and have been previously. However, the satellite imagery provides clear evidence that the system comprises point bar deposits of a meandering river. This has important implications for the interpretation of less well exposed cliff sections and interpretation of point bar deposits in subsurface datasets.

NOTES

The role of lateral and vertical geological heterogeneity in controlling floodplain groundwater dynamics and groundwater-surface water interaction: an example of an upland floodplain in Scotland, UK

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Upland floodplains provide an important function in regulating river flows and controlling the coupling of hillslope runoff with rivers. A floodplain in an upland area of the River Tweed catchment, Scotland, was characterised using geophysics, 3D geological mapping, hydrogeological testing and geochemical sampling, and monitored from September 2011 to February 2013 for variations in groundwater levels, river stage, soil moisture and meteorological parameters, including a period of nine months of exceptionally high rainfall.

The floodplain contains an unconsolidated, permeable alluvial and glaciofluvial aquifer 8 to 15 m thick, with transmissivity 50 to 1000 m^2/d, which is coupled to the hillslope by permeable solifluction deposits. The floodplain aquifer is a significant store of, and conduit for, catchment water. It gains recharge from the river and the adjacent hillslope, transmitting groundwater downstream and acting as a buffer to restrict water flowing from the hillslope from directly entering the river.

Floodplain groundwater level fluctuations are driven primarily by changes in river level and the propagation of pressure waves through the floodplain aquifer. There is significant lateral variation in floodplain groundwater response. Most of the floodplain aquifer is hydraulically connected to the river, but groundwater at the edge of the floodplain is strongly controlled by hillslope sub-surface flow.

The geological structure and lithology of the hillslope-floodplain transition is an important hydrological control. It can enhance the influence of subsurface hillslope runoff to the floodplain, which has implications for runoff modelling, flood prevention interventions on hillslopes aimed at reducing runoff, and development at floodplain edges. Vertical heterogeneity in hydrological properties within the floodplain aquifer alters hydrological response, causing different depths of the floodplain to respond differently to hillslope and river inputs. These vertical variations need to be better taken into account in floodplain and hillslope-floodplain studies.

This research demonstrates the importance of understanding the 3D geology and hydrogeology of floodplains in order to advance catchment research and effective flood management measures.

NOTES

Stratigraphy and Provenance of the Lower Old Red Sandstone of the Midland Valley Basin, Scotland

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The 9 km thick Lower Old Red Sandstone (LORS) succession of the northern part of the Midland Valley Basin ranges from Wenlock to Emsian age and comprises largely of conglomerates in the east, passing westwards into sandstones and siltstones. Predominantly of fluvial and alluvial origin, these facies accumulated across the Strathmore basin, with associated deposition occurring northwards across adjacent terranes. Despite decades of investigation, and several advances in provenance studies in recent years there are still some significant uncertainties in understanding the tectonic setting of the basin and the origin of the source terrain. Palaeocurrent data reveal conflicting evidence for a source to the north, east and west, grain size distribution indicates a proximal source potentially to the east and provenance data suggest a northerly and unknown easterly source and provenance is still poorly constrained. The aim of this work is introduce the provenance implications in the northern part of the Midland Valley Basin stratigraphy and to begin to establish a source terrain for the sediment through a combination of petrographical point count and field data.

NOTES

A geological framework for urban sustainability on the banks of the River Ganges: Varanasi, Uttar Pradesh

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The densely populated city of Varanasi, situated on the banks of the River Ganges, is one of the oldest continually inhabited cities in the world and is nominated for world heritage status. With significant religious and cultural importance, Varanasi is included in a list of 100 cities under Phase-1 of the Government of India's Smart City Mission. To be selected for the next stage, Varanasi requires a Smart City Plan that will address a number of present and future challenges, including outdated surface and subsurface infrastructure, severe surface water contamination, and concerns over groundwater vulnerability. An understanding of the geology at a city and regional scale can make a valuable contribution towards plans to address these challenges. Therefore a new collaborative project between BGS and IIT Kharagpur is developing a geological framework for the city, integrating geomorphological and geological mapping, an extensive borehole drilling and sampling programme, groundwater investigations, and remote sensing. These investigations are primarily aimed at: (i) building a city-wide attributed 3D subsurface geological model – the first of its kind in India; (ii) understanding compartmentalisation of the groundwater system; and (iii) developing further knowledge about the dynamics of the River Ganges and continuing landscape evolution in the region. Field research for the project began in January 2016, and has thus far included completion of 60 boreholes, preliminary geological mapping, an initial phase of sampling for sediment provenance and luminescence dating, and water sampling for groundwater chemistry and age. This poster provides a summary of the project scope and describes initial results.

NOTES

Groundwater – meltwater interaction in a proglacial aquifer in an active glacial catchment in SE Iceland

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Groundwater plays a significant role in the hydrology of active glacial catchments, with evidence that it may buffer changes in meltwater river flow and partially compensate for glacial loss. However, to date there has been little direct research into the hydrogeology and groundwater dynamics of proglacial aquifers. Here we directly investigate the three dimensional nature of a proglacial sandur (floodplain) aquifer in SE Iceland, using hydrogeological, geophysical, hydrological and stable isotopic techniques, and provide evidence of groundwater-melt water dynamics over three years.

We show that the proglacial sandur forms a thick (at least 50-100 m), high permeability (transmissivity up to 2500 m^2/day) aquifer, extending over an area of approximately 6 km^2. At least 35 million m^3 of groundwater is stored in the aquifer, equivalent to ~23-28% of total annual river flow through the catchment. The volume of mean annual groundwater flow through the aquifer is at least 0.1-1 m^3/sec, equivalent to ~10-20% of mean annual river flow. Groundwater across the aquifer is actively recharged from local precipitation and strongly influenced by individual rainfall events and seasonal precipitation. Glacial meltwater influence on groundwater also occurs in a zone extending from 20-500 m away from the meltwater river, for at least 3km down-sandur, and to at least 15 m deep. Within this zone summer recharge from the river to groundwater occurs when meltwater river flows are high, maintaining high summer groundwater levels compared to winter levels; and groundwater temperature and chemistry are strongly influenced by meltwater. Beyond this zone there is no substantial meltwater influence on groundwater.

From ~2 km down-sandur there is extensive groundwater discharge via springs, supporting semi-perennial streams that form distinct local ecosystems, and providing baseflow to the main meltwater river.

This research indicates that predicted continued climate change-related reductions in glacier coverage and increases in precipitation are likely to increase the significance of groundwater storage as a water resource, and of groundwater discharges in maintaining environmental river flows in glacier catchments.

NOTES

The influence of flow sequence and event clusters on fluvial flood hazard: a morphodynamic approach

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The United Kingdom experienced severe storm 'clusters' during the winter of 2015/6. Whilst the associated flood Return Periods (RP) of each individual storm were significant, it was the very high frequency of these repeat inundation events which further magnified the flood risk to devastate properties, economies and communities. This evidenced the inter-dependency and influence of storm sequencing, antecedent conditions and river morphology over a channel's capability to convey subsequent flow events. Thus, the aim of the present paper is to examine the sensitivity of river flood hazard to 'clusters' of flow events.

Using river flow gauge data, stochastic modelling combined a hidden Markov Model (HMM) with generalised Pareto distribution (GP) to derive 100 synthetic flow sequences (50 year duration) of comparable probability densities to the observed record. HMM-GP reorders the magnitude, spacing and frequency of events to produce different flow 'clusters' within each sequence. The full flow sequences form the inflow boundary conditions for a traditional quasi-unsteady 1D sediment transport model, effective for long-term prediction of adjustment to channel geometry and conveyance capacity. Using updated geometries, 1D or 1D-2D hydraulic modelling can then assess the sensitivity of flood hazard to flow sequence and be interpreted for 'cluster' influence.

Herein, 'clusters' are defined as a temporal grouping of multiple peak flows above a selected sediment transport threshold discharge. Using the case study location of the River Caldew (Carlisle, England) a discrete high flow 'event' was specified as a discharge above the 10% of 1 year RP. Two temporal grouping approaches were employed to cluster these events: a fixed window (up to 30 days) after a defined event; or, a defined number of antecedent dry days (ADD ≤ 30) between consecutive events. This yielded approximately 3500 above-threshold events and up to 200 clusters for each 50 year flow sequence. For all 100 simulated sequences, each cluster was characterised in terms of antecedent duration, intra-cluster event spacing, event peak discharge, cluster cumulative discharge, skewness, number of events.

The associated model outputs (flood hazard, sediment transport and channel conveyance capacity) were then analysed and cross-correlated to cluster characteristics. Results clearly show that: (i) clusters generate sediment transport loads an order of magnitude higher than that of isolated events of equivalent cumulative flow discharge; (ii) strong correlations are found between morphodynamics and the number of events within a cluster; (iii) flood hazard shows high sensitivity to morphodynamic response to clusters and flow sequence.

NOTES

Geological controls on hillslope to reservoir sediment connectivity: An applied perspective

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Sediment routing within catchments occurs along pathways linking source areas on hillslopes with transport in stream channels and is influenced by the efficiency of source and transport components. These two elements combine to determine the first-order sediment source potential (sediment 'potential') of a catchment. However, the influence of topography, geology, vegetation cover and land use, results in marked spatial and temporal variability in the functioning of sediment transport processes within the catchment.

Sediment routing systems are particularly interrupted by reservoirs in many upland catchments; within Scotland, there are approximately 650 controlled reservoirs used for water supply storage and hydropower generation. Sediment input from upstream catchments affects the water storage capacity over the lifespan of the reservoir, along with its water quality and the stability of its 'lacustrine' habitats. Furthermore, disruption of the sediment conveyor by the reservoir impacts the functioning of the downstream river system.

Geomorphometric methods for modelling connectivity and sediment potential typically account for topography and land use factors but neglect the nature of the rocks and sediments at the Earth's surface. In Scotland, resistant metasedimentary bedrock of the Highlands in the north, sedimentary rocks of the central lowlands and Southern Uplands, and extensive but heterogeneous coverage of unlithified glacial and postglacial sedimentary deposits, provide a diverse range of geological materials available for erosion. Variation in the erodibility of these rocks and sediments is likely to strongly influence the distribution of sediment potential within catchments.

Combining geological mapping and geotechnical data, we have developed an erodibility parameter for sediment source potential mapping and integrated this within connectivity modelling frameworks. We have applied the modified geomorphometric modelling procedures in conjunction with geomorphic mapping to develop a quantitative approach for mapping sediment potential in test catchments in Scotland located upstream from reservoirs. We explore how our integrated approach to sediment potential mapping may be used to inform decision making in land use planning and environmental management, particularly in relation to sediment delivery to reservoirs and natural lakes. This supports the broader application of holistic ecosystems approaches to land use policy, as exemplified by the Scottish Government's Land Use Strategy.

NOTES

Forensic analysis of the 2008 Central Queensland Floods

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In January 2008 a major flooding event severely impacted an open cut mine in Central Queensland, Australia causing major flooding of a number of pits, loss of major equipment, loss of production, and ultimately, a large insurance claim. This paper presents the forensic, root cause analysis of the flooding event in terms of interaction between rainfall, rivers and reservoirs.

Rainfall in the vicinity of the mine was minimal compared to the intense 72 hour rainfall event in the mountainous areas 140 km to the west of the mine site.. Rain fell in short, intense bursts over the upper catchment of an area approximately the size of England and Wales. The catchment contained less than 30 gauging stations, most with records of less than 50 years duration. Five of these stations were critical to understanding water transfer through the catchment. One of the five had a record duration of only 14 years.

There are three major pathways from the area of intense rainfall in the upper catchment to the mine, each with its own flow characteristics. A major reservoir is sited on one flow channel. The scarp associated with the mountainous area is steep and rugged. The gradient across the flood plain is between 1:1000 to 1:2000.

At the junction of the three flow pathways, the floodplain is approximately 6 km wide with low irrigation levees transverse to the flow. This 6 km wide flow is then constrained to flow through a 1 km wide gap between the southern and northern groups of open pits.

Assessing the possible interactions between rainfall, rivers and reservoirs required knowledge of the following

- Magnitude, intensity and manner of rainfall;
- Interaction of intense rainfall bursts with landform, floodplain, vegetation, channel and constructed geomorphology;
- Relevance of the siting and adequacy of gauging;
- Flood pulse sequencing and discharge characteristics of reservoirs;
- Palaeochannels and their relationships to surface and sub–surface flow-paths;
- Expansive/cracking and dispersive properties of clay minerals in soils and palaeochannels;
- Characteristics of frequency distributions used to extrapolate rainfall and flow data to longer time periods;
- Field characteristics of poorly gauged catchments;
- Potential value of direct observations of flood characteristics syn and post flooding; and
- Sources of primary, secondary, tertiary and anecdotal data and their validity.

It was concluded that (a) field based observational data are often much more useful than statistically reconstructed data, and (b) geomorphological evaluation of the whole–of–catchment is vital.

NOTES

Multi-source flood risk assessment based on join probability analysis in costal cities

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Quantitative multi-hazard risk assessment is important for hazard risk mitigation and management in regions exposed to multiple natural hazards. Risk analysis of flooding from multiple sources is essentially a multi-hazard issue, especially in coastal cities that may be impacted by fluvial, pluvial and costal floods. Correlations and dependence commonly exist between different flood drivers as they may be triggered or influenced by the same weather system. An integrated assessment framework for multi-source flood risk is proposed to quantify the probability and potential loss caused by heavy rain, extreme river flow and storm surge in costal cities. The Copula theory is applied to measure the dependence between the three flood drivers and fit their joint probability distributions, creating concurrent events under different scenarios of probability. Taking the concurrent events as boundary inputs, a GPU-accelerated hydrodynamic model is used to predict the corresponding flood extent and depth. Then, different types of vulnerability curves that illustrate the possible loss of different exposures as a function of hazard (flood extent and depth) will be used to facilitate the calculation of the probability of loss at various levels. London, which is at high risk to pluvial, fluvial and costal floods, is selected as a case study site in this work to demonstrate the applicability of the proposed multi-hazard risk assessment framework. Preliminary results show that, compared with single-hazard risk assessment, the integrated multi-hazard risk assessment framework provides more reliable information and guidance for regional land-use planning, disaster prevention and emergency management.

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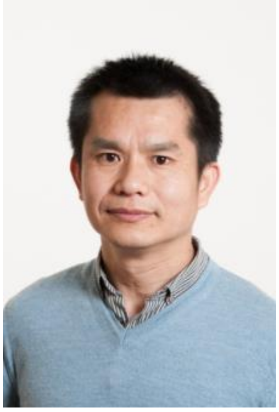

Is China's fifth-largest inland lake to dry-up? Incorporated hydrological and satellite-based methods for forecasting Hulun Lake water levels

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Hulun Lake, China's fifth-largest inland lake with an area of over 2,000 km^2 and average depth of ~ 6 m, experienced severe declines in water level (~4 m) in the period of 2000-2010. This has prompted concerns whether the lake is drying up gradually. A multi-million US dollar engineering project to construct a water channel to transfer part of the river flow from a nearby river to maintain the water level was completed in August 2010. This study aimed to advance the understanding of the key processes controlling the lake water level variation over the last five decades, as well as investigate the impact of the river transfer engineering project on the water level. A water balance model was developed to investigate the lake water level variations over the last five decades, using hydrological and climatic data as well as satellite-based measurements and results from land surface modelling. The investigation reveals that the severe reduction of river discharge (-364±64 mm/yr, ~70% of the five- decade average) into the lake was the key factor behind the decline of the lake water level between 2000 and 2010. The decline of river discharge was due to the reduction of total runoff from the lake watershed. This was a result of the reduction of soil moisture due to the decrease of precipitation (-49±45 mm/yr) over this period. The water budget calculation suggests that the groundwater component from the surrounding lake area as well as surface run off from the un-gauged area surrounding the lake contributed ~ net 210 Mm^3/yr (equivalent to ~ 100 mm/yr) water inflows into the lake. The results also show that the water diversion project did prevent a further water level decline of over 0.5 m by the end of 2012.

Overall, the monthly water balance model gave an excellent prediction of the lake water level fluctuation over the last five decades and can be a useful tool to manage lake water resources in the future.

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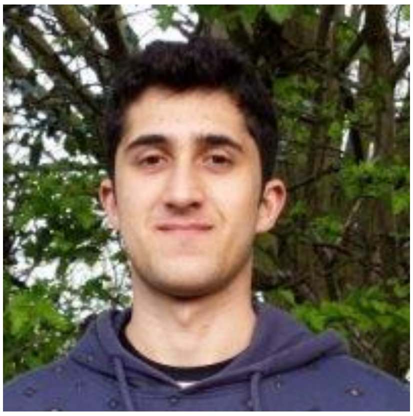

Sediment-triggered meander deformation in the Amazon Basin

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External sediment supplies are a fundamental component of alluvial systems, yet a complete understanding of their role in meandering channel dynamics remains relatively primitive. Meander migration is the principal mechanism by which river channels increase their sinuosity and occupation in the floodplain. We use an almost yearly archive of Landsat imagery, in concert with a decadal time series of rivers from across the Amazon Basin, to show that meander migration increases channel length as a power function. We characterised the dominant meander movement mechanism by defining an index we term the meander symmetry index. The index measures the ratio between downstream and upstream meander erosion about the apex and bounded by inflection points. Indices greater than one represent more translational meander deformation, that is, downstream migration, whereas indices close to one indicate more extensional migration (i.e., increasing meander amplitude).

Our results suggest that rivers located in sediment-rich regions migrate more rapidly, and possess higher symmetry indices indicative of more translational bend development. Conversely, rivers with low sediment yields show more extensional bend development. Since alluvial material is responsible for the construction of point bars, we propose that rivers conveying larger sediment loads build bars more quickly, predominantly downstream of the apex, which promotes bank erosion. An analysis of point bar locations in two meandering streams shows that bars positioned downstream of the apex correlate with bends that undergo translational development. Therefore, our results suggest that point bar growth and its relationship to the sediment budget of rivers plays an important role in meander migration. The significance of these findings is manifold: a broader understanding of the role of point bars in the evolution of meandering planforms is required to inform numerical models to permit accurate predictions of channel change, floodplain development, and sediment cycling; mechanisms of bend deformation control the development of alluvial architecture, and therefore, interpretations of the stratigraphic record and; finally, the movement of river bends is of particular interest to those undertaking risk analyses or forecasting the rate and trajectory of river bends in the future.

NOTES

Cosmogenic nuclide concentrations in Neogene rivers of the Great Plains reveal the evolution of fluvial storage and recycling

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The measurement of the duration of near surface residence of sediment grains from the stratigraphic recordhas the potential to quantitatively reconstruct processes such as stratal condensation, sediment recycling and the exposure histories of unconformities. Geomorphological measurements of dates and rates of surfaces and erosion respectively has enabled significant advances in understanding, however, the radiogenic half life of typical cosmogenic nuclides such as 10Be and 26Al means they are not suitable for the stratigraphic record. Instead, we have applied the stable cosmogenic nuclide of 21Ne to quartz-rich sediment to quantify the routing history of the river systems that have drained the southern Rockies of Wyoming and Colorado during Neogene times. The Neogene sediments of Nebraska record fluvial systems of the Great Plains that flow from the Rockies towards the east and into the Mississippi catchment. This succession is <300 m thick, and records successive episodes of fluvial incision and aggradation associated with regional tilting from 6 to 4 Ma and periods of climate change. As part of an evaluation of the application of 21Ne to the stratigraphic record, we sampled quartzite pebbles from an Upper Miocene, Pliocene and modern river channel of the North Platte approximately 400 km from their mountainous source. The quartzite is derived from a single exposure of the Medicine Bow quartzites in Wyoming, therefore all three intervals recorded the same travel distance from source. Additionally, we know the erosion rate of the Medicine Bow quartzites from detrital 10Be analyses, and we also sampled shielded bedrock samples from the quartzite to evaluate for any non-cosmogenic 21Ne. This means that the concentrations of 21Ne in detrital pebbles >400 km from their source could be corrected for both inherited non-cosmogenic and erosion induced accumulation at source. Therefore, any additional amounts of 21Ne must record storage and exposure during transport down the river systems. Based on 40 analyses of pebbles from these intervals, we are able to demonstrate that approximately half of the pebbles record significant excess 21Ne resulting from storage and transport, indicating a mixing of first generation and recycled pebbles throughout the succession. Furthermore, the numbers and concentrations of excess 21Ne in the pebbles are comparable between the three time intervals indicating little change in the extent of storage and recycling of river sediment from late Miocene to present. These results represent the first application of stable cosmogenic nuclides to the stratigraphic record and point to a significant development in our ability to quantify sediment routing systems.

NOTES

Linear inverse modelling and scaling analysis of drainage inventories

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It is widely accepted that the stream power law can be used to describe the evolution of longitudinal river profiles. Over the last 5 years, this phenomenological law has been used to develop non-linear and linear inversion algorithms that enable uplift rate histories to be calculated by minimising the misfit between observed and calculated river profiles. Substantial, continent-wide inventories of river profiles have been successfully inverted to yield uplift as a function of time and space. Erosional parameters can be determined by independent geological calibration. Our results help to illuminate empirical scaling laws that are well known to the geomorphological community. Here we present an analysis of river profiles from Asia. The timing and magnitude of uplift events across Asia, including the Himalayas and Tibet, have long been debated. River profile analyses have played an important role in clarifying the timing of uplift events. However, no attempt has yet been made to invert a comprehensive database of river profiles from the entire region. Asian rivers contain information which allows us to investigate putative uplift events quantitatively and to determine a cumulative uplift history for Asia. Long wavelength shapes of river profiles are governed by regional uplift and moderated by erosional processes. These processes are parameterised using the stream power law in the form of an advective-diffusive equation. Our non-negative, least-squares inversion scheme was applied to an inventory of 3722 Asian river profiles. We calibrate the key erosional parameters by predicting solid sedimentary flux for a set of Asian rivers and by comparing the flux predictions against published depositional histories for major river deltas. The resultant cumulative uplift history is compared with a range of published geological constraints for uplift and palaeoelevation. We have found good agreement for many regions across Asia. Surprisingly, single values of erosional constants can be shown to produce reliable uplift histories. However, these erosional constants appear to vary from continent to continent. Future work will investigate the global relationship between our inversion results, scaling laws, climate models, lithological variation and sedimentary flux.

NOTES

Can machine learning reveal sedimentological patterns in river deposits?

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River deposits are rich in sedimentological patterns that reveal formative environmental dynamics. Interpreting these patterns is the key to characterizing fluvial hydrocarbon reservoirs and aquifers, and provides the data needed to calibrate physics-based models of modern rivers. However, traditional process-based interpretations are usually biased to a limited number of classifications, concepts, and process-models. Have we recognised all significant patterns? And, are all patterns that we recognise significant? We know our understanding is incomplete and biased because rivers and their deposits are highly variable. Variability in river systems is great today, is predicted to change under environmental and climate change scenarios, and is greater still when integrated over all of geological time. Machine learning provides a means of analysing such bias and uncertainty within our data domains.

Herein, we apply machine learning techniques to objectively classify the information encapsulated in sedimentary logs from two modern braided rivers: the Río Paraná, Argentina, and the South Saskatchewan River, Canada. We apply various data classification techniques, such as Self-Organising Maps, for unsupervised clustering of sedimentary logs. Early results show that machine learning classification has indeed the potential to reveal interpretable sedimentological information by grouping well-logs according to consistent sedimentological patterns.

Being able to classify sedimentological information in such a semi-automatic way opens new avenues for the analysis of much larger data domains, the interpretation of which would otherwise require vast manual expert effort. Furthermore, automated detection of sedimentological features from data enables the quantification of levels of uncertainty within the data domain. As such, machine learning provides a rigorous pathway to integrate uncertainty information into data-driven predictive models, and allows the identification of ‘poorly understood’ aspects of river systems.

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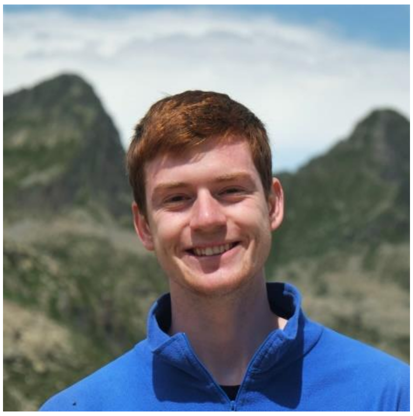

Regional Cenozoic Uplift of Europe from Linear Inverse Modelling of Longitudinal River Profiles

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The shape of a river profile is controlled by the interplay between uplift and erosion. It is generally accepted that the phenomenological stream power law provides a useful basis for determining how this shape evolves as a function of time and space. Typically, erosion is parametrised using two terms. The first term controls the upstream advection of knickzones and assumes that the advective velocity is a function of upstream drainage area and local slope. The second term controls ‘rock diffusivity’, which acts to lower the river profile. In the geomorphological community, the stream power law is usually solved by assuming steady state and by plotting upstream drainage area as a function of slope. Here, we use an integrative approach to solve the equation without the need to assume steady state. Previous work has shown that the ‘rock diffusivity’ term, together with the exponent of local slope (i.e. *n*), can be ignored at long wavelengths. This simplification enables the linear inverse problem to be posed and solved using the method of characteristics. Large inventories (i.e. thousands river profiles) can be inverted to determine regional uplift rate histories as a function of time and space. We present results from an analysis of a Western Eurasian drainage network, consisting of 1,126 river profiles. This region encompasses at least four areas of high elevation where the origin of topography is much debated (i.e. Scandinavia, Spain, Turkey, Italy). Linear inverse modelling yields excellent fits between observed and calculated river profiles. The key erosional parameters were determined using independent geological observations (e.g. stratigraphic evidence for marine incursions, emergent marine terraces, thermochronological constraints). Our results suggest that each of these areas has undergone significant regional uplift in Cenozoic times. Since the linearized approach is computationally efficient, it is possible to systematically test the sensitivity of our results to key input parameters (e.g. upstream drainage area, *m*). This analysis confirms that inverse modelling of large numbers of river profiles yields coherent results and that this general approach is a powerful tool for helping to determine the spatial and temporal evolution of topography.

NOTES

A comparison of two active-margin deltas: contrasting drainage responses to Neogene plate boundary processes

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Large rivers are the primary means by which sediment is transferred from areas of active erosion to sites of deposition in terminal basins. These rivers, or their tributaries, are also the principal agent by which erosion takes place; they are the prime modulators of the landscape, responding both to tectonically driven rock uplift (or lateral transfer) and climatic processes, and influencing these processes in return. The most continuous record of these processes over geological timescales are preserved in deltas at continental margins; understanding the record stored in these marine repositories is crucial to testing models of landscape and fluvial evolution.

Most of the Earth's largest rivers supply deltas that are deposited on passive margins. These fluvial systems are typically stable over geological time scales, and their deltas are relatively unaffected by plate boundary processes. Large active margin deltas, by contrast, are rare, with deposition being strongly affected by tectonic processes. Fluvial systems supplying these delta are much more susceptible to drainage capture or diversion, which can have a significant impact on sediment flux, as well as reservoir distribution and quality. We look at the depositional record of two such rivers and their deltas: the Amur in the Russian far-east, and the Colorado in the southwestern US. We use a multi-disciplinary approach, incorporating multiple sediment provenance techniques and sediment budgets, to understand the long-term flux of sediment to the continental margins, and the stability of the drainage systems themselves. In the case of the Amur, we demonstrate a relatively stable fluvial system for over 20 Ma, despite changes in tectonic boundary conditions, with sediment flux instead being primarily affected by climatic changes. In the case of the Colorado, we demonstrate that the present-day drainage configuration is much younger (~5 Ma), having been significantly modified by changes in plate boundary processes.

NOTES

Sediment control assessment of proposed waste rock facilities at Simandou

Angelo Papaioannou, WSP Group

Client organisation – Rio Tinto

Rio Tinto is investigating the feasibility of developing a major iron ore mine at Simandou, Guinea, W. Africa http://www.riotinto.com/guinea/about-simandou-10974.aspx
Schlumberger Water Services (SWS) were engaged by Rio Tinto to assist with hydrologically based tasks concerning this project. This presentation concerns work related to erosion and sediment control for the scheme undertaken in 2008-2012 forming an important component within a much wider hydrological remit and culminating as a standalone chapter within the Definitive Engineering Studies (DFS) report[1] .
The sediment control studies included both generic (mine site wide) and targeted considerations focused on the proposed waste rock facilities (WRFs) for the scheme. The generic considerations entailed deployment of well-established good practice measures to control erosion and sediment mobilisation typical of those for comparable projects generating significant ground disturbance. This presentation focuses on specific assessment work undertaken in respect of the proposed major WRFs. The key considerations included:

1. Characterisation of the waste rock streams (total and annual quantities plus sequencing for life of mine (LoM)) and key characterisation (rock type, PSDs and erodibility).
2. Land form management, focusing on placement (timing, configuration/geometry), enhanced stabilisation and drainage management.
3. Erosion/sediment generation prediction and mobilisation as suspended sediment in drainage.
4. Deployment of sediment control ponds downstream of the WRFs and predictive assessment of their anticipated control performance.

The assessment of sediment control performance was significantly guided by design criteria/objectives to demonstrate compliance with IFC (International Finance Corporation) standards for suspended sediment concentrations within mine water discharges to the receiving water environment. This entailed developing a suite of time variant analytical models for the assessment and provides a departure from more simple and formulaic solutions more typically applied to underpin engineering and design considerations for this specific aspect of mine scheme assessment. The principal steps within the sediment and erosion control assessments for the WRFs included:

1. Time variant modelling of drainage, erosion and suspended sediment regimes for the WRFs.
2. Time variant hydraulic routing of the resulting drainage regimes from WRFs plus modelling of associated suspended sediment capture performance for a variety of potential sediment control pond configurations.

On this basis we wish to present and share salient details of the work undertaken and hopefully prompt feedback so these methods can be refined in future applications of a comparable nature.

[1] Rio Tinto; Simandou Iron Ore Project Guinea; Definitive Engineering Studies - Mine Water Management; ref 50837/R3; December 2012

NOTES

Nhecolândia wetland as record of environmental change: Using past and present dynamics to infer sensitivity to future climate changes

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Dr. Chris Hackney, University of Southampton, UK
Dr. Arnoud Bloom, University of Leicester, UK
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Dr. Ryan Pereira, Newcastle University, UK
Dr. Tom Wagner, Nothumbria University, UK

The Pantanal wetland in Brazil is a region of distinct landscapes and fauna of great importance, being considered by UNESCO as a World Natural Heritage Site and Biosphere Reserve. It is also an important economic region, providing US$100 million a year through the touristism sector. Additionally, it is a high scale cattle breeding area, holding 6% of the Brazillian meat production. Some studies have shown that the southern area of Pantanal, the Nhecolândia region, has undergone an aridification process in the last thousand years. The Nhecolândia region is characterized by its lakes and its high biodiversity, and is situated on the southern fringe of the Taquari River megafan. It is marked by about 10,000 ponds, bordered by sand ridges, with geochemical compositions that vary spatially, with freshwater, oligosaline and saline ponds juxtaposed very close to each other. Several authors have attempted to explain the origins of this peculiar Pantanal landscape and the salinity variations between the isolated ponds. Hypotheses include the reworking of fluvial sediments by eolian processes, the confinement of floodplain areas due to cross-cutting and overlapping of marginal levees, and wind deflation assuming that past arid climates gave rise to the presence of saline lakes from relict sabkhas. Despite the plethora of evidence and arguments presented by many authors to interpret the genesis of Nhecolândia landscape, the origin of these lakes has remained a controversial topic. Here, we propose to identify changes in the Nhecolândia landscape, hydrology and geochemistry through analysis of fluvial records and sedimentological analysis in order to understand current wetland dynamics. Using this understanding we will then assess and report on the sustainability and potential climatic risks for the Pantanal biodiversity and general functioning of the wetlands in the future for preservation and management purposes (people-centered risk communication).

NOTES

Proximal outcrop to distal core deposits comparisons for the hydrocarbon industry: examples from the Barmer Basin

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Analysis of both outcrop and core data is well used throughout the petroleum industry. This research has analysed the Ghaggar-Hakra Formation of the Barmer Basin, India. The proximal outcrops have been used to determine the nature of the fluvial system and are then linked to distal cores in the central Barmer Basin. The subsurface formation is composed of two members; the fluvial Pushka Member and the lacustrine Kamyaka Member, whereas the outcrop deposits only represent the Pushka Member.

The outcrop sediments are composed of three separate fluvial successions, with interbedded well-developed floodplain deposits. The lowermost succession, the Darjariyon-ki Dhani Sandstone contains channels, gravel bars, and sparse floodplain deposits, representing a low sinuosity system. Sarnoo Sandstone containing channels, gravel bars, point bars, and well-developed floodplain deposits, representing a high sinuosity system. Capping the formation, the Nosar Sandstone is dominated by stacked and amalgamated channels and gravel bars, with sheetfloods and intermittent floodplain deposits towards the top of the succession, representing a low sinuosity system. The rejuvenation of the fluvial system is attributed to the regional tectonic framework.

By drawing comparisons between the channel fill and gravel bar sedimentology of the Nosar Sandstone, alongside the petrographical analysis, we are able to attribute the deposits to the lower-most sandstone succession in the core data – the Pushka Member. Above this are the lacustrine deposits (Kamyaka Member), overlain by a second low-sinuosity fluvial system, both successions cannot be related to the outcrop deposits. The interbedded nature of fluvial and lacustrine deposits suggests migration of the lacustrine shoreline or fluvial system through time. Migration of the lacustrine or fluvial environments may have resulted from renewed tectonic activity and therefore may correlate to a change in fluvial style in the proximal setting. However, a climatic control on the position cannot be ruled out.

Comparisons between the outcrop and core data suggest that the Ghaggar-Hakra Formation represents deposition in a dominantly fluvial environment draining from the basin margin into a lacustrine system in the basin centre. The early stage Cretaceous structural development of the basin margin is likely to have had a strong influence on the fluvial regime, especially in later Ghaggar-Hakra times. As the deposits in core relate to the outcrops, the three-dimensional architectural elements and facies models can act as perfect analogues to the subsurface. Therefore the models are used for predictions of reservoir quality, net to gross ratio, and the potential locations of impermeable barriers.

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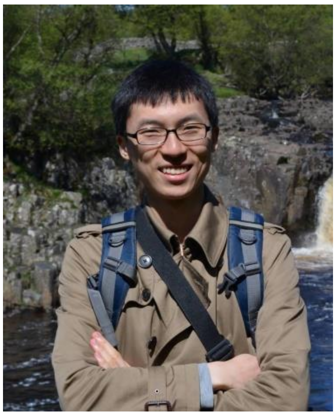

A new high-performance depth-averaged modelling framework for flow-like landslides

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Intense or prolonged rainfall may trigger flow-like landslides, which are featured by their high flow velocity and long travel distance. These events pose great threat to human lives and properties and have a significant influence on local landscapes. Numerical modelling provides an indispensable means to predict flow-like landslides, quantify their influence on geomorphological changes and facilitate risk analysis and management. To reduce the prohibitive computational cost of the three-dimensional (3D) simulations, most of the existing physically based flow-like landslide models are based on the solution to the two-dimensional (2D) governing equations derived by integrating the fully 3D equations along the vertical axis. However, most of the existing depth-averaged models face a number of issues when they are used to handle real-world applications.

This work presents a new depth-averaged flow-like landslide model on a global Cartesian coordinate system. New governing equations are derived in a mathematically rigorous way based on the shallow flow assumption and Mohr-Coulomb internal rheology. Particularly, the new mathematical formulation takes into account non-hydrostatic pressure and curvature effects caused by complex topography. The new governing equations are solved using a shock-capturing Godunov-type finite volume method to ensure accurate simulation of complex flow dynamics, with a novel numerical scheme proposed to discretise the friction source terms. The widely used hydrostatic reconstruction approach is improved and implemented in the context of the new governing equations, providing well-balanced and non-negative numerical solutions for mass flow over rough terrains. Different basal resistance formulas are implemented and tested for various types of flow-like landslides. Finally, the new model is accelerated by implementation on high-performance Graphic Processing Units (GPUs) to substantially improve the computational efficiency and support large-scale simulations at high resolutions.

The new flow-lake landslide model is validated against several test cases, including a flow-like landslide in loess plateau, China and a rock avalanche in Socompa, Chile. Satisfactory results are obtained, demonstrating the model’s much improved predictive capability for wider applications.

NOTES

Geomorphic Flux From Himalayan Flashflood Equates to 1000 yrs Average Erosion Rate

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Extreme flood events are increasingly reported from the western Himalaya; we use geomorphic analyses to reconstruct both the spatial distribution and approximate the recurrence interval for these events. During the summer of 2010, an enhanced monsoon resulted in extensive flooding of the Indus Valley of Pakistan. An unusual aspect of this event was the intense precipitation in the arid upper reaches of the Indus River in Ladakh. On August 5th, a mesoscale convective system caused intense, short-lived precipitation, with estimates of 75-100 mm falling in approximately 30 minutes. The short-lived convective nature of the rainfall meant TRMM data was unable to locate the main event. However, a geomorphic reconstruction of river discharge and hillslope activity demonstrates that the precipitation was limited to a 3 to 6 km wide band on the southward facing slopes of the Ladakh Range, and that this can be traced approximately 120 km along the strike of the range. In addition to mapping out the extent of the event, we also reconstruct the total flux mobilised on selected hillslopes by debris flows; this was achieved by measuring width/depth ratios across a range of scales, and then assigning a stream order to the debris flows which are then mapped over selected sub-catchments. This process provided a volume of mass flux which was then compared to background erosion rates derived from detrital cosmogenic 10Be measurements. This comparison reveals that the Ladakh event mobilised the equivalent of 800-1200 yrs of the mean background erosion rate in these catchments. Repeat 10Be measurements from the same catchments before and after the event record a reduction in concentrations which are explored in terms of the scale of debris flows principally responsible for the flux. Two years after the Ladakh event, another major flood event occurred in Uttarakhand, resulting in >5700 deaths. Initial investigations of the erosion of dated moraines and the deposition of new terraces indicate that this was also the most significant for at least 1000 years. Whether the occurrence of two major events with repeat intervals on a millennial timescale is significant in terms of changing frequency of extreme monsoonal storms remains uncertain.

NOTES

Future flood extents: capturing the uncertainty associated with climate change

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Floods are the most common and widely distributed natural risk to life and property worldwide, causing over £6B worth of damage to the UK since 2000. Climate projections are predicted to result in the increase of UK properties at risk from flooding. It thus becomes urgent to assess the possible impact of these changes on extreme high flows and thus the impact on flood extents, and evaluate the uncertainties related to these projections.

This paper aims to assess the changes to flood extent for the 1:100 year return period event for the River Don in Scotland (UK) as a result of climate change. It is based on the analysis of the Future Flow dataset (1961-2098 across the UK) for the Parkhill gauge station on the River Don (Collet et al., 2016). Extreme value (EV) analyses (with the GEV and GP distribution functions) are fitted for the 11 climate-change ensembles over the baseline (1961-1990) and the 2080s (2069-2098) to account for climate non-stationarity. Monte Carlo simulations, sampling from the EV distributions of 1:100 year return period events, are undertaken using a 1D-2D hydraulic model (LisFLOOD) of a 5km stretch of the river Don. Full Monte Carlo simulations are undertaken for the baseline and future planning horizon and results are analysed. Results show the change to extent from the baseline to the future (+24%), and capture the significant uncertainty associated with the climatic projections and the EV distributions. This suggests that capturing these uncertainties (both in the baseline and in future estimates) is essential when planning engineering interventions.

NOTES

Subsidence Controls on River Morphology in the Ganga Plain

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The Ganga Plain represents a large proportion of the current foreland basin to the Himalaya. The Himalayansourced waters irrigate the Plain via major river networks that support _7% of the global population. However, some of these rivers are also the source of devastating floods. The tendency for some of these rivers to flood is directly linked to their large scale morphology. Systematic variations in the large scale morphology of the river systems are recognised across the extent of the Ganga foreland basin. In general, the rivers that drain the east Ganga Plain have channels that are perched at a higher elevation relative to their floodplain, leading to more frequent channel avulsion and flooding. In contrast, those further west have channels that are incised into the floodplain and are historically less prone to flooding. Understanding the controls on these contrasting river forms is fundamental to determining the sensitivity of these systems to projected climate change and the growing water resource demands across the Plain. Here, we present a new basin scale approach to quantifying floodplain and channel topography that identifies the degree to which channels are super-elevated or entrenched relative to their adjacent floodplain. We explore the probable controls on these observations through an analysis of basin subsidence rates, sediment grain size data and sediment supply from the main river systems that traverse the Plain (Yamuna, Ganga, Karnali, Gandak and Kosi rivers). Subsidence rates are approximated by combining basement profiles derived from seismic data with known convergence velocities; results suggest a more slowly subsiding basin in the west than the east. Grain size fining rates are also used as a proxy of relative subsidence rates along the strike of the basin; the results also indicate higher fining rates (and hence subsidence rates for given sediment supply) in the east. By integrating these observations, we propose that higher subsidence rates are responsible for a deeper basin in the east with perched, low gradient river systems that are insensitive to climatically driven changes in base-level. In contrast, the lower subsidence rates in the west are associated with a higher elevation basin topography, and entrenched river systems recording climatically induced lowering of river base-levels during the Holocene.

NOTES

Testing the sensitivity of the Andes to environmental change using alluvial fan stratigraphy

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Dynamic depositional processes that we observe in the landscape today are actively creating time integrated stratigraphy, but to what extent do these recent records translate the climatic and tectonic state of the landscape? Using the Iglesia basin of the south Central Argentine Andes as a natural laboratory, we test the extent to which well-constrained alluvial fan stratigraphy records known tectonic and climatic change. We measure downstream grain size trends along the modern river systems and older fan surfaces of three alluvial fans, along strike of the Andean Frontal Cordillera, and evaluate the extent to which our results can be explained by recently-published models of down-system grain size fining.

A number of recent stratigraphic models apply self-similar solutions for down-system grain size fining in order to predict spatial and temporal trends in grain size. This approach describes the selective extraction of sediment downstream, which arises as a function of the magnitude and characteristics of the input sediment supply and the spatial distribution of basin subsidence, through utilising only the mean and standard deviation of local grain sizes. Where depositional systems can be observed as having self-similar surface grain size distributions, we have an extremely valuable quantitative tool for modelling fluvial stratigraphy without the need for multiple hydraulic variables that are essentially unknowable for the geological past. We can use these solutions to describe grain size fining as a function of the wavelength and amplitude of subsidence and the filled state of the basin, in principle giving us access to the climatic and tectonic boundary conditions behind the stratigraphy. We assess whether coherent grain size distributions that approximate self-similarity can be observed in our field measurements and we evaluate the extent to which self-similarity grain size fining models are capable of predicting known climatic and tectonic boundary conditions.

Through a comparison of three fan systems, ranging in length from 20-40 km, fed by catchments with distinctly different characteristics, varying in size and glacial cover, we exploit an excellent opportunity to evaluate the controls on climate signal translation. We demonstrate that fan surface reworking plays a significant role in modulating the preservation of climate signals in stratigraphy and ultimately test to what degree these stochastic processes have influenced the preserved depositional pattern. Without such an understanding of the controls on signal preservation for modern systems, we cannot begin to understand the limits of interpretation for the Ancient.

NOTES

A High-Performance Integrated Hydrodynamic Modelling System for Sustainable Catchment Systems Management

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As a consequence of climate change, population growth and rapid urbanisation, 'extreme' flood events will increase in both frequency and severity in the near future. Traditional 'hard' engineered approaches to flood control schemes are not guaranteed to provide an acceptable level of protection under these changing conditions; ensuring flood resilience and long-term sustainability has become a momentous challenge. In a catchment scale, a new paradigm is to manage flood risk at the source by working with natural processes (WWNP), ordinarily accomplished through altering, restoring or using the landscape features to reduce flood risk and offer multiple benefits, e.g. improving water quality and increasing biodiversity. However, neither well-defined approaches nor recognised models have been developed as yet to provide scientific evidence of this approach, facilitate its implementation and elucidate the practice. This is beyond the capability of the traditional hydrological or simplified hydrodynamic models due to their incapability in representing the intense rainfall induced transient hydrological and hydrodynamic processes.

We need a new generation catchment systems model to better understand the complex catchment response processes following intense rainfall and subsequently use it facilitate the design customised systematic management strategies to adapt catchments to convey reduced flood risk. Such a modelling system must be able to reproduce transient rainfall-runoff and overland flows based on the shock-capturing hydrodynamic solution to the 2D shallow water equations (SWEs). However, the existing SWE models cannot produce satisfactory results for overland flows due to their incapability of correctly computing slope source terms in the presence of small water depth. Most of these models also use explicit or semi-implicit schemes for friction term discretisation, which do not recover the correct asymptotic flow behaviour when water depth becomes small and hence cause numerical instability. Furthermore, these hydrodynamic models are typically computationally demanding, preventing their wider applications to support high-resolution simulations at an entire catchment scale which is essential for supporting multi-level sustainable catchment systems managements. Resolving all of these challenging issues, we present a high-performance hydrodynamic modelling system to support sustainable catchment systems management. Based on finite volume shock-capturing solution to the fully 2D SWEs, the modelling system features 1) a novel surface reconstruction method (SRM) to correctly compute slope source terms even in the presence of very small water; 2) a fully implicit friction term discretisation scheme that recovers the correct asymptotic behaviour of governing equations and maintains numerical stability when the water depth becomes small, and 3) unprecedented computational speed provided by the implementation of high-performance GPU computing. The new modelling system is able to simulate the whole catchment of ~1000 km^2 with ground-breaking resolutions (~1m).

NOTES

 

The Queensferry Crossing: Bridge Foundations in an Estuarine Environment

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The Queensferry Crossing is a new major road bridge across the Firth of Forth, which has involved significant construction activity within the estuary. The paper describes the project, focussing on the interaction between the crossing and the estuary and the management of the potential engineering and environmental impacts. The management strategy adopted included predictive 3D hydrodynamic modelling, best-practice design methodologies supported by physical modelling of proposed scour protection, and monitoring throughout construction and into the post-construction phase to verify the predicted behaviours. The design and construction of the foundations are described, with examples of localised scour and deposition effects identified by the monitoring regime and how they were addressed.

NOTES

Describing Fluvial Systems: linking process to deposits and some considerations of grain size and scale

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Interpreting the ancient from understanding the modern lies at the heart of much of sedimentology, and how we characterize and quantify the nature of alluvial deposits. This understanding can be achieved from a variety of approaches to describing fluvial systems, from physical experiments, to interpretation of channel change through sequential imagery, through to surveys and subsurface characterization of modern channels and their deposits. All of these have to be viewed through the lens of preservation, and the factors that may favour, or limit, the preservation of various depositional niches. This talk will illustrate the nature of a range of alluvial deposits from study of modern environments, with attention on finer-grained alluvial channels that have received relatively little study in comparison to sand- and gravel- bed rivers.

The talk will follow three strands of research that detail a series of collaborative projects concerning different aspects of alluvial sedimentary structures and architecture from study of modern channels. First, examination of dune bedforms, perhaps the dominant small-scale alluvial bedform across a wide range of large alluvial channels, shows their morphology, and especially leeside angle, to be very different to classic angle-of-repose dunes. The talk will illustrate a unique dataset that quantifies these characteristics, and will be used to discuss possible controls on such dune morphology, what we might expect to see when examining such bedforms in the ancient sedimentary record and the implications of these characteristics for reconstruction of flow depths from cross-set thickness. Secondly, the talk will examine the alluvial architecture of the Río Bermejo River in Argentina, a highly active meandering river that transports a large fine-grained sediment load. A combination of morphological surveying and subsurface characterization using Parametric Echo Sounding (PES) reveals a series of distinctive facies that may help define such finer-grained rivers in the ancient record: the talk will illustrate the deposits of the Río Bermejo from both parts of the highly active meandering channel as well as at a river confluence. Lastly, the talk will examine the nature of large-scale scours and their infill in the Ganges-Brahmaputra-Meghna fluvial system, investigate how scour depths change in a downstream direction across the fluvial – tidal region, and how scour depths respond to such distributive flows. A combination of MBES and subsurface seismic surveys also allows us to examine the infill of these scours, how these relate to models derived from smaller alluvial channels, and how the scale and mobility of such scours may influence large-scale erosion surfaces. The talk will aim to highlight the uses, abuses, advantages and drawbacks of using such studies to help disentangle the meaning of alluvial architecture in ancient sediments.

NOTES

Stochastic modelling approach for synthesizing streamflow

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Practitioners are keen to maximize long-term sustainability of flood risk management (FRM) projects, such as simulation of the morphological response of rivers for scheduling dredging intervention or designing flood defence levels; assessing long-term loading patterns acting on defence structures; and accounting for the antecedent conditions of flood storage reservoirs. A range of mathematical tools and software's, mainly based on the use of single *N* year extreme flow or rainfall event, are available to conduct a thorough assessment of fluvial flood risk and various related aspects of FRM projects. Utilizing multiple realizations of flow sequences can assure a robust approach for attaining long-term sustainability of FRM projects. Previous studies by author have been shown to generate reliable results (multiple realizations of daily streamflow sequences) through successful application of stochastic modelling approach such as Hidden Markov Model (HMM) coupled with the generalized extreme value distribution (HMM-GEV) and Generalized Pareto (HMM-GP) distribution (Pender et al., 2015). HMM-GP model has been rigorously accessed for its ability in capturing various statistical characteristics and stochasticity of the simulated flow sequences. Model has been robustly validated across four hydrologically distinct catchments (Rivers Dee, Falloch, Caldew and Lud) and demonstrates excellence performance.

This paper presents an extension to the HMM based modelling approach and thoroughly access the suitability of approach in simulating streamflow at much finer temporal resolution of 15 minutes. It should be noted that, daily flow sequences could easily miss an entire significant flooding event. Thus, multiple flow sequences at finer resolution of 15 minutes are highly desired for robust modelling as to attain more confidence in their general applicability. Many fine refinements in the HMM-GP modelling procedure have been proposed to effectively capture the dynamics of the flow sequences and to generate replicate series at specified resolutions. Model has been applied to a range of hydrologically distinct catchments in the UK. Results show that the model produces excellent performance, effectively captures extreme events, and is generically applicable across a range of hydrological regimes.

NOTES

Visualizing bed deformation and sediment dispersal across dune fields

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Dunes are the most prominent roughness elements within alluvial rivers and they generate the most common sedimentary structures of river channel deposits, yet their behaviour remains inadequately understood. Dunes deform as they migrate downstream over time, and this deformation is enhanced when the dunes are not in equilibrium with the flow. However, we still have an incomplete knowledge of *how* dunes deform. Therefore, this study applies cross-correlation analysis to successive 2D dune profiles from flume experiments, and successive 3D maps of dunes from the Mekong River, Cambodia, in order to visualize dune deformation and to quantify spatial and temporal variability in the magnitude and direction of sediment transport. The residuals from the cross-correlation analysis visualise different dune deformation processes. The results show that significantly more sediment dispersal processes exist in nature than are included in current explanations and predictions of dune dynamics. The areal and temporal resolutions of the cross-correlation affect the processes that are being visualised: analysis of single dunes reveals local patterns of deformation that are not revealed by cross-correlation of multiple dune wavelengths, and; irregularities in dune patterns are dissipated over time. The analysis highlights that some dunes systematically gain or lose sediment within the moving dune field. The sediment re-distribution that eventually dissipates such local sinks and sources of sediment within the dune field always involves multiple dunes.

This study provides both the background and a methodology for the interpretation of dune deformation, variability in sediment transport across dune fields, and enhanced deformation during bedform growth and decay under unsteady flow conditions.

NOTES

Groundwater typologies of the transboundary Indo Gangetic basin alluvial aquifer

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Groundwater abstraction from the transboundary Indo-Gangetic Basin (IGB) alluvial aquifer comprises 25% of global groundwater withdrawals and sustains agricultural productivity in Pakistan, India, Nepal and Bangladesh. Despite the importance of the aquifer, there are few, if any, transboundary frameworks which draw all these data together to provide basin-scale understanding of large-scale hydrogeological processes in the aquifer system. Here we present new groundwater typologies of the IGB aquifer which have been developed to provide a new lens with which to view the IGB. Traditionally considered, and mapped, as a single homogenous aquifer of comparable aquifer properties and groundwater resource at a basin-scale, the typologies illuminate the significant spatial differences in groundwater recharge, permeability, storage, and water chemistry which occur across the IGB at a basin-scale. These changes are shown to be predictable and systematic, concurrent with the large-scale changes in sedimentology of the Pleistocene and Holocene alluvium aquifer, climate, and more recently irrigation practices.

In developing the typologies we have provided high-resolution maps of groundwater-levels, groundwater storage trends, abstraction and groundwater-quality The data reveal that poor groundwater quality is likely to be a greater problem than depletion. We estimate the volume of groundwater to 200 m depth to be >20 times the annual flow of the Indus, Brahmaputra and Ganges and show the water-table has been stable or rising across 70% of the aquifer between 2000 and 2012. Groundwater-levels are falling in the remaining 30% amounting to a net annual depletion of.8 ±3.0 km^3. Over 60% of the aquifer area, access to potable groundwater is restricted by excessive salinity or arsenic.

In situ observations also provide evidence of the strong link between groundwater and surface water within the basin. Given the high volume of abstraction in parts of the basin, the measured rate of water-table decline is too small to derive from direct rain-fed recharge alone. Field studies in the IGB show that abstraction can markedly increase recharge, reduce natural discharge, and induce younger water deeper into the aquifer. Recent depletion in northern India and Pakistan measured by GRACE has occurred within a longer history of groundwater accumulation through canal leakage. We conclude that in-situ groundwater observations are essential to provide the spatial detail essential for policy development and the multi-decadal context for short term evaluations based on satellite gravity data.

NOTES

Is it possible to drought proof North Australia?

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Current global issues include climate change, access to water, and hunger/malnutrition. To this list we could add numerous associated impacts (poverty, epidemics, over population, decline in biodiversity). We could also argue that they are all inter–related.
In this paper we develop the proposition that the critical factor is water. We acknowledge that all life, directly and indirectly, relies on seed material, but without water the growth of the seed, and the continued maintenance of the plant and subsequently the animal, would not be possible.

Over population, or the distribution of the world's population, is undoubtedly an horrendous problem. Australia is a huge continent, sparsely populated, with large tracts of undeveloped land. The argument has been raised that it should be possible to feed a large proportion of the world's starving population by utilising those large tracts of land.

But is it that easy? Australia's rainfall is strongly seasonal, predominantly falling in the summer period when temperatures are high and sun days outnumber rain days by around 30 to 1. Australia is also seasonally arid, and in the northern part of Australia rainfall is not only strongly seasonal, it is notoriously unreliable and of short duration, often receiving the majority of the annual rainfall in less than a week. Consequently, evaporation exceeds precipitation for the majority of the year. Most of Australia's river systems are ephemeral, and in the northern part of Australia, ALL river systems are ephemeral, often carrying water for only a few short weeks/days of the year before receding into isolated pools and evaporating.

In a land where rainfall is intense, strongly seasonal and of short duration, and where evaporation is greater than precipitation for 95% of the year over 95% of the continent, is it enough to say "the land is there". The issues to be addressed are enormous. Is it possible to store water for the long periods (perhaps 11 months of the year) when no rain falls? Is the chemical composition of stored groundwaters suited to agriculture? How much surface and/or groundwater can be used without compromising long term viability? Is it possible to store and/or harvest water for an agricultural industry suited to meeting at least a proportion of the world's needs? Is it possible to drought proof the North? Is the concept "food bowl of a nation" realistic?

NOTES

Effect of dynamically varying zone hedging policies on surface water reservoir operational performance during climate change

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Hedging is universally recognised as a useful practice for redistributing water shortages to avoid occasions of large, crippling water shortages during surface water reservoir operation. However, when based on zones of the available reservoir storage, hedging has traditionally been static in that the rationing ratio (i.e. the supply/demand ratio) is constant from one period to another. Given the seasonal variations in inflows into reservoirs, it should be expected that certain periods or months in the year should require less hedging and hence be able to supply more water than others, thus further enhancing the effectiveness of hedging as a systems performance enhancer. In this study, we have examined the effect of dynamically varying hedging policies on the performance of Pong reservoir on the Beas River in Himachal Pradesh, India. Using a coupled sequent-peak and genetic algorithms, optimised rule curves involving single and multiple hedging zones were developed, together with their associated rationing ratios. Three situations were considered for the rationing ratios: static (in which the ratio was constant for all period), monthly varying, and seasonally varying. The optimised rule curves were then used to drive reservoir simulations to assess the effect of projected climate change on the performance of the reservoir in meeting its primary irrigation obligations. The results show that without hedging, poor performance of the reservoir results, which further deteriorates as the catchment becomes drier due to projected climate change. This problem disappeared with hedging, with the largest effect on the vulnerability and other performance indices deriving from the single zone static hedging. While, for example, the introduction of additional hedging zones did result in further reductions in the vulnerability, such effects were minimal. With regard to dynamically varying the hedging ratio, it was observed that the optimal hedging ratio was higher during the Monson periods when the inflow into the reservoir was at its highest, as expected, thus resulting in a lowering of the amount of water spilled. However, dynamically varying the rationing ratios resulted in minimal changes in the performance indices when compared to the static situation. The significance of this study stems from its demonstration of the effectiveness of hedging in offsetting the impact of water shortage caused by climate change and the fact that hedging does not have to be over complex to be effective as simple single zone hedging with a constant rationing ratio can be as effective as a much more complex multi-zone, multi-ratio hedging scheme.

NOTES

The application of reservoir modelling techniques to solve geotechnical and groundwater issues in glacial and post glacial deposits in Glasgow U.K.

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The innovative Accessing Subsurface Knowledge (ASK) network was recently established in the Glasgow area by the British Geological Survey and Glasgow City Council to deliver and exchange subsurface data and knowledge. This provides an ideal opportunity to communicate and test a range of different models and to assess their usefulness and impact on a vibrant community of public and private sector partners and decision makers. Characterising the three-dimensional (3D) distribution of sediment and how it affects hydraulic conductivity and other factors is a common stage in many oil reservoir modelling. However, such methods are not commonly applied onshore even though there is increasing demand to better constrain lithological and hydrological parameters, particularly in glacigenic and fluvial deposits which underlie one third of the cities in Europe.

Stochastic modelling techniques are commonly used to model facies variations in oil field models. These techniques have been applied to an area containing >4,000 coded boreholes to investigate the glacial and fluvial deposits in the centre of the city of Glasgow. We test the predictions from this method by removing different proportions of the control data and re-running the simulations to determine how predictability varies with data density. We also explore how lithology effects the distribution of hydraulic conductivity required for improving management of groundwater resources and mitigating against adverse impacts of groundwater flow. As well as forming a potential resource for water supply, energy and waste water disposal, groundwater can play a role in flooding, Sustainable Drainage Systems (SuDS) and the transfer of contaminants.

NOTES

Capacity Building For The Formtion of a Geo-Ecotoxicological Research Group

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The intimate link between catchment geology, surface water chemistry, and ecotoxicology provides a strong justification for the formation of a geo-ecotoxicological research group. Geological characteristics of some regions present high levels of toxic substances such as Arsenic, Chromium, and Manganese that subsequently generate elevated concentrations of these substances in water with potential to adversely affect aquatic organism health. In some catchments, the presence of elevated aqueous concentrations of substances has occurred over long periods of time (i.e., geological timescales) and organisms may have adapted to these chemical conditions; however, more recent disturbances (e.g., mining, landslides etc.) to the geological landscape can impose toxic conditions upon aquatic biota. Therefore, understanding the main processes that link catchment geology with surface water quality is mandatory for environmental scientists.

An interdisciplinary group of advisors (professionals) and students (graduates and postgraduates) from ecotoxicology and geology fields is proposed. The aim of such group will be to enhance understanding of the important scientific aspects across these disciplines and build improved approaches for solving environmental issues that evolve at the intersection of geology and ecotoxicology. Joint courses are envisioned that can be delivered both in Scotland and Brazil with potential for assessment of field sites and integrated research projects. Over the long term, this will allow development of new ways of addressing complex issues in environmental science that require interdisciplinary solutions.

NOTES

Big rivers and Quaternary deposits: A sedimentary study of the Euphrates river system

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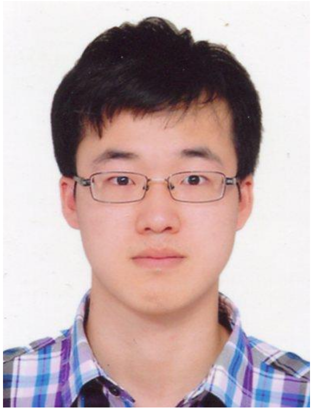
The Tigris-Euphrates is a long-lived, big river system, around 2800km in length, which drains SW Asia. The system developed in the Late Miocene as Eurotype, continental, axial drainage system that follows broad regional structural features. Good preservation and outcropping of the Pliocene and Quaternary Euphrates deposits yield a viable local analogue for subsurface fluvial reservoirs in the region. We report on a detailed study of the sedimentary characteristics of these Pliocene and Quaternary fluvial deposits on the basis of fieldwork carried out in Syria in 2009, from Aleppo to near the Syrian-Iraq border.

We demonstrate that that the Euphrates fluvial system has developed from small and probably short-lived isolated cut and fill channels in the Pliocene, characterised by abundant debrite and slump facies, though to a broad meandering system in the modern day. The Quaternary deposits represent a braided to meandering system that was more energetic than that of the modern day Euphrates. The Quaternary facies include a dominance of gravels, pebbly sands and sands as channel associations, coupled with sands, muds and paleosols representing channel abandonment, overbank and crevasses-splay associations. Channel widths, where observed, range from 50-500m, and minimum fill thicknesses range from 3-7m. The combined channel-fill for stacked channels is up to 25m thick. Lateral correlation of channel elements over at least 1km of section indicates rapid and extensive lateral migration occurred. Smaller-scale crevasse splay lobes can be identified in the overbank deposits, with a width of 30-60m and sand thickness of 0.5-1.5m. The geometry, nature and dimensions of these architectural elements provide a useful analogue for subsurface reservoirs. However, lack of complete preservation of these Quaternary fluvial deposits at outcrop remains an issue for accurately determining the scale of sedimentary features and also the size of the paleo-river.

NOTES



Fluid mixing process in a shallow nature lake

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Lake Taihu is located in the Yangtze Delta plain in Southeast China. It has a surface area of 2,250km^2 and is the third-largest freshwater lake in China. With an average depth of 2 meters, it is typical shallow lake with its flow hydrodynamics predominantly driven by seasonal winds. Following the rapid economic development in China in the last three decades, Lake Taihu has experienced dramatic degradation of water quality. The notorious 2007 blue green algae outbreak event resulted in hundreds of thousands people short of drinking water and caused enormous economic losses. It is proposed that flesh water from the Yangtze River should be artificially transferred to the lake to dilute the pollution and improve water quality. In order to specify the most appropriate route(s) and times to transfer the Yangtze flesh water, there is a need to better understand the lake's transport and mixing properties and ensure engineering feasibility and efficacy.

This work develops a numerical modelling tool to investigate and better understand the fluid mixing processes in Lake Taihu, with an aim to provide useful guidance for effective engineering solutions to improve water quality. The integrated fluid mixing modelling framework consists of two components, i.e. a shallow flow model for predicting hydrodynamics and a particle-tracking model that calculates the trajectories of passive particles released in the flow. Driven by winds, the velocity field of the lake can be efficiently predicted by the two-dimensional shallow flow model, which is then used to integrate the particle motion equations to enable particle tracking and reveal the Lagrangian dynamics and mixing properties of the flow.

The aforementioned fluid mixing modelling framework is firstly applied to reproduce the wind-driven flow hydrodynamics in Lake Taihu for continuous 12 months, with results compared favourably with field measurements. The verified flow field is then used to predict particle dynamics. Transport and mixing properties of the lake are analysed by calculating the Finite Time Lyapunov Exponent (FTLE) and Lagrangian coherent structures, which are well-defined methods in dynamics theory. With the improved understanding of fluid mixing in the lake, the existing and proposed water transfer projects are assessed; the 'best' routes and times to introduce flesh water to guarantee fluid mixing and improve water quality are determined from the numerical analysis.

NOTES

Insights in Fluvial Reservoir Architecture from Understanding the Myriad of Well Test Pressure Build-up Responses

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Translating what we see in a vertical well profile to what is happening laterally at inter-well distances in fluvial reservoirs and aquifers is a challenge facing the subsurface community exploring ancient fluvial systems. Producing fluids from a well and then shitting it in and observing the pressure build-up provides a signal from the near well bore region. Interpretation of that build-up response in fluvial reservoirs is very complex. Fluvial reservoir rocks have some on the most complex architectural arrangements leading to a myriad of pressure responses. What the pressure ‘sees’ – responds to – in 3-D is very difficult for geologists and engineers to comprehend.

At the present time the engineers have no single analytical model to cover all the myriad of fluvial pressure responses. ‘End-point’, relatively simple models exist. Complex geological models can be built from rich Google Earth images. The latter can be interpreted for various facies. Models can be constructed with different channel scenarios, many geostatistical realizations and ranges of geologically-based well test models can be produced. These models – taking care to avoid numerical artefacts – can capture the responses to complex architecture. Exploration of the possible responses by geo/flow modelling and comparison of synthetic geotype curves with real build-up data, can help constrain the more appropriate architectural scenarios. This paper summarises what models and understanding we have to date.

Architecture will impact the well spacing, well design, well completion strategy, hydrocarbon recovery and habitat of remaining oil in a fluvial reservoir. At the end, after all this integrated geological and engineering work and understanding, even with seismic data, there might be an unexpected and undetected fault/fracture in or near the well. Faults and fractures mimic channel boundaries and matrix heterogeneities in the pressure response domain, so this fluvial reservoir geoengineering work will never provide an unique answer!

NOTES

Analysing fluvial response to a well-documented increase in global temperatures

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Analysing key controls on sedimentary sequences is challenging as the three main allocyclic factors (tectonics, eustacy, and climate) are intrinsically linked, and can often produce similar stratigraphic signatures. The Paleocene-Eocene Thermal Maximum (PETM) is a record of an increase in global temperatures up to 5°C. The PETM has been identified and extensively studied in a number of fluvial successions in the Bighorn Basin, NW Wyoming, allowing sedimentological insights into the effects of a rapid warming climate on fluvial systems to be gained.

This study aims to assess the sedimentological response of the fluvial systems at several localities across the entire Bighorn Basin to assess the response to the PETM by documenting fluvial facies prior to, during- and post- PETM. This shall be undertaken in conjunction with a basin scale facies analysis to better place the PETM into context with the rest of the basin fill, both spatially and temporally to assess the extent of any changes if identified.

In the most distal northern portion of the basin a large amalgamated channel deposit, termed the ‘boundary sandstone’ is observed at the PETM, whereas at Polecat Bench, 14 km away, a change to thicker more welded paleosol deposits are observed at the PETM. In the SE portion of the basin we see a gradual change in the colouration of soils from drab greys to red mottled soils, with the latter increasing in thickness up-section. However, laterally the red soils grade into drab grey soils, highlighting issues of extrapolating trends over even short distances.

A comparison of the different sites suggests there are no ubiquitous trends across the basin at the PETM. Basin scale facies analysis suggests that there is no clear sedimentological response to the PETM as the sedimentary succession deposited during the PETM shows no significant difference to the succession developed either prior to or post the PETM section. This either suggests that the response is different depending on position within the basin, or that there is no obvious sedimentological response to this short lived (~200,000 year) climatic event.

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FIRE SAFETY INFORMATION

JAMES WATT CENTRE 1

The James Watt Centre is equipped with Fire Protection Equipment to a high standard that is maintained and inspected in line with current legislation and Health and Safety requirements, this includes an extensive automatic Smoke Detection system and a Temperature activated Sprinkler system in the main auditorium.
In keeping with recent changes in the legislation the James Watt Centre is a designated No Smoking venue and anyone found in contravention of this may be requested to leave the premises, your cooperation and assistance in this matter is appreciated.
In the event of a Fire: **ANY PERSON DISCOVERING A FIRE SHOULD RAISE THE ALARM BY OPERATING THE NEAREST FIRE ALARM CALL POINT / BREAK GLASS.**

The fire alarm sounds as a two-tone electronic siren (similar to a yodel), there is no first stage.

In the event of the alarm sounding Conference and Event Organisers should direct their delegates / guests to evacuate the premises by the **NEAREST** fire exit and assemble either in the Piazza to the west (front) of the building, or in the car park to the east (rear) of the building, accessed via the doors on the north and east sides of the building.
Fire exits are clearly marked throughout the centre and there are doors all round the main hall and in the lounge area.

Delegates / Guests should be discouraged from stopping to collect personal belonging and they **MUST NOT** re-enter the building until authorised by the Fire Authorities or a member of the University Security Staff.

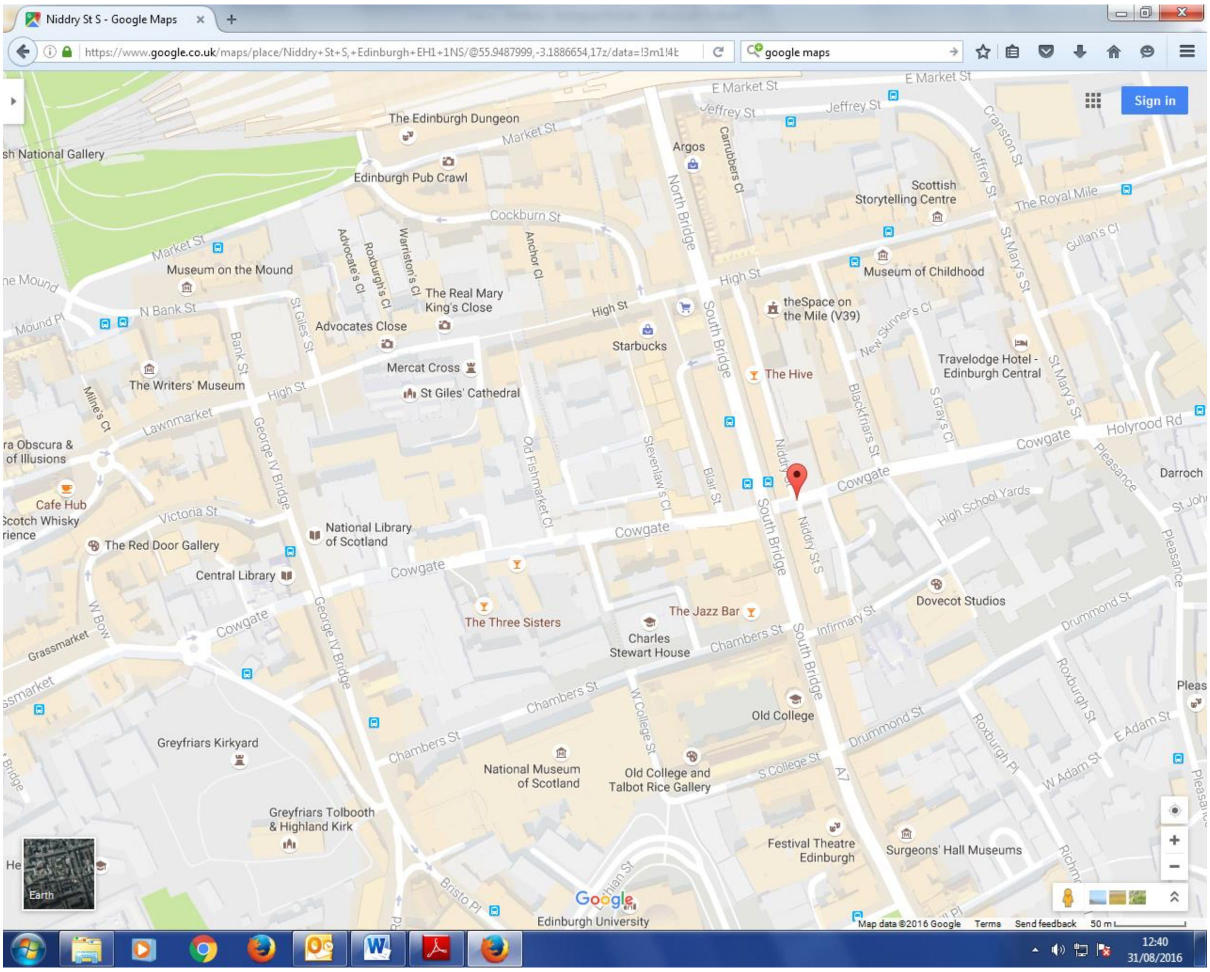
The Duty Security Supervisor and the **Control Desk (extn 3500)** must be advised in advance if any individuals might require extra assistance in the event of an evacuation.

DRINKS RECEPTION & CONFERENCE DINNER INFORMATION

Drinks reception - Tuesday 27 September from 16.30 in the BGS Lyell Centre

Conference dinner – Wednesday 28 September at The Caves from 19.15

Address: 8-10 Niddry Street South, Edinburgh EH1 1NS
Tel: 0131 510 1122



19.15 – 8pm – Ghost tours of The Caves (ghost tour will be every 10 minutes. 25 people max per group)

8.15pm – Dinner*

* Half a bottle of wine will be allocated to each guest during dinner. A cash bar will be available if you would like a drink on arrival and if you would like more wine during dinner.

FIELD TRIP INFORMATION

08:45 Gather outside Institute of Petroleum Engineering, Heriot-Watt University (Adjacent to Lyell Centre)

9:00 Coach will depart for Spireslack, Glenbuck, Nr. Muirkirk

15:00 Coach will depart for Heriot-Watt University

16.00 Coach will arrive back at Institute of Petroleum Engineering, Heriot-Watt University

- Sandwich lunch, Hi-Vis Vests and Helmets will be provided

Contact: Patrick Corbett – 07710242817 if necessary on the day (note there is no phone reception in the quarry)