Abstracts

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S Dawson and A Dawson 2007

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Project 495

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Human Coastal Interactions

Roman peat-extraction pits as possible evidence for the timing of coastal changes: An example from the Belgian coastal plain.

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The Belgian coastal plain bears a rich archaeological heritage, however, traces from the period of Roman occupation are rare. Potsherds *in situ* were never found until now and building structures are completely lacking. On the other hand, ovens for the production of raw salt from the Roman period, implying peat extraction, are well documented. This testifies Roman activity or at least land use in the coastal plain. From a geological point of view, it is problematic to pin the Roman period in the sediment succession. Occupation horizons or particular horizons indicating surfaces free from inundation for extended periods are not present in the sediments. That is why it is difficult to image a picture of the landscape. Moreover, the period of time of Roman occupation coincides with a profound change in the coastal landscape. It is somewhere in that period that brackish clastic sediments replaced a long-lasted peat accumulation associated with the formation of tidal channels and a landward shift of the coastline. Whether the onset of the marine/brackish inundation happened before, during or after the period of Roman occupation has not been detected yet. A reliable chronology is essential to resolving the stratigraphic position of the Roman land-use activities, and in particular, the environmental conditions of the landscape.

Peat-extraction pits have been studied in detail at locations where a concentration of Roman potsherds were found at the surface. Peat-extraction pits are a well-known feature in the coastal plain, but it is generally thought that they date from the late mediaeval period. The detailed study of the pits together with the stratigraphical and palaeogeographical context documented that the pits date from the period of Roman occupation. The complex stratigraphy of the infill of the pits, together with the undisturbed overlying tidal deposits testify that the peat extraction happened before the tidal channels re-occupied their mid-Holocene predecessors, and well before the tidal environment was re-installed. Digging of the pits affected the peat area in general which locally subsided. This situation must have enhanced the process of tidal inundation and is to be considered as an additional cause for the start of the profound coastal changes. This evidence was never documented so obviously in the Belgian coastal plain. The presence of the sherds at the surface is most probably the result of later erosion and reworking by the tidal channels.

Impact of future sea-level rise on coastal transport infrastructure: the case of the London-Penzance railway line

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The London to Penzance rail line is a vital transport link for Devon and Cornwall. The main railway route between Exeter and Plymouth, or more specifically the 4.2 miles between Dawlish and Teignmouth, lies very close to sea level and has been susceptible to frequent closure during high seas and storm events. The latest projections of sea-level rise (SLR) by the Intergovernmental Panel on Climate Change (IPCC, 2007) suggest a global average of up to 60 cm by 2100. Predicting future return periods of extreme events that disrupt the Dawlish railway depends heavily on future rates of SLR as well as changes in tidal range, storm patterns and vertical land movement. With regards to the latter, the United Kingdom Climate Impacts Programme (UKCIP) argues that the coastline of Southwest England is subjected to the fastest rate of subsidence in the UK (~1 mm/yr). However, their published future regional estimates of sea-level rise are based on isostatic trends calculated from a limited number of low quality (intercalated) late Holocene sea-level index points. Consequently, and in contrast to most other regions in the UK, we believe that is not possible to infer, from the available data set, accurate rates of relative late Holocene land- and sea-level change for Southwest Britain.

A new sea-level rise analysis undertaken at the University of Plymouth, funded by Greatwestern Research and the Devon and Cornwall County councils, will estimate future return periods of extreme water levels and the resulting closure frequencies of the railway at Dawlish-Teignmouth under various climate-change scenarios. The project aims to: (1) collect new, compaction-free, late Holocene sea-level index points from which, with the aid of geophysical modelling, the relative isostatic subsidence rate of the region will be determined; (2) in collaboration with the MetOffice, estimate future regional rates of sea-level rise, using the revised estimates of isostatic subsidence as well as current estimates of changes in tidal range and storm patterns; (3) establish scenarios of rail closure for the Dawlish/Teignmouth railway section for the 21st century in the light of future regional sea-level rise predictions; (4) develop models of the socio-economic impacts on the Westcountry economy that result from various rail-closure scenarios; (5) establish guidelines for local businesses and stake-holders and advice for sustainable pro-active rail and governmental policy. This paper will present the first results of the project, including new stratigraphical investigations and historical analyses of railway

Inlet-margin barrier behaviour in northwest Ireland: sediment budgets and forcing mechanisms.

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The northwest coast of Ireland is characterised by bedrock-controlled coastal valleys that are occupied by sand-dominated estuaries. The glacial history of this coastline imparts a significant inherited framework, primarily in the glacially-eroded accommodation space and the supply of derived sediment. It is thought that this sediment supply has ceased, and that contemporary and late-Holocene sediment availability and shoreline behaviour has been driven by reworking of existing coastal deposits (Carter et al., 1989). This certainly seems to be the case in west Donegal. Here, estuary inlets often comprise supratidal sand barriers, in the form of dunes and supratidal strands, which contain significant volumes of sediment. Over the historical timescale, these supratidal landforms exhibit varied adjustments in spatial extent and configuration – and this reworking of deposits often facilitates the release of a notable quantity of sediment into the estuary-inlet system, promoting further changes to the shoreline. This paper will present the historic evolution of inlet-margin barrier morphology on this coastline, and quantify the changing sediment budgets. The possible forcing mechanisms responsible for these changes will be addressed, particularly with reference to the potential role of short-term events (such as storms), and longer-term adjustments to extrinsic forcing (such as sea-level change) and intrinsic control (such as accommodation space).

The genesis of the Oer-IJ estuary, a former tidal system in the central part of Holland

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The name of “Oer-IJ” refers to the whole area consisting of the former tidal outlet which in pre-historic times lay near the present-day town of Castricum and the adjacent estuary which extended via the towns of Uitgeest, Heemskerk and Velsen as far as Amsterdam. There the estuary was connected to the Utrechtse Vecht river, a branch of the river Rhine at the time (presently called Oude Rijn – Old Rhine).
The Oer-IJ was the predecessor of the IJ-meer which developed fully during the Middle Ages and subsequent centuries. In the 19th Century this lake was reclaimed, thus creating the IJ-polders which provided new, extremely fertile farmlands.

The Oer-IJ in turn developed during the period 3000-2500 BC from a yet older tidal system which lay to the north of the present-day city of Haarlem. Via the tidal outlet of the Oer-IJ the adjacent tidal areas of the estuary, the high peat moors near the present-day city of Zaandam and the village of Halfweg, and the Flevo lakes (in the present-day province of Flevoland) could drain into the North Sea. The draining of the coastal area was the main reason for the tidal outlet to remain open during prehistoric times. When, during the Mid Iron Age (approximately 400 – 300 BC) a new northern connection to the sea developed, the Flevo lakes got a natural connection to the Waddenzee. Thus the Oer-IJ estuary to a large extend lost its function as outlet of the hinterland. Therefore, the mouth of the Oer-IJ near Castricum started to silt up: sand carried along from the sea into the mouth of the Oer-IJ by tide and storm surges could not be cleaned out any more by out-flowing water since the strength of the current was markedly reduced. As a result, the size of the tidal inlet decreased steadily during the Mid and Late Iron Ages. Because of this silting-up, large parts of the former salt marshes and adjacent border zones of the peat areas started to definitively stand clear of the water and thus became suited for permanent occupation by man. The numerous archaeological finds from those times which have been dug up in the Oer-IJ region indicate that human beings indeed used these areas. During the early period of our era (Roman Ages) the whole of the Oer-IJ area got closed from the sea by an extended uninterrupted sand barrier. From those days onwards the whole of the former tidal area of the Oer-IJ could be occupied and used for agriculture.
The history of the silting up of the Oer-IJ could be studied well during the past few decades, due to the numerous archaeological excavations which have been carried out in this region. In the excavation pits the deposits of the Oer-IJ could be well investigated and – above all – dated. With the help of the data obtained, the siting-up of the Oer-IJ could be mapped.
During the lecture the “rise and fall” of the Oer-IJ and the way man has taken advantage of the natural developments will be considered. Among other

things the results from geo-archaeological investigations in the Vinex locations in the Broekpolder and Assendelft, the digging-up of a canoe near Uitgeest and the investigations in the PWN dune area will be shown.

Coastal Resilience

Relative sea-level changes in West Greenland during the last millennia

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The Greenland Ice Sheet is a unique laboratory for studying the response of the earth's crust to changes in ice sheet mass balance and associated variations in relative sea-level. It is the only remaining ice sheet in the northern hemisphere and, in contrast to the Antarctic ice sheet, has abundant opportunities for reconstructing relative sea-level change. Thus far, one may identify two phases of RSL research in Greenland. Phase 1, dating from the mid 1960s up until the 1990s, saw the collection and radiocarbon dating of marine molluscs, drift wood and other detrital carbonaceous deposits that were used to reconstruct first order patterns of postglacial RSL change. Data were typically integration from large geographical areas and age and height errors for individual index points are c. ± 5 to 10 m and ± 500 to 1000 cal. yrs. Phase 2, largely from the 1990s onwards, saw the development of more detailed, local RSL reconstructions using the isolation basin methodology. However, this approach provides at best millennial scale trends in RSL (age errors typically ± 150 cal. yrs BP and height errors ± 0.5 m), whilst the collection of data from drowned basins dating from the late Holocene is both challenging and limited by the availability of such basins in each landscape setting.

Here, we present preliminary results from a third and new phase of research that seeks to use salt marshes as high resolution archives of RSL change during the last millennia. Greenland salt marshes tend to be small and, where they have developed over glaciomarine deposits, are extensively disturbed by frost heave. To overcome this problem, we target the collection of multiple thin (<10 cm thick) basal peats that lie directly above bedrock and which are therefore not affected by either frost heave or significant compaction. Because RSL has been rising in the late Holocene, the marsh sequences typically comprise a thin (<5 cm) organic unit that is overlain by mineral-rich salt marsh deposits. Contemporary and fossil diatoms, combined with AMS dated terrestrial plant macrofossils provide altitude and age controls from a field site located near Sisimuit, central west Greenland. High resolution sampling and preliminary range finder dates of the most recent 0.8 m of RSL rise suggest an average RSL rise of 1-1.5 mm yr since AD 1300 but with significant variations within the overall trend. This paper discusses our sampling approach, presents preliminary results and considers the challenges faced in developing high resolution RSL records from arctic salt marshes.

Holocene winter storminess trends for the North Atlantic region – evaluating a driver of coastal change

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Analysis of Greenland (GISP2) ice core chemistry data together with historical records of past climate point to major change in North Atlantic circulation around AD 1420 – possibly the most pronounced such change during the entire Holocene. Prior to this time during the so-called period of Medieval warmth, winter circulation was slack and storm frequency was low. After ca. AD 1420 the vigour of North Atlantic circulation increased with a stronger cell of Icelandic low pressure and a strengthened Siberian high. The effect on Scotland's coastline was profound with the widespread initiation of sand drift (e.g. Culbin, Forvie). Remarkably, this changed mode of atmospheric circulation across the northern hemisphere has been maintained until present. This interpretation suggests the hypothesis that a marked increase in sand drift and the development of suites of coastal dunes as well as accelerated coastal erosion began to take place soon after ca. AD 1420.

Analysis of sea salt concentrations for GISP2 also a long-term decline in winter storminess throughout the Holocene. Superimposed on this trend are intervals of time when storminess has been well above average. Apart from the post AD 1420 time interval, the most pronounced period of inferred extreme storminess and coastal erosion appears to have been between ca. 6-5 kyr BP with secondary maxima between ca. 8.4-7.9 kyr BP and ca. 4.0-2.5 kyr BP. We infer that these intervals of exceptional North Atlantic winter storminess (as well as the post- AD 1420 time interval) are likely to have been the key coastal dune-building phases during the Holocene. By contrast the periods of low winter storminess, centred on ca. 9 kyr BP, ca. 3.5-3.0 kyr BP and the well-known Medieval Warm Period, are inferred to have been times of coastal dune stability.

Glacio-isostatic uplift and sea surface changes during the mid and late Holocene in northern Britain and Ireland

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This paper outlines the analysis of high quality altitude data using Gaussian Quadratic Trend Surface Analysis. Patterns of glacio-isostatic uplift for three displaced shorelines around the coasts of the northern United Kingdom and Republic of Ireland are determined and offshore sea surface changes inferred. The data consist of altitude measurements on strictly comparable relict shore features, dated by radiocarbon assay supported by microfossil analyses. The three shorelines are the Main Postglacial Shoreline (here re-named the Menteith Shoreline) (6400-7700 sidereal years BP), the Blairdrummond Shoreline (4500-5800 BP) and the Wigtown Shoreline (1520-3700 BP). The over 3000 altitude measurements are analysed using an improved programme for Gaussian Trend Surface Analysis.

The altitude measurements are referenced to a common datum for both the United Kingdom and Republic of Ireland, and are based on local Mean High Water Spring Tides, to ensure comparability. To ensure comparable location, all measurements are referenced to a common grid system (Britain and Ireland are normally on separate grids). In the programme employed, the surfaces are depicted by conventional isobase models, both individually and combined around a common centre with a common axis. Each model is shown in this presentation. The fit of each model to the data is estimated by the programme and shown to be very close. The programme also permits the determination of the most likely level to which the surfaces descend (the “zero level”), thus estimating sea surface levels beyond the isostatically uplifted surfaces at the time those surfaces were reached. The zero levels indicated permit a graph of sea surface change to be drawn, which, from its broad comparability with available graphs from elsewhere, is believed to legitimately describe sea surface levels at the time the shorelines were reached, within the margins of error specified.

The approach described in this paper is evaluated in terms of shoreline correlation, distribution and age. It is maintained that the models produced are the most accurate for a glacio-isostatically affected area yet produced, and that they offer considerable potential in reconstructing Holocene sea surface changes.

Quaternary sea-level change and coastal sediment dynamics in western Britain

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The coasts of southwest England and southern Ireland show a range of features characteristic of sea-level (SL) changes over the Quaternary, including (raised) shore platforms cut into bedrock; (raised) beach sediments; and buried/overstepped cliff and shore features. Age constraints on these features are few but include amino acid ratios on marine shells and some radiocarbon and luminescence ages on overlying sediments. The shoreline features have been interpreted mainly in terms of their SL (and thus climatic) signatures. This approach assumes a cyclic pattern of glacials and interglacials that is imprinted rhythmically on coastal sediments and on a regional scale. Whilst regional lithostratigraphies in western Britain support this overall pattern (to some extent and over some time periods), local scale patterns are controlled more strongly by coastline geometry and sediment supply and thus present a different SL and climatic picture. This presentation considers the extent to which SL change moderate coastal sediment dynamics (sensu lato) and, thus, re-evaluates some of the relationships between SL change, climate change, and coastal processes. The presentation draws from field examples in Cornwall (SW England) and counties Cork and Kerry (S Ireland).

Methodologies for reconstructing and dating

Glacial Rebound Modelling and Ice Sheet Reconstructions from Ireland

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The British Isles have been the focus of a number of recent modelling studies owing to the existence of a high quality sea-level data set for this region and the suitability of the data for constraining shallow Earth viscosity structure, local to regional ice sheet histories and the magnitude/timing of global melt water signals [e.g. *Shennan et al*., *J*. *Quat. Sci., 21, 2006*]. Because of the fragmentary nature of the existing RSL record from Ireland, the majority of these studies have tended to focus upon the British component of the British and Irish Ice Sheet. Notable exceptions to this trend are provided by the rebound modelling efforts of Lambeck [*J. Geol. Soc. London, 153, 1996*] and Lambeck & Purcell [*J. Quat. Sci., 16, 2001*] although fundamental uncertainties surrounding the precision and accuracy of the existing RSL records meant these data were of limited use as constraints on former ice thickness. However, we have recently compiled a new, quality-assessed, sea-level database for Ireland [Brooks & Edwards, *Ir. J. Earth Sci., 24, 2006*] and have also retrieved new (Holocene) sea-level data from Ireland's west coast. In this paper, we employ these new sets of data to constrain models of Irish Ice Sheet evolution prior to and following the LGM.

We find that (1) assuming the influence of lateral Earth structure beneath the British Isles produces only a minor impact on simulations of RSL in this region, the Irish component of the British and Irish Ice Sheet depicted in the recent glacial rebound modeling analyses of Shennan *et al*. (2006) is largely incompatible with empirical observations of Late Devensian and Holocene RSL from Ireland. (2) Our revised 'best fit' ice model for Ireland comprises a thick, spatially extensive Irish Ice Sheet of around 700m over much of north and central Ireland at the LGM. Relatively thick ice out to the continental shelf off the west coast of Scotland and Ireland coupled with thick Irish Sea ice is required to produce a sufficient fit with observational RSL data from the Late Devensian. (3) The Irish RSL data strongly favour very rapid deglaciation after 21 000 BP: early (pre 21 000 BP) deglaciation produces unacceptably low simulations of maximum Late Devensian RSL in the north of Ireland and SW Scotland whilst gradual deglaciation between 20 000 to 16 000 BP deteriorates the fit with observations of Holocene RSL. (4) All realistic ice-earth model solutions considered in these analyses deliver maximal simulations of Late Devensian RSL along Ireland's west coast that are well below present msl. These findings are not in agreement with the suggestion of higher than present Late Devensian RSL along this stretch of coastline [e.g. *McCabe et al., J. Quat. Sci., 1, 1986; McCabe et al., Quat. Sci. Rev., 24, 2005; Thomas & Chiverrell, Quat. Sci. Rev., 23, 2006]*. (5) Reconstructions of palaeogeography associated with the newly developed glacial rebound model

suggest that at no point during the post-glacial period was Ireland connected to Britain via a land bridge.

The controversy of high Irish relative sea-levels: where models and field data (dis)agree.

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Mud deposits containing foraminifera have been reported from contexts several metres above modern sea level from a number of locations around the Irish coast. Some workers contend that these are clearly deposited in a marine context and interpret them as forming part of sequence of sedimentary facies comparable to those encountered at the margins of tide-water glaciers. This glaciomarine interpretation requires high (above modern) relative sea-levels (RSL) during the last deglaciation.

Other authors prefer a terrestrial origin for these deposits, citing errors in the interpretation of certain sedimentary features, and contradictions with other field evidence in adjacent areas. Furthermore, geophysical models describing the process of post-glacial isostatic rebound have been incapable of simulating the magnitude and manner of crustal deflection required to accommodate the glaciomarine hypothesis. Supporters of the 'terrestrial school' use this as additional evidence of erroneous interpretation, whilst members of the 'glaciomarine school' suggest any mismatch simply highlights problems with the geophysical models.

The correct interpretation of these deposits is of critical importance given the universal application of glacial rebound models, and increased interest in the mechanisms associated with sea level rise and dynamic ice sheet response to climate change.

This paper presents simulated RSLs from an updated glacial rebound model for Ireland that incorporates a new, terrain corrected Irish ice sheet component, calibrated with reference to British and Irish sea-level data. Model results are compared with the 'glaciomarine' sea-level data and reveal that whilst high RSL in the north east of Ireland may be obtained, model outputs remain incompatible with the rates of change inferred. Similarly, high RSLs from western and southern Ireland are wholly incompatible with model outputs and require contradictory alterations to crustal response models. The significance of these results is discussed with reference to suggested model limitations and emerging field data concerning high/low-stands around the Irish coast

Modern salt marsh environments in Greenland and their usefulness in sea-level reconstructions

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This study is a first attempt to characterise the sedimentary, microfossil and isotopic characteristics of salt marshes in West Greenland, with the intention of creating modern training sets to aid in reconstructing relative sea-level change over recent centuries. Relative sea-level is rising quickly in Greenland, which means salt marsh sediments are progressively eroded over time, and modern salt marsh sediments only record recent sea-level changes.

High temporal and height resolution saltmarsh studies in other temperate areas combine well-developed modern and fossil datasets of foraminifera and/or diatoms as well as other biological and sedimentological data to reconstruct past sea levels. Preliminary analysis of foraminifera shows assemblages in studied West Greenland salt marshes are dominated by a monospecific assemblage of *Jadammina macrescens*, while diatom assemblages have much higher species diversity, with ~40 different species found in high numbers across the marshes. Salt marsh plant communities are similar to those in other temperate areas, with *Puccinnellia maritima* and *Carex rariflora* dominating the low and upper marshes. Stable carbon isotope concentrations may provide an additional proxy for tidal inundation which can add to the environmental information available to reconstruct sea-level changes.

No quantitiatve reconstructions of contemporary or fossil foraminifera, diatom or isotope records from salt marsh material have been attempted in Greenland to date. Initial investigations on modern west coast salt marshes show the potential to use in particular diatoms to reconstruct changing sea levels, with foraminifera and isotopes as complimentary techniques to pinpoint the onset of saline conditions in peat deposits.

Recent sedimentation history of the salt marshes in the Avon Estuary (Devon)

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Many estuaries in Devon and Cornwall have been silting up in the past 150 years as a result of upland sediments released by mining activities. Unlike the nearby rivers Plym and the Tamar, the catchment of the Devonshire Avon, which flows from Dartmoor to the English Channel at Bantham, has largely been free of mining activities. Anecdotal evidence, however, suggests that in more recent decades the salt marshes and tidal flats of the Avon Estuary have been subjected to increased sedimentation rates with harmful consequences for oyster farms and navigation. The University of Plymouth has entered a partnership with the Aune (Avon) Conservation Society to create research opportunities for Masters students, aiming to test proposed hypotheses relating to the cause of increased sedimentation rates, including the building of the Avon Dam in the 1950s, changes in land-use practices, and natural fluvial processes such as bank erosion. This paper makes a contribution to Working Group A2 of IGCP Project 495 (Quaternary coastal evolution and fluvial archives of environmental change).

We performed ^{210}Pb and ^{137}Cs analyses on three cores in the salt marshes in the upper catchment to establish sediment accretion rates. The same cores were subjected to metal analyses, which established a middle 19th century chronostratigraphic marker of Pb input from the only short-lived mining activity in the catchment. Mineral magnetic properties were determined for the sediments in the cores, for soils in the surrounding catchment and for suspended sediments in the river. These properties vary depending on underlying solid geology and parent soil, providing unique 'fingerprints' for different catchment zones which were used to infer the provenance of the salt-marsh sediment.

Our results show that, since the early 1960s, sedimentation rates in the salt marshes have doubled or trebled. Magnetic analyses point at intensively-farmed arable land as the primary source of sediments recently deposited in the estuary. Tracer data indicate that prior to widespread conversion of pasture to arable land (1960 onwards), the dominant sediment source in the catchment was channel bank erosion, suggesting that intensification of agricultural activity may be responsible for a change in sediment delivery to the estuary. These findings have implications for agricultural land management and illustrate the importance of considering the downstream consequences of soil erosion.

Comparing quantitative and qualitative reconstructions of relative sea level: an evaluation of relative sea-level data from Ho Bugt, western Denmark.

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The evolution of the salt marshes around the Ho Bugt embayment in western Denmark was investigated using litho- and biostratigraphical (diatoms) analyses and AMS ^{14}C and optically stimulated luminescence (OSL) dating. In addition, diatoms were sampled from the modern salt-marsh environment to establish their relationship to contemporary water levels. From 39 calibrated AMS ^{14}C ages and 3 OSL ages, a mid to late Holocene relative sea-level history for the Ho Bugt embayment is established using two methods: 1) a qualitative, lithology-based approach and 2) a quantitative, diatom-based transfer-function approach.

The reliability of the sea-level index points (SLIPs) inferred by use of a Weighted-Averaging Partial Least Squares (WA-PLS) transfer function (Szkornik, 2007), was assessed by use of 'goodness of fit' statistics and the modern analogue technique (MAT) (Birks et al., 1990; Birks, 1998). Comparison of the qualitative, lithology-based reconstruction and the quantitative, diatom-based reconstruction shows that both techniques demonstrate the same overall trend in relative sea-level for the Ho Bugt embayment for the last 7,000 cal. yr. BP. However, in the majority of cases, the SLIPs inferred by use of the WA-PLS diatom-based transfer function appear to plot higher (i.e. showing a higher relative sea-level prediction) than those SLIPs inferred by use of a qualitative, lithology-based approach. This is especially true for the oldest part of the record (before 2500 cal. yr. BP). Here the difference (height) in relative sea-level predictions between the two reconstruction methods is around 0.5 m.

In addition, the two reconstruction methods provide very different vertical (height) errors. Height errors for the WA-PLS inferred SLIPs are much smaller than those inferred using a lithostratigraphical approach. This is an important point to note and one which has lead many authors to argue that transfer functions are able to provide highly precise reconstructions of relative sea-level. However, comparison of the two methods in this study suggests that the WA-PLS transfer function may over-estimate relative sea-level predictions by up to 0.5 m. Such potential inaccuracies clearly outweigh any gains in precision. Although quantitative techniques are increasingly being employed in sea-level research, it is clear from this study that a thorough understanding of lithostratigraphy should form the framework of any sea-level investigation.

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Examining the evidence for a recent acceleration in the rate of sea level rise using combined instrumental and proxy data

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Sea level rise is a potentially devastating consequence of climate change but multi-decadal records of sea level change are severely lacking. Historical records of sea level change, such as tide gauge data and map evidence, are available but generally lack the precision and detail required and cover only relatively short time spans. There is a need to combine historical evidence with geological evidence to address this. Foraminifera are single celled protists which inhabit highly constrained vertical distributions on salt marsh surfaces. Analysis of surface distributions can be compared to fossil data using transfer functions and artificial neural networks with the resulting sea level reconstructions validated against the historical records. The combined data will provide high resolution records of recent sea level changes and will be used to calculate rates of sea level rise. Preliminary results will be presented alongside a time plan for continuing research.

Shallow time slices from deep 3D-seismics: a new way to reconstruct Holocene coastal systems

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In recent years, shallow time slices of marine 3D-seismics acquired for petroleum-exploration purposes have been used to reconstruct paleolandscapes that are presently buried and submerged. These shallow time slices provide information on the distribution of various lithological units that are present in the upper tens of meters of the subsurface, despite the long wavelength (60 ms) of the acoustic signal used in the surveys. In some of the time slices, meanders and dendritic patterns are clearly visible.

The creation and analysis of shallow time slices (40-120 ms) present various challenges, especially for shallow-water areas. In these areas, striping is a problem because the hydrophone geometry used to record the 3D-seismics is designed to optimize the observation of information from the deep subsurface, and because processing of the 3D data focuses exclusively on maximizing the information for the deep subsurface. The shallower the water, the stronger the need to correct acquisition and processing artefacts. In order to optimize data visualization, we applied a method called histogram equalization to the amplitude data. This method adjusts the image contrast by using the histogram of the amplitude data of a time slice. In a next step, it is necessary to check which seismic attributes are best suited to further differentiate lithology and define geometry.

Thus far, features observed on shallow time slices, which inherently suffer from poor vertical resolution, had not been ground-truthed with information from high-resolution seismic profiles or with cores, so that nothing could be said about the thickness and depth of features that are visible on the time slices, or about their lithological characteristics. Here, we present a first attempt to provide this information, using datasets from two areas. These areas were chosen because they represent a range of shallow water depths, and because sufficient data are available for validation.

The Dogger Bank, a former island situated on the northern part of the Dutch continental shelf, is characterized by moderately deep water (20-30 m). Time slices show meanders and dendritic drainage patterns (Figure 1). Comparison with high-resolution seismics and core information shows that the fills that form these patterns are sandy and gravelly units within thick clay layers. The fills are located at depths between 5 and 15 m below the seabed and are as little as 2 m thick (Figure 2). The coastal zone offshore Rotterdam and The Hague is located in very shallow water (<20 m). Time slices show some irregular patterns and a straight, elongate feature. Comparison with high-resolution seismics and core information shows that the irregular features represent muddy estuarine and tidal-channel fills in sandy substrates. The straight feature is a reflection of a pipeline extending from The Hague into the

North Sea, indicating that near-surface features are still visible on time slices that image the subsurface at depths of a few tens of meters.

With abundant 3D-data available, we will be able to reconstruct the spatial distribution of shallow sedimentary systems for large parts of the Dutch continental shelf, providing valuable information for dredgers, windpark developers, the aggregate industry, spatial planners and policy makers.

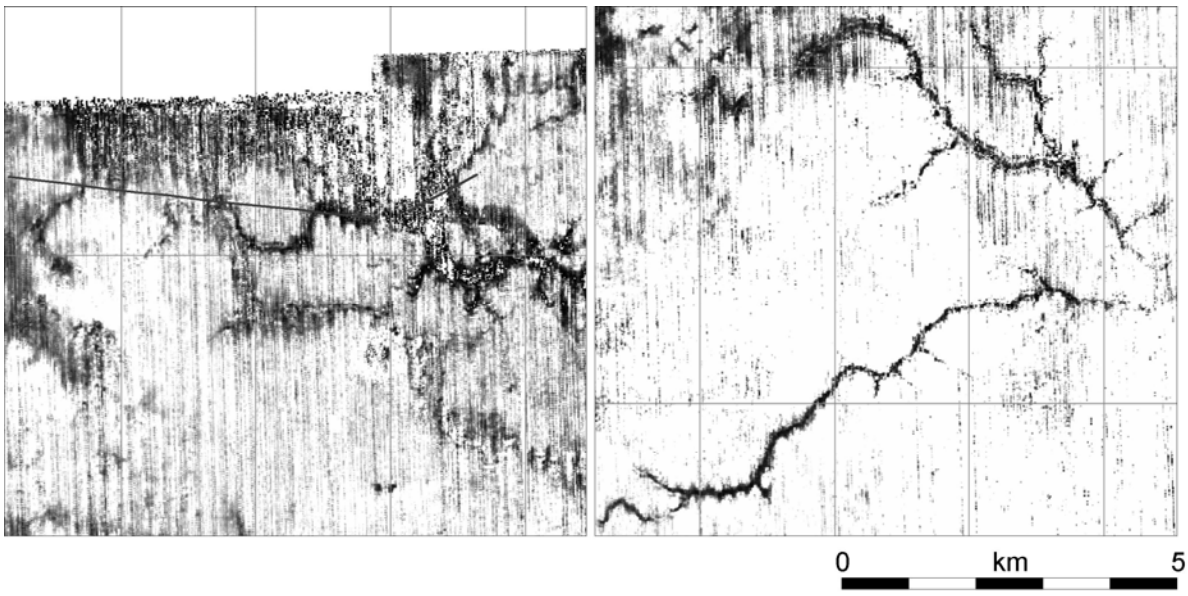

Figure 1. Time slices from the Dogger Bank: Meandering drainage pattern (left) and dendritic drainage pattern (right). The dark gray lines on the left panel mark the cross sections shown in figure 2.

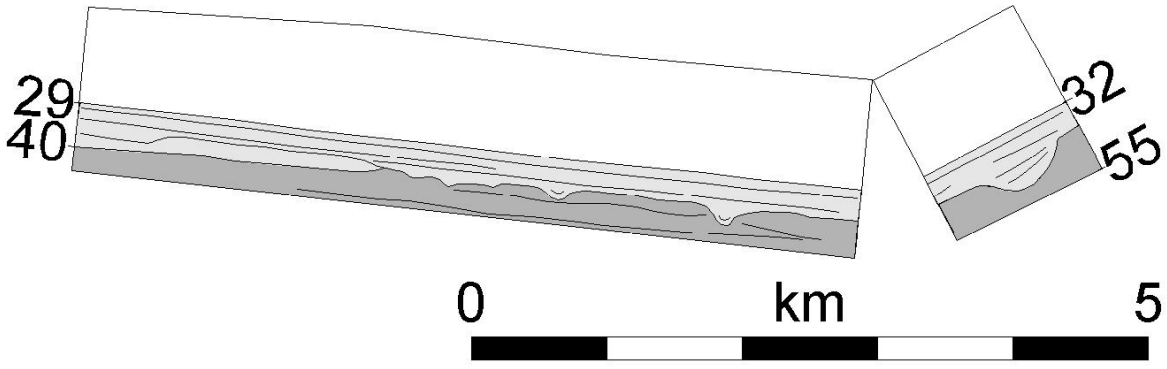

Figure 2. Cross sections from the meandering drainage pattern, constructed from high-resolution seismic profiles. Numbers next to the profiles refer to depths below sea level.

POSTERS

The use of diatoms as sea-level indicators in Ho Bugt, western Denmark.

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Microfossil-based transfer functions have been widely used in sea-level studies to reconstruct changes in relative sea level (e.g., Horton, 1997; Zong and Horton 1999; Gehrels, 2000; Hamilton and Shennan, 2005). However, the statistical methodology adopted by the sea-level community differs to that employed by many palaeolimnologists, particularly with regards to data screening and the use of ordination techniques. This study attempts to harmonise the statistical methodology, used to explore modern training sets and develop diatom-based transfer functions, by incorporating methodological aspects from both communities.

A total of five modern transects were investigated from the salt marshes within the Ho Bugt embayment, western Denmark. A total of 140 surface samples were analysed for diatoms, pH, salinity (conductivity), particle size (sand, silt and clay fractions) and loss on ignition (LOI). Samples were surveyed to a nearby geodetic benchmark and linked to Danish national vertical datum (DNN). Following laboratory analysis, a thorough data screening process was adopted using many of the techniques commonly employed in palaeolimnology. The ordination techniques of Principal Components Analysis (PCA), Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) were all used to explore the modern diatom and environmental data and to identify anomalous samples and to eliminate redundant environmental information.

Results of CCA analysis established that both pH and elevation exert strong, independent and statistically significant influences on modern diatom distributions in the Ho Bugt embayment. Analysis of the interaction between pairs of environmental variables through variance partitioning, suggests that pH is more closely associated with other environmental variables making elevation the best environmental variable to reconstruct. Unimodal models were subsequently developed for the fully screened data set (97 samples, 151 taxa) based on Maximum Likelihood (ML), Weighted-Averaging (WA) and Weighted-Averaging Partial Least Squares (WA-PLS) regression models. The WA-PLS (two component) model was found to perform best when $RMSEP_{jack}$ (0.129 m) and max $bias_{jack}$ (0.127 m) statistics were compared. This model was subsequently applied to core RØ1 from the salt marsh at Røgel to quantitatively reconstruct changes in palaeo-marsh surface elevation. Although the transfer function developed here is shown to perform very well, current work is examining the statistical reliability of these diatom-predicted

reconstructions by investigating ‘goodness of fit’ and ‘analogue’ statistics for individual fossil samples.

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Recent estuarine sedimentation rates from shallow inter-tidal environments in Western Scotland: implications for future coastal development.

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Abstract

During the mid-late Holocene large sections of the Scottish coastline have been characterized by falling relative sea-levels resulting from differential glacio-isostatic uplift of this region of northern Britain. The complex interplay between crustal and sea level movements continues to influence the morphological development of the Scottish coast. A number of geophysical models predict ongoing uplift of the Scottish landmass supported by recent GPS measurements.

A detailed geochemical study has been undertaken on selected sediment cores from four mature coastal marsh environments in Argyll, Western Scotland. This provides an opportunity to investigate the linkages between current estimated crustal movements, Twentieth century sea-level rise for the region and the historical rates of sedimentation recorded within marsh sediments across a western section of the proposed Scottish glacio-isostatic uplift dome.

Vertical distributions of $^{210}Pb_{excess}$ and ^{137}Cs activity have been measured and provide independent models of marsh development derived from the historical record of sediment accumulation. Down-core activity profiles of radionuclides are only reliable as a means of modeling recent marsh evolution provided no post-depositional disturbance has compromised the historical record of sediment accumulation contained within the marsh sediments. Solid-phase major and trace element down-core geochemical distributions provide a means of assessing the extent to which post-depositional disturbance may have influenced the reliability of the radiometric dating methods. Dating of the marsh cores reveals subtle variations in the rates of sediment accumulation over the last c. 70 years between sites. For much of the Twentieth century sedimentation rates have been in good overall agreement with various estimations for sea-level rise during this period, although at sites across the Firth of Lorne these rates do exceed such estimates. Comparison with available storm frequency data indicates that the evolution of these marsh environments is unlikely to have been influenced by significant storm activity during the late Twentieth century.

Over the most recent period of marsh development (~10 years) a significant increase in sedimentation rates is recorded at all sites across the study region. This signifies the response of the mature marshes to a recent increase in the rate of regional relative sea-level rise which is now outpacing current rates of crustal uplift.

These findings in combination with geomorphological evidence, suggest that the coastal marshes within Argyll are extremely sensitive to changes in coastal forcing. The implications of the study with regard to current geodynamics in Scotland and future coastal development are discussed.

Keywords: Salt-marsh; radiometric dating; $^{210}Pb_{excess}$; ^{137}Cs; geochemistry; sea-level rise; Western Scotland.