Institution: University of Liverpool

Unit of Assessment: 17A Geography, Environmental Studies and Archaeology: Geography and Environmental Studies

Title of case study: Quaternary Geology: minerals and resource planning in the UK

1. Summary of the impact

Researchers in the Earth Surface Processes and Environmental Change (ESPEC) Research Group have communicated Quaternary geology to user communities explicitly guiding the location of sites for mineral extraction and infrastructure (airports / wind turbines) in terrestrial and offshore environments. This ranges from contract investigations in Wales, English Heritage Aggregate Levy Sustainability Fund (ALSF) research in Kent, Sussex and Lancashire to the current NERC BRITICE-CHRONO Consortium. The understanding provided has informed infrastructural and mineral resource planning, aiding mitigation for heritage and environmental assets. Data are embedded in National and Regional Planning (e.g. Welsh Assembly, Lancashire County Council, Natural England, English Heritage).

2. Underpinning research

Understanding sediment-landform associations in fluvial, coastal and former glacial environments allows research questions to be addressed about physical processes that shape landforms and landscape, and environmental and climate change over time. It also provides data of value to the minerals and renewable energy sectors. The scientific basis is the landform and sediment record which can be investigated by e.g. assessing the glacial sand and gravel resource to enhance understanding of the last glaciation[2,6]. ESPEC research led by Chiverrell (Reader, 1998-date), Thomas (SL, 1974-2009) and Plater (Professor, 1990-date) has been supported by >15 grants ranging from applied research for Government (e.g. Northwest Wales 2004) to Heritage Funding (ALSF Dungeness and Ribble Valley) to RCUK research on the earth system (BRITICE-CHRONO). Examples of associated research undertaken 1992-2013 are outlined below:

- The former British-Irish Ice Sheet left a rich legacy of landforms that document the pace of ice retreat[2] and forms large reserves of sand and gravel. Chiverrell and Thomas's research has focused on Western Ireland, the Irish Sea Basin (including the Isle of Man, Ireland, Wales[6]) and the Shropshire-Cheshire-Lancashire lowlands (1992 to date).
- Riverine deposits are important aggregate resources. The ALSF Ribble Valley Project (2005-2007) led by Chiverrell delivered an assessment of the aggregate reserve, and developed a comprehensive chronological model for fluvial landform development, addressing research questions regarding; the controls on river and floodplain dynamics, timing and causation of fluvial environmental change, and linking millennial timescale changes in the fluvial system to human and climatic drivers of environmental change[1].
- ALSF research by Plater 2002-04, building on work funded by Brett Aggregates, ARC and the Romney Marsh Research Trust extending back to 1992, established factors and interactions that enable long-term resilience of the Romney Marsh / Dungeness Foreland depositional complex (SE England) to changes in relative sea-level, storm magnitude and frequency, and variations in sediment supply[4,5]. This body of work and Plater's contribution to allied ALSF research on Rye Bay is brought together in a substantive research monograph on the depositional history of the region, underpinning future resource use planning[5].
- Linking to Plater's work with aggregate companies on the UK south coast, Lafarge-Tarmac supported a NERC-CASE PhD (2009-2012, supervised by Plater, Lang, Mauz, revealing the seabed in the eastern English Channel to be an erosional landscape dissected by a complicated network of palaeovalleys, a landscape shaped by cycles of erosion and deposition by fluvial and coastal processes since the last glacial maximum, contradicting an existing hypothesis of formation by catastrophic mega-flooding[3].
- Research completed 2012-2013 as part of the ongoing NERC Consortium Project (BRITICE-CHRONO) (2012-2018) aims to establish how quickly marine-influenced portions of the

last British-Irish Ice Sheet (BIIS) retreated 24,000 years ago and what controlled the speed of retreat[2]. This research has (Centrica PLC ~ July 2013) and will continue to enhance understanding of offshore geological and geomorphological records, which is largely dominated by glacial features, information much needed by marine infrastructure (e.g. renewable energy and power cable) and the marine aggregates industry.

3. References to the research

Publications

[1] Chiverrell, R. C., G. C. Foster, et al. (2010). "Sediment transmission and storage: The implications for reconstructing landform development." Earth Surface Processes and Landforms 35(1): 4-15. DOI: 10.1002/esp.1806

[2] Chiverrell, R. C., I. M. Thrasher, et al. (2013). "Bayesian modelling the retreat of the Irish Sea Ice Stream." Journal of Quaternary Science 28(2): 200-209. DOI: 10.1002/jqs.2616

[3] Mellett, C. L., D. M. Hodgson, et al. (2012). "Preservation of a drowned gravel barrier complex: A landscape evolution study from the north-eastern English Channel." Marine Geology 315-318: 115-131. DOI: 10.1016/j.margeo.2012.04.008

[4] Long, A.J., Waller, M.P. and Plater, A.J. (2006). Coastal resilience and late Holocene tidal inlet history: The evolution of Dungeness Foreland and the Romney Marsh depositional complex (UK). Geomorphology 82(3-4): 309-330. DOI: 10.1016/j.geomorph.2006.05.010

[5] Long, A.J., Waller, M.P. and Plater, A.J. 2007: Dungeness and Romney Marsh: Barrier Dynamics and Marshland Evolution. ISBN-13: 978-1-84217-288-9; ISBN-10: 1-84217-288-3

[6] Thomas, G. S. P. and R. C. Chiverrell (2007). "Structural and depositional evidence for repeated ice-marginal oscillation along the eastern margin of the Late Devensian Irish Sea Ice Stream." Quaternary Science Reviews 26(19-21): 2375-2405. DOI: 10.1016/j.quascirev.2007.06.025

Funding for the research

NERC British Geological Survey / Exxon-Mobil, Quaternary Geology of the Isle of Man 2003/4, £6000, P-I Chiverrell

Isle of Man Government (Manx National Heritage and the Gough Richie Trust), Quaternary environmental change on the Isle of Man, 1997-1999, £120,000 , P-I Thomas

Romney Marsh Research Trust, The evolution and landscape history of Dungeness Foreland. 1992-1995, £135000, P-I Plater

Welsh Assembly Government: Department of Planning, Sand and gravel deposits of Northwest Wales, 2004, £89000, P-I Thomas and Chiverrell

Aggregate Levy Sustainability Fund: English Heritage, The evolution and landscape history of Dungeness Foreland, 2004-6, £180,000, P-I Plater

Lydd Airport Company, Geotechnical investigations at Lydd Airport, 2009-11, £38000, PI Plater

Aggregate Levy Sustainability Fund: English Heritage, Aggregate Extraction and the Geoarchaeological Heritage of the Ribble Valley and Kirkham Moraine, 2005-2007, £240,000 and £96,000, P-I Chiverrell

NERC/Tarmac Industrial Case PhD Studentship, Drowned landscapes of the English Channel 2009-2012, £50000, P-I Lang

NERC Consortium Grant, BRITICE-CHRONO: constraining rates and style of marine-influenced ice-sheet decay, 2013-2018, £3.6m with £350k at Liverpool, Liverpool P-I Chiverrell

4. Details of the impact

Methodologies developed during mineral assessments 1992-5, reinforced and updated for new technologies in the 2003-9[1,2] are testament to the impact of this research. Potential aggregate resources can be rapidly and cost-effectively identified in formerly glaciated and fluvial environments. Approaches made were more cost-effective than widespread drilling of boreholes, negating the need for costly and time intensive geophysical techniques and excavation of trial pits. Liverpool researchers undertook mineral assessments in Northwest Wales[1,2], Lancashire[3,4], and assessments underpin activities of Regional Aggregate Working Parties (RAWP)[1]. The glacial landform record in northwest Wales[2], on the Isle of Man, Lancashire, Cheshire and Shropshire has guided the location of sand and gravel extraction sites. Research also tested and applied new

technologies e.g. LiDAR and IfSAR digital elevation models in mineral resource assessments, with presentations to RAWP (Wales and Northwest England) and to the Quarry Productions Association Annual Conference.

The ESPEC Research Group has been a key player (PI: Plater, PI: Chiverrell) in various research projects funded by the English Heritage Aggregate Levy Sustainability Fund, addressing environmental impacts of aggregate extraction by providing a thorough evidence base to inform resource planning. In southeast England, ALSF Grants (3280, 3281, and 4521) to Plater 2002-2004 explored the long-term resilience of the Dungeness Foreland depositional complex, a region long affected by aggregate extraction[5,6]. Between 2005- 2009 two ALSF grants (PI: Chiverrell) focused on environmental processes, aggregate extraction and geoarchaeological heritage of the Ribble Valley and Kirkham Hills[3,4,6]. These ALSF projects have enhanced understanding of natural and heritage assets in these aggregate extraction areas, archived by English Heritage's Archaeological Data Service[4,6] as a resource for the community, extractive industry, local authorities and environmental regulators for future resource planning. For example Lancashire Country Council states "*results of both of them have been incorporated into the Lancashire Historic Environment Record and are made available to users of the Record*" and that "*It is particularly useful in providing a basis for assessment of areas away from those (such as Ribchester)*". In 2006 Natural England re-designated the Dungeness SSSI on the basis of ALSF project outcomes and required Lydd (London Ashford) Airport to commission a study 2009-2011 (led by Plater) that "*fed into the recent public inquiry which resulted in approval of the runway extension in April 2013*"[7,8]. The current operational policy of Natural England for the SSSI designation is to "*direct developers to seek the advice of Andy Plater*", with examples including "*Parsons Brinkerhoff and Lydd Airport on the runway extension"* and *"Halcrow/CH2MHill on the Broomhill sea defence upgrade*" (2009-2013)[8].The research association with the aggregates industry has extended offshore, with a NERC Industrial CASE PhD 2009-2012 with Lafarge-Tarmac. Research by Mellett, supervised by Lang, Mauz, Plater, investigated the drowned landscapes of the eastern English Channel refining understanding of controls on gravel and sand deposition and the timing of deposition of marine aggregates, thus indicating where likely future aggregate resources may be present.

Robust assessment of Quaternary geology and communication with aggregate and other resource industries is embedded in the on-going NERC Consortium Britice-CHRONO Project, aiming to constrain rate of retreat of the marine-influenced portions of the last British-Irish Ice Sheet (BIIS) and to understand the controls on rates of ice retreat. Direct relevance of this research to the UK economy is demonstrated in KE agreements with Project Partners, Scottish Power over the Western High Voltage Link and renewable energy companies in the UK and Ireland (2012-3). Extensive Round 3 Wind Development Zones (R3Z) in the Irish Sea (Centrica Renewable Energy) and North Sea (Forewind Consortium) overlap with the proposed Britice-CHRONO transects. Centrica have received reports (2013) characterising the sea floor and the "*work has provided unique insights into the recent [Quaternary] geological setting of the project, thereby allowing us to make a number of useful predictions regarding potential geohazards relevant to future construction*" wind turbines in the Irish Sea[9]. Connections with terrestrial and marine aggregate extractive industries have continued, because improved understanding of the sea floor condition and glacial geology, Britice-CHRONO's deliverables, are critical for resource appraisal (e.g. aggregates) and site development (e.g. power infrastructure and renewable energy schemes). First, informing engineering geologists by providing direct information on the bed and sub-surface conditions (sediment type, geometry, bed morphology) and elsewhere with indirect, process-based model predictions of substrate conditions[9]. These data provide an informed basis for engineering design and implementation, reducing development and installation costs. Second, we inform commercial and regulatory bodies on the environmental history with advice on identifying sites of potential archaeological or geo-ecological significance.

5. Sources to corroborate the impact

[1] Implementing the Methodology for Assessing the Environmental Capacity for Primary Aggregates (IMAECA) - Executive Summary. University of Liverpool (Thomas and Chiverrell) completed the aggregate assessment and GIS analysis and is embedded in documents of the Regional Aggregate

Working Party annual reports e.g. page 149.

[2] The Sand and Gravel Resources of North West Wales – Summary. The entire report was produced by Thomas, Chiverrell and Chester (of the University of Liverpool).

[3] English Heritage: communicating science : via the Archaeological Data Service

[4] Letter of support from Lancashire County Council Planning Department detailing how the Ribble/Kirkham datasets are Lancashire Historic Environment Records and have been used in the assessment of development proposals.

[5] English Heritage: communicating science : via the Archaeological Data Service

[6] The Inspector of Ancient Monuments (Programmes & Projects) & Senior National Minerals and Environmental Adviser can be contacted to endorse the impact of the Dungeness, Ribble and Kirkham ALSF projects with regard to understanding the Historic Environment and planning issues requiring Heritage understanding.

[7] Research by Plater and the Romney Marsh underpins the SSSI designation pages 6, 18-24 detailing use of the research by local government and Natural England. This can be corroborated with a supporting letter from the Lead Conservation Advisor Land Management Team, Natural England.

[8] Letter of support from the Planning Executive for Lydd (London Ashford Airport) outlining the contribution of the research to the Public Inquiry in April 2013 and approval of the runway extension for Lydd (London Ashford Airport). This contact can corroborate the input of Liverpool's research to the Geomorphological Assessment for the now underdevelopment Lydd (London Ashford) Airport extension.

[9] Centrica PLC has provided a letter of support for Britice-Chrono NERC Consortium and the recent related consultancy undertaken by the research team on the glacial geomorphology and geology in the Irish Sea.