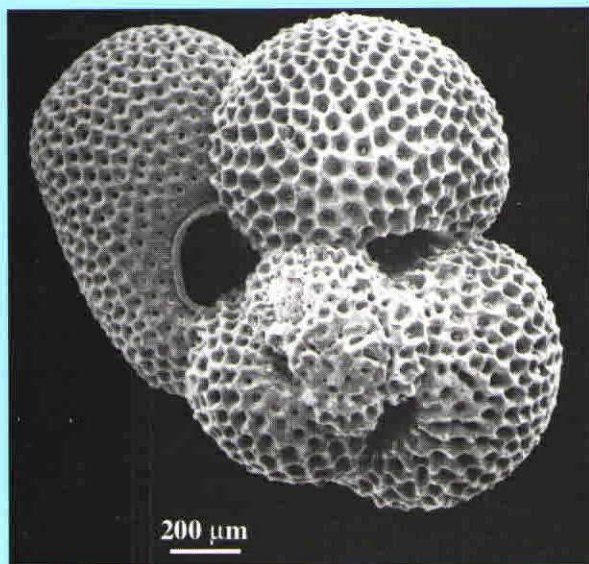

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COVER PHOTOGRAPH:

Photomicrograph of *Globigerinoides sacculifer*, a species of Foraminifera studied by the late Brian Funnell (see Obituary in this issue). Photograph kindly provided by Julian Andrews.

EDITORIAL

As the editorship of the *Quaternary Newsletter* passes from Stewart Campbell to me, I would like to thank Stewart on behalf of the QRA for his dedication and skill. Since 1996, Stewart has ensured that *QN* has provided a stimulating and well-presented mix of news, research and comment.

Insight, debate and variety are essential to the continued success of *QN*. Material with these qualities will be welcomed from all members of the QRA, whether amateur, professional, young Turk, sage, iconoclast or conformist. And in addition to general Quaternary matters, *QN* will also welcome material about education and conservation. Spreading the findings of Quaternary research to schools and the general public, and encouraging them to pursue their own Quaternary interests or research should be important to us all.

Finally, I'd like to make a plea on behalf of good illustrations. As maps, diagrams and photographs are just as important as text, please would contributors to *QN* submit illustrations that are well designed and produced.

Julian Murton

OBITUARY

PROFESSOR BRIAN MICHAEL FUNNELL M.A., PH.D., F.G.S. 1933-2000

The death of Brian Funnell in May 2000 has deprived Quaternary science and the wider field of Environmental Sciences in general of an active researcher whose work anticipated many of the important developments of the last few decades. He applied a specialist's knowledge of micropalaeontology to a wide range of scientific interests, including Neogene and Quaternary timescales, the palaeoceanography in the Pacific, Indian and Atlantic oceans, the palaeogeography of continental coastlines, the Quaternary successions of East Anglia and the North Sea and their correlations with Europe, and the Holocene evolution of the Norfolk and Suffolk coasts. He also had a wider influence which was the more profound for being expressed indirectly and concealed by modesty about his personal achievements. In the 1960s and 70s most geologists and geophysicists were wrestling with the fusion of their hitherto separate disciplines and regarded geography as an alien territory. It was at precisely this time that Brian developed and put into practice a vision of Earth Science as an integrated member of the family of Environmental Sciences, which includes within its scope the whole earth, its atmosphere, oceans, ice-sheets, vegetation, animal ecology, human inhabitants and their societies, constructions and influences on natural fluxes of water and chemicals. His own research, teaching and public service helped to shape the concepts of Earth System Science and Environmental Geology as they have now emerged, 30 years later. It was through his foundation, with Professor Keith Clayton, of the School of Environmental Sciences at the University of East Anglia that his widest vision found concrete expression. Brian's death came prematurely and he was active in research and publishing to the very last of his 66 years. Though his Presidency of the QRA was cut short in 1999, he used it to widen the Association's contact with other sciences and to promote the contributions that Quaternary scientists make to understanding the global environment. In recognition of his life-long contributions he was elected to Honorary Memberships of both the QRA and the British Micropalaeontological Society.

Brian Funnell was a prime mover in the study of the Quaternary of East Anglia, where he grew up and attended the City of Norwich School. At the age of 17 he took a leading role in founding the Paramoudra Club, an association of

student geologists whose members in later life became distinguished in science and industry. In 1969 the club became the Geological Society of Norfolk, and from its inception it published a valuable Bulletin containing original research papers. In the 1950s Brian published papers on the geology of the Bungay district (4) and of the area around Ingham and Bury St. Edmunds (5). These early works show the characteristic thoroughness and brevity of all his writing. Starting in 1956, he compiled a bibliography of East Anglian geology (7,10,13,15,16,28,38,104,112) grouped by decade from 1900 onwards, which was a very useful continuation of W.J. Harrison's '*A Bibliography of Norfolk Glaciology including the Cromer Cliffs, with the Forest-Bed Series*' (*Glacialists' Magazine* (1897), 1-91). Later he edited publications on the '*The Geology of Norfolk*' in 1961 (18, 20,39,67) and '*East Anglian Geology*' in 1984 (89). To the first of these he contributed a landmark paper on the Palaeogene and Early Pleistocene of Norfolk (19), reporting the results (largely his Ph.D. research) of micropalaeontological investigations at important marine Early Pleistocene sites at Ludham, Bramerton, Sidestrand, Easton Bavents, Sizewell, Thorpe Aldringham and Chillesford. He distinguished several distinct foraminiferal assemblages which could be correlated to pollen zones of the Early Pleistocene. This work on foraminifers pushed forward hugely the interpretation of the Crag and was developed further in later studies, many of which were interdisciplinary in nature and included his own work on Mollusca. Such sites as Bramerton (75), Easton Bavents (21), Covehithe (77) and Bulcamp (84) all lie within East Anglia, as do the Red Crag sites of Walton, Newbourn and Butley (48,66) and the deep boreholes at Stradbroke (66, 85), Debenham (85) and Sizewell (86). Later ventures further afield in Britain included the temperate stage site at Earnley, Sussex (87) and marine deposits in caves at Berry Head, Devon (119). Brian's work on East Anglian stratigraphy and palaeo-environments had a significance far beyond the local, for it aimed at correlation between the British, North Sea and European records (66, 97, 114,148 and especially 141) and with the geological timescale (78, 82).

Though he never belittled its importance Brian sometimes jokingly referred to East Anglian geology as his hobby, for the bulk of his contributions as a micropalaeontologist were made on the wider stage of marine geology and palaeoceanography. He took his B.Sc. in Natural Sciences at Trinity College, Cambridge, and returned in 1957 after National Service to conduct research. After two years he was elected to a Fellowship and he remained at Cambridge until 1968, becoming successively Senior Assistant in Research, University Demonstrator and University Lecturer. Because of his expertise in the study of microfossils, he became attached to the Marine Geology group led by Maurice Hill at the Department of Geodesy and Geophysics. In 1961-2 he was awarded

a Harkness Fellowship to study for a year in the USA, which he spent at the Scripps Institution of Oceanography under Fred Phleger and alongside Bill Reidel. His studies of the micropalaeontology of deep-sea sediments ranged over a broad canvas, for at Cambridge he was working on sediments from the Atlantic and Indian oceans, while at Scripps he worked on sediments from the Pacific (22,24). Because of the birth and rapid development of whole new subject areas in the 1960s, such as geomagnetic reversal stratigraphy, sea-floor spreading and plate tectonics, the main application of Brian's initial studies of oceanic microfossils was in providing stratigraphic dating. In 1964 he published a paper with Chris Harrison which for the first time documented and dated a reversal in remanent magnetism in a sequence of deep-sea sediments (25). Palaeontological dates from microfossils were also crucial in dating oceanic features and their structural history (29,30,34,35,36) and in determining the age of oceanic sediments in general to test the hypothesis of sea-floor spreading (33,43,44). For many years following the plate tectonic revolution of 1967, Brian collaborated with Alan Smith on the palaeogeographic location of cored and drilled sediments in the ocean basins (33,70) and the location of shorelines on palaeogeographic reconstructions (100,107). The latter culminated in the publication of the *'Atlas of Mesozoic and Cenozoic Coastlines'* in 1994 (132).

It was clear from the outset that Brian's main interest in studying microfossils was in the extent to which they might yield palaeo-environmental information (14). In 1971, together with Bill Reidel, Brian edited the landmark volume *'The Micropalaeontology of Oceans'* (42) and in the following two decades he continued to develop and refine the methods by which the application of biostratigraphic data could be used to establish chronologies for the Plio-Pleistocene (78,142,147). With time, however, the emphasis of his studies shifted towards palaeoceanography – the determination of variations in sea-surface temperature, sea-water chemistry, surface currents, coastal upwelling and productivity in the past. The period 1989-2000 was particularly productive for such research, in collaboration with research students and post-doctoral researchers. A series of studies, largely based on material collected through the Ocean Drilling Program, used diatom, foraminiferal and radiolarian compositional data to decipher the complex pattern of ocean circulation changes associated with the climatic deterioration through the Late Neogene (94,113,117,139,145,146,155,157,158). The significance of these findings was supported by complementary investigations into the ecological factors affecting modern species distributions (130, 152).

From the mid-1970s onward, Brian's third strong research interest was the Holocene evolution of the East Anglian coastline, particularly North Norfolk, Broadland and Suffolk. He was ahead of the game as usual, for 25 years later

the geological evolution of Holocene coastlines has become an important research theme in the context of global warming and sea-level rise. Much of Brian's work, in conjunction with a series of successful research students, was grounded in the applications of microfossils as indicators of both palaeo-environment and relative sea level, although his interests branched out to include geotechnical and geochronological studies. A number of important papers were published in the 1980s, notably 106, which explained the structure of Holocene sediments beneath the North Norfolk coast. This beautiful area of coast between Weybourne and Hunstanton, a 'natural laboratory' to Brian, became the focus of a UEA research group in the 1990s contributing to the NERC-funded LOIS (Land-Ocean Interaction Studies) programme. Brian was an active participant and was still involved in interpreting the results at the time of his death (160, 161). Many of his interpretations from earlier work have been vindicated by the results of the LOIS.

Though he might have based his whole career at Cambridge, in 1968 he was lured back to Norwich to one of two Professorships which founded the School of Environmental Sciences at the new University of East Anglia. He was heavily involved in the appointment of staff and in developing the School's teaching programme, and as second Dean of the School he oversaw the layout and equipping of permanent buildings, and nurtured the now world-renowned Climatic Research Unit. Just as he applied new techniques and approaches to his science, Brian brought the same visionary skills to the founding and development of what became the largest and most broadly based Environmental Sciences institution in Europe. The inter-disciplinary ethos that he propounded at UEA is now a model aspired to by many institutions but was very adventurous at the time. One factor in its spread was the promotion of former UEA staff and students to senior posts in some of the best Earth Sciences departments in Britain. The School's success and its influence on the general growth of an Earth System Science perspective were both sources of great pleasure to Brian in the 1990s. In 1989 he took early retirement, essentially so that he could devote more time to research. Initially he was re-employed part-time as a Research Professor, then appointed as a Professorial Fellow, and in 1994 he was made Emeritus Professor.

Throughout his career Brian gave much time to teaching and public service, holding numerous examinerships in universities. He was Chair of the British Micropalaeontological Society (1984-6) and President of the QRA (1997-9), and served on the Ocean Drilling Program, the Geological Committee of the Royal Society and the Radioactive Waste Management Advisory Committee of the Department of the Environment. He headed the Steering Committees of the Natural Environment Research Council's Thematic Programmes on

'*Palaeoclimate of the Last Glacial/Interglacial Cycle*' (133) and "*Terrestrial Initiative in Global Geological and Environmental Research (TIGGER)*", both of which enabled Quaternary scientists to participate in the growing applications of Earth Science to understanding climatic change. He took the view that the health of a country's science lies in local roots as well as national and international programmes. His earliest papers were stated to be "primarily intended for the use of local naturalists and schools" and he was a tireless supporter of the Geological Society of Norfolk, editing its *Bulletin* for many years. He was keen on exposing science to the public and conceived the imaginative idea of an Ice Age Grove, which was planted at Pigney Wood near North Walsham to illustrate the successive colonisation of Britain by trees at the start of an interglacial. Always supportive of his students and colleagues, he will be long remembered and much missed. He will be commemorated at the University of East Anglia by the planting of a *Ginkgo* (maidenhair) tree, now only native in East Asia but once a component of the forests which flourished in East Anglia during the Tertiary.

Bibliography

161. **Funnell, B.M.** (2000). Palaeoceanography: tapping the Ocean's long-term memory. In: Deacon, M.B., Rice, A.L. and Summerhayes, C.P. (eds) *Understanding the Oceans: A Century of Ocean Exploration*. Routledge, London, 124-137.

160. **Funnell, B.M.**, Boomer, I., and Jones, R. (2000). Holocene evolution of the Blakeney Spit area of the North Norfolk coastline. *Proceedings of the Geologists' Association*, 111, 205-217.

159. Andrews, J.E., Boomer, I., Bailiff, I., Balson, P., Bristow, C., Chroston, P.N., **Funnell B.M.**, Harwood, G.M., Jones, R.W., Maher, B.A., and Shimmiel, G. (2000). Sedimentary evolution of the north Norfolk barrier coastline in the context of Holocene sea-level change. In: Shennan, I. and Andrews, J.E. (eds) *Holocene Land-Ocean Interaction and Environmental Change around the North Sea*. Geological Society Special Publication No. 166, 219-251.

158. Kennington, K., Haslett, S.K. and **Funnell, B.M.** (1999). Offshore transport of neritic diatoms as indicators of surface current and trade wind strengths in the Plio-Pleistocene eastern equatorial Pacific. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 149, 171-181.

157. **Funnell, B.M.** (1998). Climatic evolution of the North Sea and North Atlantic during the Pliocene-Pleistocene (2.7 to 1.7 Ma). *Mededelingen Nederlands Instituut voor Toegepaste Geowetenschappen TNO*, 60, 227-238.

156. Haslett, S.K. and Funnell, B.M. [1998]. Low-latitude Plio-Pleistocene temporal abundance variations in the radiolarian *Cycladophora davisiana* Ehrenberg: stratigraphic and palaeoceanographic significance. In: Cramp, A., MacLeod, C.J., Lee, S.V. and Jones, E.J.W. (eds) *Geological Evolution of the Ocean Basins: Results from the Ocean Drilling Program*. Geological Society, London, Special Publication, 131, 83-89.
155. Chapman, M.R., Funnell, B.M. and Weaver, P.P.E. (1998). Isolation, extinction and migration within Late Pliocene populations of the planktonic foraminiferal lineage *Globorotalia* (*Globoconella*) in the North Atlantic. *Marine Micropaleontology*, 33, 203-222.
154. Funnell, B.M. and Boomer, I. (1998). Microbiofacies tidal-level and age deduction in Holocene saltmarsh deposits on the north Norfolk Coast. *Bulletin of the Geological Society of Norfolk*, 46, 31-55.
153. Funnell, B.M. (1997). The Coastal Change Dragon. *The Norfolk Countryside Review*, Issue Autumn/Winter 1997/98, 14-16. [The Norfolk Society: The County of Norfolk Branch of The Council for the Protection of Rural England.]
152. Funnell, B.M. and J.E. Swallow, J.E. (1997). Intra-sample, inter-sample and down-core microvariation in sea-surface temperature estimates obtained from planktonic foraminifera in the NE Atlantic. *Journal of Micropalaeontology*, 16, 163-174.
151. Funnell, B.M. (1997). The Climates of Past Ages. In: Hulme, M. and Barrow, E. (eds) *Climates of the British Isles: Present, Past and Future*. Routledge, London and New York, 65-83.
150. Funnell, B.M. (1996). Review of The Lower Palaeolithic Site at Hoxne, England. *Journal of Quaternary Science*, 11, 89-94.
149. Brew, D.S., Mitlehner, A.G. and Funnell, B.M. (1996). Holocene vegetation and salinity changes in the Upper Blyth Estuary, Suffolk. *Bulletin of the Geological Society of Norfolk*, 43, 45-61.
148. Funnell, B.M. (1996). Plio-Pleistocene palaeogeography of the southern North Sea basin (3.75-0.60 Ma). *Quaternary Science Reviews*, 15, 391-405.
147. Chapman, M.R., Funnell, B.M. and Weaver, P.P.E. (1996). High resolution Pliocene planktonic foraminiferal biozonation of the tropical North Atlantic. In: Moguilevsky, A. and Whatley, R. (eds.) *Microfossils and Oceanic Environments*. University of Wales Aberystwyth Press, 307-316. [Proceedings of the "ODP and the Marine Biosphere" International Conference, Aberystwyth, 19-21st April 1994.]

146. Haslett, S.K. and Funnell, B.M. (1996). Sea-surface temperature variation and palaeo-upwelling throughout the Plio-Pleistocene Olduvai subchron of the eastern equatorial Pacific: an analysis of radiolarian data from ODP sites 677, 847, 850 and 851. In: Moguilevsky, A. and Whatley, R. (eds) *Microfossils and Oceanic Environments*. University of Wales Aberystwyth Press, 155-164. [Proceedings of the "ODP and the Marine Biosphere" International Conference, Aberystwyth, 19-21st April 1994.]
145. Funnell, B.M., Haslett, S.K., Kennington, K., Swallow, J.E. and Kersley, C.L. (1996). Strangeness of the equatorial Ocean during the Olduvai magnetosubchron (1.95 to 1.79 Ma). In: Moguilevsky, A. and Whatley, R. (eds) *Microfossils and Oceanic Environments*. University of Wales Aberystwyth Press, 93-109. [Proceedings of the "ODP and the Marine Biosphere" International Conference, Aberystwyth, 19-21st April 1994.]
144. Funnell, B.M. (1996). Quartz- and Quartzite-Bearing Gravels of the Caistor St. Edmund Pit, Norwich, Norfolk. *Quaternary Newsletter*, 78, 42.
143. Funnell, B.M. (1995). The Coastal Change Dragon. In: Longcroft, A. and Joby, R. (eds) *East Anglian Studies*. Marwood Publishing, Norwich, 104-107. [Essays presented to J.C. Barringer on his retirement.] ISBN 1-87367-86-7.
142. Haslett, S.K., Kennington, K., Funnell, B.M. and Kersley, C.L. (1995). Plio-Pleistocene radiolarian and diatom biostratigraphy of ODP Hole 709C (equatorial Indian Ocean). *Journal of Micropalaeontology*, 14, 135-143.
141. Funnell, B.M. (1995). Global sea-level and the (pen-)insularity of late Cenozoic Britain. In: Preece, R.C. (ed) *Island Britain: a Quaternary Perspective*. Geological Society, Special Publication, 96, 3-13. ISBN 1-897799-32-2.
140. Haslett, S.K., Funnell, B.M. and Dunn, C.L. (1994). Calcite preservation, palaeoproductivity and the radiolarian *Lamprocyrtis neoheteroporos* Kling in Plio-Pleistocene sediments from the eastern equatorial Pacific. *N. Jb. Geol. Palaont. Mh.*, 1994, H.2, 82-94.
139. Haslett, S.K., Funnell, B.M., Dunn, C.L. and Bloxham, K.S. (1994). Plio-Pleistocene Palaeoceanography of the tropical Indian Ocean: radiolarian and CaCO₃ evidence. *Journal of Quaternary Science*, 9, 199-208.
138. Funnell, B.M. (1994). Recent Geology. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk (second edition)*. Norfolk Museums Service, Castle Museum, Norwich, 16-17, 188. ISBN 0-903101-60-2.
137. Funnell, B.M. (1994). Glaciers change the landscape. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk (second edition)*. Norfolk Museums Service, Castle Museum, Norwich, 14-15, 188. ISBN 0-903101-60-2.

136. **Funnell, B.M.** (1994). Solid Geology. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk*. (second edition). Norfolk Museums Service, Castle Museum, Norwich, 12-13, 188. ISBN 0-903101-60-2.
135. **Funnell, B.M.** (1994). A geological heritage coast: North Norfolk (Hunstanton to Happisburgh). In: Stevens, C., Gordon, J.E., Green, C.P. and Macklin, M.G. (eds) *Conserving Our Landscape*. English Nature, Peterborough, 59-62. [Proceedings of the Conference "Conserving our Landscape: Evolving landforms and Ice-age heritage", Crewe, UK, 1992.]
135. **Funnell, B.M.** (1994) Palaeoclimate of the Last Glacial/Interglacial Cycle: an overview. In: Funnell B.M. and Kay R.F.L. (eds) *Palaeoclimate of the Last Glacial/Interglacial Cycle*. Earth Sciences Directorate Special Publication 94/2, 7-9.
133. **Funnell, B.M. and Kay, R.L.F.** (eds) (1994). *Palaeoclimate of the Last Glacial/Interglacial Cycle*. NERC Earth Sciences Directorate Special Publication, 94/2, 1-84, NERC, Swindon. ISBN 1-85531-123-2.
132. Smith, A.G., Smith, D.G. and **Funnell, B.M.** (1994). *Atlas of Mesozoic and Cenozoic Coastlines*. Cambridge University Press. ISBN 1-521-45155-8.
131. **Funnell, B.M.** (1993). Review of *Upwelling Systems: Evolution since the Early Miocene*, Summerhayes, C.P., Prell, W.L. and Emeis, K.C., (eds) Geological Society Special Publication No. 64, (1992), London. *Marine Geology*, 115, 160-161.
130. Haslett, S.K. and **Funnell, B.M.** (1993). A new radiolarian calibration set for the eastern equatorial Pacific. *UK ODP Newsletter*, 15, 8.
129. **Funnell, B.M.** (1993). Review of: *Geology and the Environment in Western Europe*, Lumsden, G.I. (ed), Clarendon Press, Oxford, 1992. *Environment*, June 1993, 30.
128. **Funnell, B.M.** (1993). Recent Geology. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk*. Norfolk Museums Service, Castle Museum, Norwich, 16-17, 188. ISBN 0-903101-60-2.
127. **Funnell, B.M.** (1993). Glaciers change the landscape. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk*. Norfolk Museums Service, Castle Museum, Norwich, 14-15, 188. ISBN 0-903101-60-2.
126. **Funnell, B.M.** (1993). Solid Geology. In: Wade-Martins, P. (ed) *An Historical Atlas of Norfolk*. Norfolk Museums Service, Castle Museum, Norwich, 12-13, 188. ISBN 0-903101-60-2.

125. **Funnell, B.M.** (1993). Review of: *Modern Planktonic Foraminifera* (by Hemleben, C., Spindler, M. and Anderson, O.R.) Springer-Verlag, 1989. *Marine Geology* , 110, 181.
124. **Funnell, B.M.** (1992). Review of: *Modern Planktonic Foraminifera* (by Hemleben, C., Spindler, M. and Anderson, O.R.) Springer-Verlag, 1989. *Marine Geology* , 99, 275.
123. **Funnell, B.M.** (1992). A geological heritage coast: North Norfolk (Hunstanton to Happisburgh). In: Collinge, J. (ed) *Conserving Our Landscape: Evolving Landforms and Ice-age Heritage; reprints of papers*. English Nature, Peterborough, 43-48. [Proceedings of the Conference "Conserving our Landscape: Evolving landforms and Ice-age heritage", Crewe, UK, 1992.]
122. Brew, D.S., **Funnell, B.M.** and Kreiser, A. (1992). Sedimentary environments and Holocene evolution of the Lower Blyth estuary, Suffolk (England), and a comparison with other East Anglian coastal sequences. *Proceedings of the Geologists' Association*, 103, 1-18.
121. Zalasiewicz, J.A., Mathers, S.J., Gibbard, P.L., Peglar, S.M., **Funnell, B.M.** Catt, J.A., Harland, R. Long, P.E. and Austin, T.J.F. (1991). Age and relationships of the Chillesford Clay (early Pleistocene: Suffolk, England). *Philosophical Transactions of the Royal Society, London*, B333, 81-100.
120. **Funnell, B.M.** (1991). Geological Evidence from Deep Sea cores. In: Goodess, C.M. and Palutikof, J.P. *Future Climate Change and Radioactive Waste Disposal*. NIREX Radioactive Waste Disposal Safety Studies, 95-103.
119. **Funnell, B.M.** (1991). A short note on the Foraminifera obtained from Corbridge Cave sediments. (Appendix 1, In: Proctor, C.L. and Smart, P.L. A dated cave sediment record of Pleistocene transgression on Berry Head, Southwest England.). *Journal of Quaternary Science*, 6, 243-244.
118. **Funnell, B.M.** (1991). Palaeogeographical maps of the southern North Sea basin. *Bulletin of the Geological Society of Norfolk*, 40, 53-66.
117. Malmgren, K.A. and **Funnell, B.M.** (1991). Benthic Foraminifera from Middle to Late Pleistocene, coastal upwelling sediments of ODP Hole 686B, Pacific Ocean, off Peru. *Journal of Micropalaeontology*, 9, 153-158.
116. Hooper, P.W.P., **Funnell, B.M.** and Weaver, P.P.E. (1991). Late Miocene-Early Pliocene Planktonic Foraminifera and Palaeoceanography of the North Atlantic. *Journal of Micropalaeontology*, 9, 145-151.
115. **Funnell, B.M.** (1991). Cenozoic Biostratigraphy and Global Change. *Journal of Micropalaeontology*, 9, 117.

114. Gibbard, P.L., West, R.G., Zagwijn, W.H., Balson, P.S., Burger, A.W., Funnell, B.M., Jeffery, D.H., De Jong, J., Van Kolfschoten, T., Lister, A.M., Meijer, T., Norton, P.E.P., Preece, R.C., Rose, J., Stuart, A.J., Whiteman, C.A. and Zalasiewicz, Z.A. (1991). Early and early Middle Pleistocene correlations in the southern North Sea Basin. *Quaternary Science Reviews*, 10, 23-52.

113. Andrews, J.E., Funnell, B.M., Jickells, T.D., Shackleton, N.J., Swallow, J.E., Williams, A.C. and Young, K.A. (1990). Preliminary assessment of cyclic variations in foraminifers, barite and cadmium/calcium ratios in early Pleistocene sediments from hole 709C (Equatorial and Indian Ocean). In: Barbu, E. (ed) *Proceedings of the Ocean Drilling Program, Scientific Results*, 115, 611-619.

112. Funnell, B.M. (editor) (1990). Reprint of Bulletins Nos. 11-18 (1962-1969). *Bulletin of the Geological Society of Norfolk*, 39A.

111. Pearson, I., Funnell, B.M. and McCave, I.N. (1990). Sedimentary Environments of the Sandy Barrier/Tidal Marsh Coastline of North Norfolk. *Bulletin of the Geological Society of Norfolk*, 39, 3-44.

110. Jickells, T.D., Funnell, B.M. and Young, K.A. (1990). 24. Cadmium/calcium ratios in benthic foraminifers recovered during Leg 112. In: Suess, E., von Huene, R., et al., (eds) *Proceedings of the Ocean Drilling Program, Scientific Results*, 112, 407-409.

109. Funnell, B.M. and Owen, A.W. (1990). Palaeocomputing: keyboard to the past. *Journal of the Geological Society, London*, 147, 393-395.

108. Tyson, R.V. and Funnell, B.M. (1990). European Cretaceous shorelines, stage by stage. In: Ginsburg, R.N. and Beaudoin, B. (eds) *Cretaceous Resources, Events and Rhythms - Background and Plans for Research*. Kluwer Academic Publishers, Dordrecht, 237-272.

107. Funnell, B.M. (1990). Global and European Cretaceous shorelines, stage by stage. In: Ginsburg, R.N. and Beaudoin, B. (eds) *Cretaceous Resources, Events and Rhythms - Background and Plans for Research*. Kluwer Academic Publishers, Dordrecht, 221-235.

106. Funnell, B.M. and Pearson, I. (1989). Holocene sedimentation on the North Norfolk barrier coast in relation to relative sea-level change. *Journal of Quaternary Science*, 4, 25-36.

105. Funnell, B.M. (1989). Quaternary. In: Jenkins, D.G. and Murray, J.W. (eds) *Stratigraphic Atlas of Fossil Foraminifera (Second Edition)*. Ellis Horwood, Chichester, 563-569.

104. Funnell, B.M. (ed) (1988). Reprint of Bulletins Nos. 1-10 (1953-1961). *Bulletin of the Geological Society of Norfolk*, 38A.
103. Friend, P., Funnell, B.M., Kay, R. and Postma, G. (1988). Guide to the North Norfolk Coast. *British Sedimentological Research Group Excursion Guide*.
102. Jenkins, D.G., Curry, D., Funnell, B.M. and Whittaker, J.E. (1988). Planktonic foraminifera from the Pliocene Coralline Crag of Suffolk, Eastern England. *Journal of Micropalaeontology*, 7, 1-10.
101. Funnell, B.M. (1988). Foraminifera in the late Tertiary and early Quaternary Crags of East Anglia. In: Gibbard, P.L. and Zalasiewicz, J.A. (eds) *Pliocene—Middle Pleistocene of East Anglia*, Quaternary Research Association, 50-52.
100. Tyson, R.V. and Funnell, B.M. (1987). European Cretaceous shorelines, stage by stage. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 59, 69-91.
99. Funnell, B.M. and Buck, S.G. (1987). *Barrier coast and shallow marine siliciclastic facies: Holocene and Early Cretaceous of North Norfolk and Bedfordshire*. Poroperm Excursion Guide No. 10, Poroperm-Geochem Ltd., Chester.
98. Hodgson, G.E. and Funnell, B.M. (1987). Foraminiferal biofacies of early Pliocene Coralline Crag. In: Hart, M.B. (ed) *Micropalaeontology of Carbonate Environments*. British Micropalaeontological Society Series, Ellis Horwood, Chichester, 43-47.
97. Funnell, B.M. (1987). Late Pliocene and Early Pleistocene stages of East Anglia and the adjacent North Sea. *Quaternary Newsletter*, 52, 1-11.
96. Funnell, B.M. (1987). Anoxic non-events: alternative explanation. In: Brooks, J. and Fleet, A.J. (eds) *Marine Petroleum Source Rocks*, Geological Society Special Publication, 26, 421-422.
95. Funnell, B.M. (1986). Did the Chalk Potstone worms 'smoke' H_2S ? *Bulletin of the Geological Society of Norfolk*, 37, 77-88.
94. Hooper, P.W.P. and Funnell, B.M. (1986). Late Pliocene to Recent planktonic foraminifera from the North Atlantic (DSDP Site 552A): quantitative palaeotemperature analysis. In: Summerhayes, C.P. and Shackleton, N.J. (eds) *North Atlantic Palaeoceanography*, Geological Society Special Publication, 21, 181-190.

93. **Funnell, B.M.** (1985). Present and Future Strategy for Radioactive Waste Disposal. In: *Radioactive Waste Management: Technical Hazards and Public Acceptance*. Oyez Scientific and Technical Services, London, 3-9.
92. **Murphy, P. and Funnell, B.M.** (1985). Appendix 1. A preliminary study of the Holocene coastal sediments. In: *Hinchcliffe, J. and Green, C.S. (eds) Excavations at Brancaster 1974 and 1977*. East Anglian archaeology, Report No. 23, 182-185.
91. **Holliday, F.G.T., Clark, R., Funnell, B.M. and Taylor, P.** (1984). *Report of the Independent Review of Disposal of Radioactive Waste in the Northeast Atlantic*. HMSO.
90. **Funnell, B.M. and Pearson, I.** (1984). A guide to the Holocene geology of the North Norfolk Coast. *Bulletin of the Geological Society of Norfolk*, 34, 123-140.
89. **Funnell, B.M. and Cambridge, P.G.** (eds) (1984). *East Anglian Geology*. Geological Society of Norfolk, Bulletin, 34, 1-140.
88. **Funnell, B.M.** (1984). *Long-term Cyclical Changes in the Oceans*. British Association for the Advancement of Science, University of East Anglia, Section C, Geology, No. 12.
87. **West, R.G., Devoy, R.J.N., Funnell, B.M. and Robinson, J.E.** (1984). Pleistocene at Earnley, Bracklesham Bay, Sussex. *Philosophical Transactions of the Royal Society London*, B 306, 137-157.
86. **Funnell, B.M.** (1983). Preliminary note on the Foraminifera and stratigraphy of C.E.G.B. Sizewell boreholes L & S. *Bulletin of the Geological Society of Norfolk*, 33, 54-62.
85. **Funnell, B.M. and Booth, S.K.** (1983). Debenham and Stradbroke, two Crag boreholes compared. *Bulletin of the Geological Society of Norfolk*, 33, 45-53.
84. **Funnell, B.M.** (1983). The Crag of Bulcamp, Suffolk. *Bulletin of the Geological Society of Norfolk*, 33, 35-44.
83. **Funnell, B.M.** (1983). Dimensions of palaeophysiology. *Journal of the Geological Society*, 140, 1-4.
82. **Davies, A.M.C., Funnell, A.M. and Funnell, B.M.** (1982). Amino acid ratios in Crag molluscs. *Bulletin of the Geological Society of Norfolk*, 32, 39-50.
81. **Funnell, B.M.** (1981). Quaternary. In: *Jenkins, D.G. and Murray, J.W. (eds) Stratigraphic Atlas of Fossil Foraminifera*. Ellis Horwood, Chichester, 286-293.

80. Coles, B.P.L. and Funnell, B.M. (1981). Holocene palaeoenvironments of Broadland, England. *International Association of Sedimentologists, Special Publication*, 5, 123-131.
79. Funnell, B.M. (1981). Mechanisms of autocorrelation. *Journal of the Geological Society*, 138, 177-181.
78. Berggren, W.A., Burckle, L.H., Cita, M.B., Cooke, H.B.S., Funnell, B.M., Gartner, S., Hays, J.D., Kennett, J.P., Opdyke, N.D., Pastouret, L., Shackleton, N.J. and Takayanagi, Y. (1980). Towards a Quaternary time scale. *Quaternary Research*, 13, 277-302.
77. West, R.G., Funnell, B.M. and Norton, P.E.P. (1980). An Early Pleistocene cold marine episode in the North Sea: pollen and faunal assemblages at Covehithe, Suffolk, England. *Boreas*, 9, 1-10.
76. Funnell, B.M. (1979). Book Review: *Stratigraphic Micropalaeontology of Atlantic Basin and Borderlands*. Swain, F.M. (ed). *Marine Geology*, 30, 314-315.
75. Funnell, B.M., Norton, P.E.P. and West, R.G. (1979). The crag at Bramerton, near Norwich, Norfolk. *Philosophical Transactions of the Royal Society of London*, B 287, 489-534.
74. Funnell, B.M. (1979). Kimmeridge Crawl: Field trip to West Norfolk, Sunday 9th September 1979. *Bulletin of the Geological Society of Norfolk*, 31, 69-70.
73. Funnell, B.M. (1979). History and prognosis of subsidence and sea-level change in the lower Yare Valley, Norfolk. *Bulletin of the Geological Society of Norfolk*, 31, 35-44.
72. Murphy, P. and Funnell, (1979). Preliminary Holocene stratigraphy of Brancaster Marshes. *Bulletin of the Geological Society of Norfolk*, 31, 11-16.
71. Funnell, B.M. (1979). Palaeoenvironmental analysis of the Dobb's Plantation section, Crostwick (and comparison with type localities of the Norwich and Weybourne Crag). *Bulletin of the Geological Society of Norfolk*, 31, 1-10.
70. Firstbrook, P.L., Funnell, B.M., Hurley, A.M. and Smith, A.G. (1979). *Paleoceanic Reconstructions, 160-0 Ma*. National Science Foundation and Scripps Institution of Oceanography.
69. Curry, D., Adams, C.G. Boulter, M.C., Dilley, F.C., Eames, F.E., Funnell, B.M. and Wells, M.K. (1978). A correlation of Tertiary rocks in the British Isles. *Geological Society of London, Special Report*, 12 [8, 16, 50-51, 54, 55-56].

68. Funnell, B.M. (1978). The Palaeogene and Early Pleistocene of Norfolk. *Transactions Norfolk and Norwich Naturalists' Society*, 19, 340-364. [Reprint of 40, which itself is a reprint with additions, of 19]
67. Larwood, G.P. and Funnell, B.M. (eds) (1978). *The Geology of Norfolk*. Soman-Wherry Press Ltd., Norwich. [Transactions of the Norfolk and Norwich Naturalists' Society, 19, 269-376]. [Reprint of 39, which itself is a reprint with additions, of 18]
66. Funnell, B.M. and West, R.G. (1977). Preglacial Pleistocene deposits of East Anglia. In: Shotton, F.W. (ed) *British Quaternary Studies - Recent Advances*. Clarendon Press, Oxford, 247-265.
65. Funnell, B.M. (1977). Book Review: *The Geology of Continental Margins*. Burk, C.A. and Drake, C.L. (eds). *Engineering Geology*, 11, 155-156.
64. Funnell, B.M. (1977). *How the Atlantic Grew*. British Association for the Advancement of Science, University of Aston, Section C, Geology.
63. Funnell, B.M. and Wilkes, P.F. (1976). Engineering characteristics of East Anglian Quaternary deposits. *Quarterly Journal of Engineering Geology*, 9, 145-157.
62. Funnell, B.M. (1976). Chapter 1.3. Past environments of East Anglia. In: Washbourn, R. (ed) *Nature in Norfolk - a Heritage in Trust*. Jarrold and Sons Ltd, Norwich [to mark the 50th Anniversary of the Norfolk Naturalists Trust], 29-47.
61. Funnell, B.M. (1976). Book Review: *Studies in Paleo-oceanography*. Hay, W.W. (ed). *Marine Geology*, 20, 178-179.
60. Funnell, B.M. (1976). Essay Review: Geological Hazards. *Geological Magazine*, 113, 487-488.
59. Funnell, B.M. (1975). Quaternary Deposits of East Anglia. In: *Foundations on Quaternary Deposits*, The Engineering Group of the Geological Society (Norwich, September 1975), 4-6.
58. Funnell, B.M. and Hey, R.D. (eds) (1974). *The Management of Water Resources in England and Wales*. Saxon House, Westmead, U.K./Lexington Books, Lexington, U.S.A.
57. Funnell, B.M. (1975). The Origin of Mousehold Heath, Norwich. *Transactions Norfolk and Norwich Naturalists' Society*, 23, 251-333.

56. Funnell, B.M. (1974). Environmental Geology: the Prediction of Geological Hazards. *Geological Society Miscellaneous Paper*, 3, 1-2.
55. Funnell, B.M. (editor) (1974). *Prediction of Geological Hazards*, Geological Society Miscellaneous Paper, No. 3.
54. Funnell, B.M. (1974). Foreword. In: Brooks, P.F. *Problems of the Environment*. Harrap.
53. Funnell, B.M. (1973). *Coastal Scenery*. Jarrold and Sons Ltd., Norwich.
52. Funnell, B.M. (1973). Environmental Geology of Sheringham. *Geological Society of Norfolk Bulletin*, 24, 37-44.
51. Funnell, B.M. (1973). 3. Earth Sciences - The Physical Base. In: Calder, N. (ed) *Nature in the Round - A Guide to Environmental Science*. Wedenfeld and Nicolson, London, 25-36.
50. Ramsay, A.T.S. and Funnell, B.M. (1973). Tertiary Calcareous Nannoplankton. In: Hallam, A. (ed) *Atlas of Palaeobiogeography*. Elsevier Scientific Publishing Company, Amsterdam, 473-476.
49. Funnell, B.M. and Ramsay, A.T.S. (1973). Tertiary Cenozoic Planktonic Foraminifera. In: Hallam, A. (ed) *Atlas of Palaeobiogeography*. Elsevier Scientific Publishing Company, Amsterdam, 469-471.
48. Beck, R.B., Funnell, B.M. and Lord, A.R. (1972). Correlation of Lower Pleistocene Crag at depth in Suffolk. *Geological Magazine*, 109, 137-139.
47. Funnell, B.M. (1972). The History of the North Sea. *Geological Society of Norfolk Bulletin*, 21, 2-10.
46. Funnell, B.M. (1971). The Origin of the North Sea. *Geological Society of Norfolk Bulletin*, 20, 2-16.
45. Funnell, B.M. (1971). Post-Cretaceous biogeography of oceans - with especial reference to plankton. In: Middlemiss, F.A., Rawson, P.F. and Newall, G. (eds) *Faunal Provinces in Space and Time*. Geological Journal Special Issue, No. 4, 191-198.
44. Saito, T. and Funnell, B.M. (1971). Pre-Quaternary sediments and microfossils in the oceans. In: Maxwell, A.E. (ed) *The Sea*, Vol. 4, Part I, 183-204.
43. Funnell, B.M. (1971). The occurrence of pre-Quaternary microfossils in the oceans. In: Funnell, B.M. and Riedel, W.R. (eds) *The Micropalaeontology of Oceans*. Cambridge University Press, Cambridge, 507-534.

42. **Funnell**, B.M. and Riedel, W.R. (eds) (1971). *The Micropalaeontology of Oceans*. Cambridge University Press, Cambridge.
41. **Funnell**, B.M. (1970). Oceanic Micropaleontology of the South Pacific. In: Wooster, W.S. (ed) *Scientific Exploration of the South Pacific*. National Academy of Sciences, Washington, D.C., 133-151.
40. **Funnell**, B.M. (1970). The Palaeogene and Early Pleistocene of Norfolk. *Transactions Norfolk and Norwich Naturalists' Society*, 19, 340-364. [Reprint, with additions, of 19]
39. Larwood, G.P. and **Funnell**, B.M. (eds) (1970). *The Geology of Norfolk*. Soman-Wherry Press Ltd., Norwich. [Transactions of the Norfolk and Norwich Naturalists' Society, 19, 269-376]. [Reprint, with additions, of 18]
38. **Funnell**, B.M. (1969). Bibliography of East Anglian Geology [Supplement 1966, 1967, 1968]. *Geological Society of Norfolk Bulletin*, 17, 16-19, [reprinted *Bulletin of the Geological Society of Norfolk*, 39A, (1990), 102-105].
37. Fisher, M.J., **Funnell**, B.M. and West, R.G. (1969). Foraminifera and Pollen from a Marine Interglacial Deposit in the western North Sea. *Proceedings of the Yorkshire Geological Society*, 37, 311-320.
36. **Funnell**, B.M., Friend, J.K. and Ramsay, A.T.S. (1969). Upper Maastrichtian planktonic Foraminifera from Galicia Bank, west of Spain. *Palaeontology*, 12, 19-41.
35. Ramsay, A.T.S. and **Funnell**, B.M. (1969). Upper Tertiary microfossils from the Alula Fartak Trench, Gulf of Aden. *Deep-Sea Research*, 16, 25-43.
34. Jones, E.J.W. and **Funnell**, B.M. (1968). Association of a seismic reflector and upper Cretaceous sediment in the Bay of Biscay. *Deep-Sea Research*, 15, 701-709.
33. **Funnell**, B.M. and Smith, A.G. (1968). Opening of the Atlantic Ocean. *Nature*, 219, 1328-1333.
32. **Funnell**, B.M. (1967). Foraminifera and Radiolaria as depth indicators in the marine environment. *Marine Geology*, 5, 333-347.
31. Cutbill, J.L. and **Funnell**, B.M. (1967). Numerical analysis of the fossil record. In: *The Fossil Record*. Geological Society of London, Burlington House, London, 791-820.
30. Cann, J.R. and **Funnell**, B.M. (1967). The Geological Structure and History of Palmer Ridge, N.E. Atlantic. *Report of the Challenger Society*, 3, No. XIX.

29. Cann, J.R. and Funnell, B.M. (1967). Palmer Ridge: a section through the upper part of the ocean crust? *Nature*, 213, 661-664.
28. Funnell, B.M. (1967). Bibliography of East Anglian Geology [Supplement 1961, 1962, 1963, 1964, 1965]. *Paramoudra Club Bulletin*, 15, 9-19, [reprinted *Bulletin of the Geological Society of Norfolk*, 39A, (1990), 53-63].
27. Funnell, B.M. (1966). "The Palaeontology of Oceans". Sedgwick Prize Essay, 1-283, [unpublished].
26. Krinsley, D.H. and Funnell, B.M. (1965). Environmental history of quartz sand grains from the Lower and Middle Pleistocene of Norfolk, England. *Quarterly Journal Geological Society, London*, 121, 435-461.
25. Harrison, C.G.A. and Funnell, B.M. (1964). Relationship of palaeomagnetic reversals and micropalaeontology in two Late Caenozoic cores from the Pacific Ocean. *Nature*, 204, 566.
24. Riedel, W.R. and Funnell, B.M. (1964). Tertiary sediment cores and microfossils from the Pacific Ocean floor. *Quarterly Journal Geological Society, London*, 120, 305-368.
23. Funnell, B.M. (1964). The Tertiary period. *Quarterly Journal Geological Society, London*, 120 (The Phanerozoic Time-Scale: A Symposium), 179-191, [269-442] [can also be referred to as In: Harland, W.B., Smith, A.G. and Willcock, B. (eds) The Phanerozoic Time-Scale: A Symposium. *Geological Society of London, Special Publication*, 3]
22. Funnell, B.M. (1964). Studies in North Atlantic Geology and Palaeontology: 1. Upper Cretaceous. *Geological Magazine*, 101, 421-434.
21. Funnell, B.M. and West, R.G. (1962). The early Pleistocene of Easton Bavents, Suffolk. *Quarterly Journal Geological Society, London*, 118, 125-141.
20. Larwood, G.P. and Funnell, B.M. (1961). Geology [of Section 2. The Physical Background]. In: *Norwich and its Region.*, Jarrold and Sons Ltd., Norwich, for the British Association for the Advancement of Science, 18-30.
19. Funnell, B.M. (1961). The Palaeogene and Early Pleistocene of Norfolk. *Transactions Norfolk and Norwich Naturalists' Society*, 19, 340-364.
18. Larwood, G.P. and Funnell, B.M. (eds) (1961). *The Geology of Norfolk.* Soman-Wherry Press Ltd., Norwich. [Transactions of the Norfolk and Norwich Naturalists' Society, 19, 269-375].

17. Funnell, B.M. (1961). "The Climatic and Stratigraphic significance of the Early Pleistocene Foraminifera of the North Sea Basin". Doctor of Philosophy Dissertation, University of Cambridge, Cambridge [unpublished].
16. Funnell, B.M. (1961). Bibliography of East Anglian Geology [Supplement 1958, 1959, 1960]. *Paramoudra Club Bulletin*, 10, 16-18, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
15. Funnell, B.M. (1959). Bibliography of East Anglian Geology [Supplement 1955, 1956, 1957; Decade 1900-09]. *Paramoudra Club Bulletin*, 9, 6-16, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
14. Funnell, B.M. (1959). "Foraminifera and Climatic Change". Fellowship Dissertation, Trinity College, Cambridge [unpublished].
13. Funnell, B.M. (1958). Bibliography of East Anglian Geology [Decade 1910-19]. *Paramoudra Club Bulletin*, 8, 3-11, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
12. Funnell, B.M. (1958). The Yare Valley buried glacial channel. *Transactions Norfolk and Norwich Naturalists' Society*, 18, 10-14.
11. Funnell, B.M. (1957). The differentiation and correlation of East Anglian Pleistocene deposits: a review of recent research. *Paramoudra Club Bulletin*, 7, 1-3, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
10. Funnell, B.M. (1957). Bibliography of East Anglian Geology [Decade 1930-39; Decade 1920-29]. *Paramoudra Club Bulletin*, 6, 5-17, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
9. Funnell, B.M. (1957). The Norwich Chalk Belemnitidae. *Paramoudra Club Bulletin*, 6, 2-4, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
8. Funnell, B.M. (1957). 1956 Easter Field Meeting. *Paramoudra Club Bulletin*, 6, 1, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
7. Funnell, B.M. (1956). Bibliography of East Anglian Geology [Overall; Decade 1950-59; Decade 1940-49]. *Paramoudra Club Bulletin*, 5, 8-17, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
6. Funnell, B.M. (1956). The Evolution of the southern North Sea Basin. *Paramoudra Club Bulletin*, 5, 1-5, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].

5. Funnell, B.M. (1955). Geology of the Country around Ingham. *Transactions Suffolk Naturalists Society*, 9, 13-24.
4. Funnell, B.M. (1955). Geology of the Bungay District. *Transactions Suffolk Naturalists Society*, 9, 1-12.
3. Funnell, B.M. (1954). Notes on some exposures in glacial beds west of Norwich (1954). *Paramoudra Club Bulletin*, 2, 4-5, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
2. Funnell, B.M. (1954). The Yare Valley buried channel. *Paramoudra Club Bulletin*, 2, 2-3, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].
1. Funnell, B.M. (1954). An abstract of information obtained from borings in Norwich, 1951. *Paramoudra Club Bulletin*, 2, 2, [reprinted *Bulletin of the Geological Society of Norfolk*, 38A, (1988)].

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ARTICLES

A MAPPING-RELATED LITHOSTRATIGRAPHICAL FRAMEWORK FOR THE QUATERNARY OF THE UK

Andrew A. McMillan and Richard J.O. Hamblin

Background

In February 1998, an in-house Workshop was held at the British Geological Survey (BGS), Keyworth on the subject of stratigraphical classification and nomenclature of the Quaternary. Following the Workshop two BGS Quaternary Stratigraphical Framework Committees (QSFCs) were established to consider lithostratigraphical frameworks for the Quaternary deposits lying north and south of the limit of the main Late Devensian ice sheet. This brief discussion paper outlines the framework schemes which have developed over the last two years. It serves as a preface to the proposed BGS Open Discussion Meeting at Keyworth scheduled for 21 February 2001 (see QRA Circular or *Geoscientist* for details).

Traditionally, the BGS has published maps and accounts that employ a mixture of lithological, morphological and genetic terminology. To a large degree the terminology reflected the available information about the spatial distribution of surficial deposits. In recent years the opportunity has been taken to apply the principles of lithostratigraphy to Quaternary mapping. Increasingly it has become desirable to employ lithostratigraphical classifications to assist the interpretation of the regional spatial distribution of Quaternary deposits. There are benefits both for process-related research and for applied modelling. The requirement becomes more urgent as the BGS continues to develop digital mapping techniques which will enable 3-dimensional modelling of Quaternary deposits. No longer is it satisfactory to produce maps essentially of surface deposits in which, for example, tills of different lithologies and origins are depicted 'undivided' with minimal description.

The BGS Workshop addressed a number of questions fundamental to establishing a workable lithostratigraphical framework which takes as its premise its ability to be applied to geological mapping. Principal conclusions from the workshop included the following:

- The formation is the fundamental mapping unit (North American Stratigraphic Code, NACSN, 1983; Hedberg, 1976; Whittaker *et al.* 1991; Salvador, 1994)

- members and beds may also be mappable units
- grouping of formations is desirable particularly to aid regional mapping and interpretation by non-specialists
- groups may or may not be composed entirely of named formations (NACSN, 1983)
- lithological identifiers for formation names are desirable only where they clearly convey the principal lithological components of the unit
- lithogenetic classification (see McMillan and Powell, 1999) is often a practical mapping tool and it is not necessary or desirable to define all Quaternary deposits in a formal lithostratigraphy
- terrace deposits should be considered as members of formations defined by a single catchment (i.e. major river and its tributaries)

Mappability

At the time of the constitution of the BGS QSFCs it was appreciated that the Geological Society Special Report No.23—*A Revised Correlation of Quaternary Deposits in the British Isles* was in preparation. It was resolved that the results of the Geological Society report, now published (Bowen, 1999), should be taken into account in any proposed framework. The report has already received a number of constructive reviews (e.g. Green, 2000; Straw, 2000) and the contributors deserve praise for the documentation of nearly 1400 units, many of which have been described in detail in the scientific literature. The Preface by the editor, Professor David Bowen, sets out a modern basis for Quaternary onshore stratigraphy, but as Bowen and Lewis (2000) emphasize, in reply to Straw (2000), the report does not adopt oxygen isotope stages as the basis for classification but adheres to lithostratigraphical principles. Nevertheless, many of the units referred to in Bowen (1999) have been defined only locally on the basis of one or more well-exposed sections. Perhaps understandably little attempt has been made to correlate these units regionally and, as Bowen (1999) concedes, “many of the stratigraphical units proposed are not amenable to systematic and widespread mapping away from their stratotypes”.

Therein lies a serious problem for onshore mapping where correlation depends on scattered well-exposed sections. Combined with this fragmentary record and commonly ill-defined or unknown field relationships is the generally poorly fossiliferous nature of deposits, which makes it difficult to establish a robust biostratigraphy. Equally, many deposits contain little in the way of organic or other dateable material on which a chronostratigraphy may be based.

However, chronostratigraphical units may ultimately derive from lithostratigraphical criteria, and, as Bowen and Lewis (2000) have indicated in their response to Straw's review (2000), it is important that this relationship is not reversed.

A revised lithostratigraphical framework for the onshore Quaternary deposits (arising out of the QSFCs studies) emphasises the application of a 'top down' approach more amenable to mapping. Two geographical areas were considered, lying to the north and to the south of the known maximum extent of the Devensian ice sheets in Britain (Figure 1). The framework is built on the published literature (including BGS geological maps) and reference to Bowen (1999). We propose referencing the lithostratigraphy to British stage names (Rose, 1989; Mitchell *et al.*, 1973; Bowen, 1999) and to the most recently proposed time scales based on oxygen isotope stages (Bowen, 1999). Reference may also be made to the provisional late-glacial/Holocene event stratigraphy for the British Isles (Lowe *et al.*, 1999).

In the 'top down' lithostratigraphical framework the basic mappable unit, the formation, is linked to a series of lithogenetically and provenance-defined groups and sub-groups. We believe this approach potentially provides the geological surveyor with a usable scheme and the user of geological data with a more understandable system of direct relevance to small-scale mapping. It is not intended to introduce a plethora of new stratigraphical terms. We acknowledge that the group/sub-group definitions may contravene a strict interpretation of stratigraphical principles (NACSN, 1983; Hedberg, 1976; Salvador, 1994). These departures from procedure are discussed below and are likely to form the subject of further debate. In taking forward the use of groups and sub-groups the approach also differs from that adopted by Bowen (1999), although many of the component mappable formations in that publication are adopted. Opportunity will be taken not only to simplify the framework but also to clarify inconsistencies in the Geological Society report. We also recognise the very wide range of depositional environments and events associated with the Quaternary. The QSFCs are concentrating on key regions of the UK where geological knowledge and datasets, although variable in availability and quality, are sufficiently advanced to establish the framework.

Definitions

The proposed framework consists of a hierarchy of groups and sub-groups. In some regions where formations have not been defined, groups and sub-groups may currently consist solely of lithogenetic units. The broad definition of the basic building blocks are as follows:

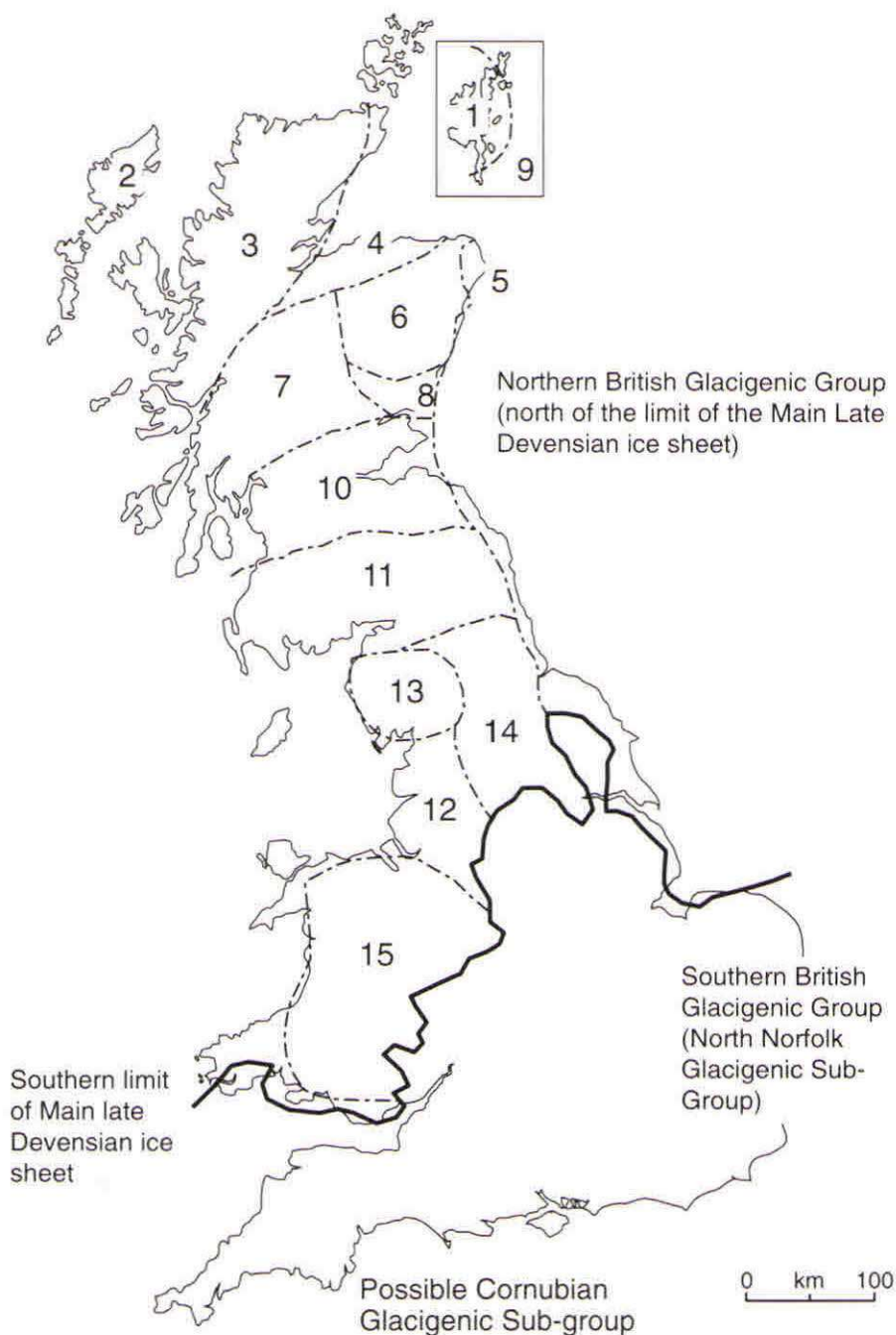


Figure 1. Distribution of glacigenic groups and sub-groups (see Also Table 1).

GROUP: an assemblage of sediments, comprising formations and/or lithogenetic units of common generic provenance. Depending on the depositional environment, component formations will contain variable proportions of locally-derived and far-travelled lithologies.

For glacial deposits (glacial, glaciofluvial and glaciolacustrine), two groups are proposed, representing deposits lying to the north and to the south of the Devensian ice sheet limit (Tables 1 and 3, Figure 1). These groups are named the **Northern British Glacigenic Group** and the **Southern British Glacigenic Group**. North of the limit, the glacial deposits are mainly of Devensian age but pockets of older deposits do occur, often concealed. South of the limit, all glacial deposits predate the Devensian stage.

Fluvial, lacustrine, estuarine, coastal (including raised marine sediments) and aeolian deposits are geographically defined within a series of **Catchment Groups** defined by major river drainage systems (Tables 2 and 3, Figure 2). North of the Devensian limit these deposits are generally Late Devensian to Holocene in age. South of the Devensian limit, the age of deposits ranges from post-Anglian to modern. A total of 12 Catchment Groups for deposits of geographically-related rivers are proposed for the area north of the Devensian limit. Eleven groups are proposed for the area south of the Devensian limit (including the **Trent Catchment Group** and the **Severn Catchment Group** which straddle the line). Additional Catchment Groups may be introduced for deposits of islands. Each group will contain river valley formations, named after the principal rivers of the group area. North of the Devensian limit, one formation is usually considered sufficient to define the fluvial deposits (floodplain alluvium and terrace deposits) of a major river and its tributaries. Terrace deposits may be assigned member status. The alluvium of tributaries or upper reaches of rivers, where lithologically and texturally distinctive, may be assigned member status. The formation may also contain other surficial deposits such as peat, lacustrine deposits and head that lie within the river catchment. These may be accorded member status or remain as lithogenetic units.

South of the Devensian limit, in major catchments such as the Thames, Trent and Severn terrace deposits commonly represent multiple glacial – interglacial cycles. It is proposed to establish groups for the fluvial, lacustrine, organic, estuarine and coastal deposits within these and other regional catchments and for deposits of drainage basins which did not survive the Anglian glaciation (e.g. the **Dunwich Group** for pre-Anglian fluvial deposits of the Bytham, Proto-Thames and a 'Northern River' now termed the Ancaster River). Again, a single formation may encompass the component terrace deposit members of each major river and its tributaries.

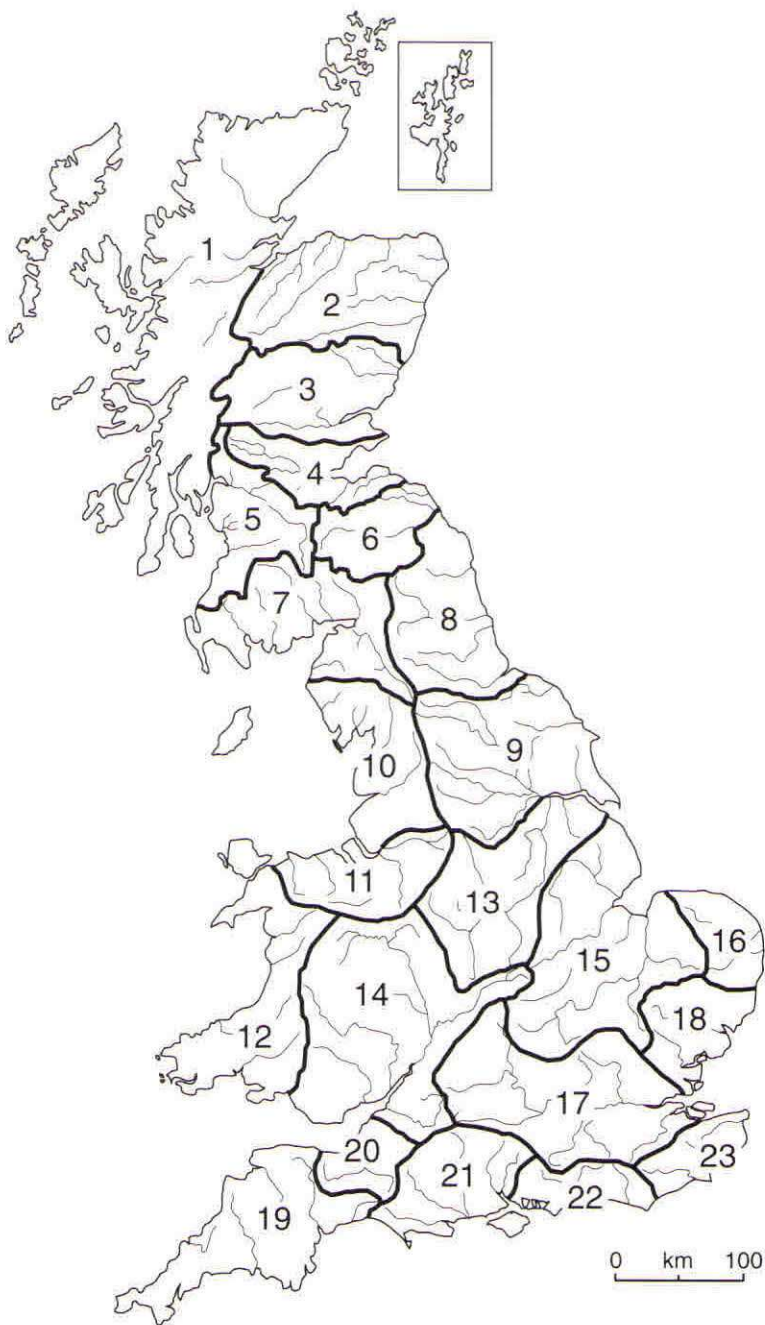


Figure 2. Quaternary catchment groups (excluding pre-Anglian deposits). See Table 2.

GROUP	SUB-GROUP	NOTES
NORTHERN BRITISH GLACIGENIC GROUP (NBG)	1. Shetland Drift 2. Western Isles Drift 3. Northern Highland Drift 4. Banffshire Coast Drift 5. Logie - Buchan Drift 6. Cairngorm - East Grampian Drift 7. Central Grampian Drift 8. Mearns Drift 9. North Sea Coast Drift 10. Midland Valley Drift 11. Southern Uplands Drift 12. Irish Sea Drift 13. Central Cumbria Drift 14. Pennines Drift 15. Welsh Drift	<p>The Northern British Glacigenic Group comprises glacigenic deposits mostly associated with the dispersal and deglaciation of the Main Late Devensian ice sheet and local readvances. OIS range from 2 to 12 for NBG sub-groups (They mainly range from 2 to 5). Enclaves of older deposits are included.</p> <p>Sub-groups 1-15 each consist of lithologically distinct glacigenic deposits possessing dominant lithological characteristics of the regional geology, linked to centres of ice build-up and dispersal. The general surface distribution of each sub-group is shown on Figure 1. Note that units of one sub-group may interfinger units of another. The deposits may consist of diamictons, glaciofluvial sand and gravel, glaciolacustrine and glaciomarine deposits and palaeosols.</p>
SOUTHERN BRITISH GLACIGENIC GROUP (SBG)	1. North Norfolk Glacigenic	<p>The Southern British Glacigenic Group currently comprises one sub-group of deposits of pre-Devensian ice sheets. Although constituent formations may be defined lithologically, the deposits cannot be linked directly to remote centres of ice build-up.</p>

Table 1. Proposed glacigenic groups and sub-groups.

GROUP*	NOTES
1. Northern Highland and Argyll Catchment 2. North-east Scotland Catchment 3. Tay Catchment 4. Forth Catchment 5. Clyde Catchment 6. Tweed Catchment 7. Solway Catchment 8. Northumbria Catchment 9. Yorkshire Catchment 10. Cumbria - Lancashire Catchment 11. Cheshire - North Wales Catchment 12. Cambrian Catchment	Groups 1-12 each consist of deposits within a geographically defined series of river catchments (Figure 2). In addition to fluvial deposits of Holocene age, the groups include all coastal and marine deposits of Holocene to Late Devensian age. OIS ranges from 1 to 2. The alluvial and terrace deposits of each major river and any tributaries may be assigned to a single formation. Members may be established for deposits of distinctive lithology. Formations established for coastal, marine and organic deposits may fall within one or more groups.
13. Trent Catchment 14. Severn Catchment 15. Ouse - Nene Catchment 16. Yare - Waveney Catchment 17. Thames Catchment 18. Suffolk Catchment 19. Cornubian Catchment 20. Somerset Catchment 21. Solent Catchment 22. Sussex Catchment 23. South Kent Catchment	South of the Devensian limit, groups 13 - 23 are each defined by major drainage basins (Figure 2) and include all post-Anglian, non-glacigenic sediments: fluvial, lacustrine, aeolian, coastal and slope deposits. The alluvial and terrace deposits of each major river and its tributaries may be assigned to a single formation. The deposits of each terrace of a river may constitute a member, which may be subdivided formally or informally into beds.
24. Dunwich	The Dunwich Group is raised to encompass all pre-Anglian fluvial deposits of the Proto-Thames, the Bytham River and a 'Northern River' now termed the Ancaster River. The courses of the Bytham and Ancaster rivers were overrun by, and that of the Thames diverted by, the Anglian ice sheet.
25. Clay - with - flints 26. Pebble Gravel 27. Wealden Rivers 28. Mendip	Groups 25 - 28 comprise interfluvial deposits of southern England.
29. Crag	The Crag Group includes all the wholly or dominantly marine formations which precede the Anglian Glaciation in East Anglia
* Note that other catchment groups may be established for non-glacigenic deposits of islands	

Table 2. Proposed catchment and other non-glacigenic groups.

STAGES	OIS	GLACIGENIC GROUPS & SUB-GROUPS		CATCHMENT & OTHER GROUPS	
		North of the Devensian limit	South of the Devensian limit	North of the Devensian limit	South of the Devensian limit
HOLOCENE	1			series of groups defined by river catchments and solid geology	
DEVENSIAN	2 - 5d	NORTHERN BRITISH GLACIGENIC GROUP	series of ice centre related sub-groups		series of groups defined by major river systems
IPSWICHIAN	5e				
WOLSTONIAN	6 - 10				
HOXNIAN	11				
ANGLIAN	12				
CROMERIAN	13-21				
BEESTONIAN					
PASTONIAN					
PRE-PASTONIAN					
BAVENTIAN					
ANTIAN/ BRAMATONIAN					
THURNIAN					
LUDHAMIAN					
PRE-LUDHAMIAN					
PLIOCENE					

Table 3. Relationship of groups and sub-groups to Quaternary stages.

In addition to Catchment Groups, a small number of groups are defined for deposits of interfluvial areas south of the Devensian ice sheet limit (Tables 2 and 3). The Pliocene to Early Pleistocene **Crag Group** is also defined to include all the wholly or dominantly marine formations which precede the Anglian glaciation in East Anglia.

SUB-GROUP: For glacial groups, especially north of the Devensian limit, where the provenance of the deposits is strongly influenced by patterns of the build-up and decay of an ice sheet (e.g. Central Grampians - Rannoch Moor) or ice dome (e.g. Central Cumbria - Lake District), we consider that it is desirable to demonstrate lithological similarities of suites of sediments of varying age. We propose to subdivide the **Northern British Glacigenic Group** into a series of sub-groups whose names demonstrate either the centre of local ice-dispersal or are determined by the location of the principal depositional centres. A sub-group may consist of formations of lithologically similar deposits representative of one or more glacial – interglacial cycles. There are examples where it is possible to demonstrate interdigitation between formations belonging to different sub-groups that are the product of more than one ice stream. North of the Devensian ice sheet limit it is proposed to define 15 glacial sub-groups (Table 1). South of the Devensian limit the **Southern British Glacigenic Group** presently comprises a **North Norfolk Glacigenic Sub-group**, which encompasses all pre-Devensian glacial deposits (Table 1). Other sub-groups, such as a possible Cornubian Glacigenic Sub-group, may be established. Approximate geographical boundaries to the groups and sub-groups are shown in Figure 1.

FORMATION: a geographically-mappable unit that may consist of one or more lithologies defined by type section, or more commonly by type area. A formation may also include concealed deposits correlated between boreholes or by seismic stratigraphy. Where possible, top and base should be defined but it is recognised that the nature of these boundaries and the bounding deposits may vary laterally. Formations may stand on their own or form part of one or more groups. Where appropriate, formation names should include a lithological as well as geographical qualifier. Terms such as till, sand and gravel, silt or clay are acceptable. Formations may be sub-divided into members and beds.

LITHOGENETIC UNIT: a unit, mappable or otherwise, defined by its lithology, sediment – landform associations (e.g. morainic deposits) and mode of origin and classified according to the current BGS Rock Classification Scheme (McMillan and Powell, 1999).

Discussion

We consider that the aggregation of formations into groups and sub-groups will enable a more generalized regional lithostratigraphical classification to be established. It should readily identify the extent of those deposits with similar lithological characteristics that may or may not be directly linked to the age of those deposits. Clearly this system may be of benefit to non-Quaternary specialists whose interests may lie in the hydrogeological (e.g. for recharge studies) or geotechnical properties of Quaternary sediments. Equally, it may improve understanding of provenance and in turn demonstrate cyclical similarities for example, in ice-sheet build-up and decay.

However, as in any lithostratigraphical scheme, there are areas of concern that require debate. We outline a few of the issues for discussion.

- Should provenance be reflected in lithostratigraphy? According to Hedberg (1976, p.41), this should be discouraged, but he does accept that the name of a high-ranking unit may appropriately “be derived from a more extensive geographic feature or area than the names of its lower ranking components”. Thus the grouping of formations according to geographical centres of ice dispersal or by catchment is acceptable.
- Should genetic terminology be employed in group/sub-group nomenclature? Again, a strict interpretation of the international stratigraphic codes (NACSN, 1983; Salvador, 1994) indicates that such qualifiers should not be used. Yet many of the obvious and meaningful geographical group names are already employed in the geological literature both for Quaternary sediments and Solid units. Qualifiers such as ‘drift’ or ‘glacigenic’ are believed to aid the general user of the geological information who is not a Quaternary specialist (see discussion in Foster *et al.*, 1999).
- Should groups/sub-groups reflect deposits of single or multiple major events? For glacigenic groups, the concept, as developed for west Cumbria (McMillan in Akhurst, 1997; Merritt and Auton, in press) and NE Scotland (Merritt *et al.*, in press), was to group formations according to lithological (and hence provenance-related) characteristics, irrespective of age of deposits (commonly unknown). Others argue strongly for a single glacial-event-driven group stratigraphy (assuming the event is known). Indeed, as a general rule, Salvador (1994) states that “the union of adjacent strata separated by regional unconformities or major hiatuses into a single lithostratigraphic unit should preferably be avoided even if no more than minor lithologic differences can be found to justify the separation”. However, discontinuities are commonplace in Quaternary glacigenic sequences and the difficulties of defining ‘regional unconformities’ should not be

underestimated. We are seeking a 'top down' system that will accommodate the classification of complex successions but will be capable of modification as new data come to hand. In many areas of the UK it is currently not possible to attribute mappable units (formations) to single glacial events. New sub-groups may need to be set up as new data become available to erect an event-driven formational stratigraphy.

- Should formation or member status be applied to terrace deposits of major catchments? Some argue that terrace deposits, often comprising deposits of warm and cold phases of a glacial cycle, need to be accorded formational status. Others contend that a single formation should encompass a series of catchment terrace deposits of a major river *and* its tributaries, enabling individual terrace deposits to be mapped as members or beds.

The BGS Quaternary Framework Committees are charged with drafting a report which may develop the ideas outlined above and recommend procedure for future lithostratigraphical mapping of onshore Quaternary deposits in the UK. We should like to take the opportunity of next year's Open Meeting (21 February 2001) to discuss the issues raised with a view to recommending a workable 'top down' stratigraphical framework.

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References

- Akhurst, M.C. (compiler) (1997). Geology of West Cumbria district. *Memoir of the British Geological Survey*. Sheets 28, 37 and 47 (England and Wales).
- Bowen, D.Q. (ed) (1999). *A Revised Correlation of Quaternary Deposits in the British Isles*. Geological Society Special Report No. 23.
- Bowen, D.Q. and Lewis, S.G. (2000). Some observations on 'Eastern England': a reply. In: Bowen, D.Q. (ed) *A Revised Correlation of Quaternary Deposits in the British Isles*. *Quaternary Newsletter*, 91, 7-9.
- Foster, S.S.D., Morigi, A.N. and Browne, M A E. (1999). *Quaternary geology – towards meeting user requirements*. British Geological Survey, Keyworth, Nottingham.

Green, C.P. 2000. Review of Bowen, D.Q. (ed) (1999). *A Revised Correlation of Quaternary Deposits in the British Isles*. Geological Society Special Report No.23. *Quaternary Science Reviews*, 19, 823-825.

Hedberg, H.D. (ed) (1976). *International Stratigraphic Guide*. John Wiley and Sons, New York.

Lowe, J.J., Birks, H.H., Brooks, S.J., Coope, G.R., Harkness, D.D., Mayle, F.E., Sheldrick, C., Turney, C.S.M. and Walker, M.J.C. (1999). The chronology of palaeoenvironmental changes during the Last Glacial – Holocene transition: towards an event stratigraphy for the British Isles. *Journal of the Geological Society*, 156, 397-410.

McMillan, A.A. and Powell, J.H. (1999). BGS Rock Classification Scheme: the classification of artificial (man-made) ground and natural superficial deposits: applications to geological maps and datasets in the UK. *British Geological Survey Research Report*, RR/99/4.

Merritt, J.W. and Auton, C.A. (in press). An outline of the lithostratigraphy and depositional history of the Quaternary deposits in the Sellafield district, west Cumbria. *Proceedings of the Yorkshire Geological Society*, 53.

Merritt, J.W., Auton, C.A., Connell, E.R., Hall, A.M. and Peacock, J.D. (in press). The Cainozoic geology and landscape evolution of north-east Scotland. *Memoir of the British Geological Survey*, Sheets 66E, 67, 76E, 77, 86E, 87W, 87E, 95, 96W, 96E and 97 (Scotland).

Mitchell, G.F., Penny, L.F., Shotton, F.W. and West, R.G. (1973). *A Correlation of Quaternary Deposits in the British Isles*. Geological Society Special Report No. 4.

North American Commission on Stratigraphic Nomenclature (NACSN) (1983). North American Stratigraphic Code. *The American Association of Petroleum Geologists Bulletin*, 67, 841-875.

Rose, J. (1989). Stadial type sections in the British Quaternary. In: Rose, J. and Schluchter, C. (eds) *Quaternary Type Sections: imagination or reality?* A A Balkema, Rotterdam, 45-67.

Salvador, A. (ed) (1994). *International Stratigraphic Guide*. Geological Society of America, Boulder (2nd edition).

Straw, A. (2000). Some observations on 'Eastern England'. In: Bowen, D.Q. (ed) *A Revised Correlation of Quaternary Deposits in the British Isles*. *Quaternary Newsletter*, 91, 2-6.

Whittaker, A., Cope, J.C.W., Cowie, J.W., Gibbons, W., Hailwood, E.A., House, M.R., Jenkins, D.G., Rawson, P.F., Rushton, A.W.A., Smith, D.G., Thomas, A.T. and Wimbledon, W. (1991). A guide to stratigraphical procedure. *Journal of the Geological Society*, 148, 813-824.

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A NEW GLACIAL STRATIGRAPHY FOR EASTERN ENGLAND

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We were pleased to read in *QN* 91 the report on the recent field trip to East Anglia (Lawson and Allen, 2000), and to see our several contributions reported by the authors. However, as that report is of necessity brief, we thought that those readers of *QN* who were not on the field trip, and who may be as 'stunned' by our new proposed stratigraphy as those in the party at Happisburgh (p.16), might welcome some expansion on the background to our conclusions. Our new stratigraphy (Table 1) replaces the rather more complex stratigraphies of Banham (1968, 1988), Hart and Boulton (1991) and Lunkka (1994) (Table 2).

Table 1. A revised stratigraphy for the pre-Devensian tills of North-East Norfolk. For simplicity only the names of the formations and of the till members are shown. Outwash sands and gravels and lacustrine deposits also occur.

Overstrand Formation	Hanworth Till Member
Lowestoft Formation	Walcott Till Member
Corton Formation	Happisburgh Till Member

Table 2. The pre-Devensian till stratigraphies of North-East Norfolk according to Banham (1968, 1988), Hart and Boulton (1991), and Lunkka (1994).

Banham (1968, 1988)	Hart and Boulton (1991)	Lunkka (1994)
Lowestoft Till = Marly Drift		Lowestoft Till Formation, Marly Drift Member
Third Cromer Till	Walcott Diamicton Member	Cromer Diamicton Member, Mundesley Diamicton Member
Second Cromer Till	Eccles Diamicton Member	Walcott Diamicton Member
First Cromer Till	Happisburgh Diamicton Member	Happisburgh Diamicton Member

The key discovery to emerge from our recent survey of the geology of East Anglia was the realisation that the Walcott Till, which was long considered to be a chalkier facies of the North Sea Drift/Cromer tills deposited by Scandinavian Ice (Perrin *et al.*, 1979), is in reality the lateral equivalent of the Lowestoft Till. This conclusion is derived from detailed mapping, sedimentological, micropalaeontological and palynological evidence (Moorlock *et al.*, 2000; Hamblin, 2000).

This means that the Walcott Till is not one of the 'North Sea Drift' tills. Thus, there is no compelling evidence that the Scandinavian and Scottish ice-sheets co-existed in north Norfolk. The Scottish ice which deposited the Lowestoft Till extended across northeast Norfolk, rather than being excluded from this area as would have been the case if the Scandinavian ice had occupied the area while it deposited the Walcott Till. Indeed we feel that the mutually distinctive lithological content of the three pre-Devensian tills in East Anglia (Happisburgh Till Member or First Cromer Till, Walcott Till Member or Second Cromer Till, Hanworth Till Member or Third Cromer Till) is best explained by formation during separate glacial events. Definitive evidence that there are separate glacial events is provided by links with lithostratigraphy elsewhere. The older glaciations can be separated on the basis of their correlation with the pre-Anglian Bytham River deposits at Leet Hill, and the younger glaciations are separated by mineralogical comparison with tills in Lincolnshire and Yorkshire.

Although we are confident of our lithostratigraphy (Table 1), and feel that this favours three separate glaciations, the assignation of these glacial episodes to Oxygen Isotope Stages (OIS) is inevitably tenuous in the absence of geochronometry of associated sediments and the absence of continuous successions. However, recent U-Series and ESR dates on organic deposits at Marks Tey (Rowe *et al.*, 1999) and Hoxne (Grün and Schwarcz, 2000) appear to confirm the long-held belief (Shackleton and Turner, 1975) that the chalky Lowestoft Till of East Anglia (our Walcott Till Member of north Norfolk and Lowestoft Till Member elsewhere) was deposited during OIS 12, and we are taking this as the keystone for our correlations with the global OI stages at the moment.

Our suggestion that the oldest of the glaciations (our Corton Formation) dates from OIS 16 arose from the discovery of boulders of basic volcanic rocks, high-grade metamorphic rocks and Carboniferous limestone, many of which have angular edges, in the Second Terrace deposits of the Bytham Sands and Gravels at Leet Hill (Rose *et al.*, 1999). These erratics are of northern provenance and are interpreted as of glacial derivation, although reworked into the river deposits. They do not resemble the erratic suite of the Lowestoft Formation, but do suggest a correlation with one of the Scandinavian North Sea Drift tills, especially the one that followed the flow track determined by Fish *et al.*, (2000).

This interpretation is supported by the presence of clasts of sandy till, similar to that of the Happisburgh Till, in the Bytham Sands and Gravels, in association with these far-travelled boulders. Clearly, as the Bytham River deposits at Leet Hill underlie the Lowestoft Till, the Scandinavian till must be the older of these deposits and must correlate with the Happisburgh Till of the Corton Formation (lowermost North Sea Drift Till/ First Cromer Till).

Therefore, the Second Terrace of the Bytham Sands and Gravels, which received an influx of sediment from the Scandinavian ice sheet correlates with the Corton Formation. We know that the First Terrace of the Bytham Sands and Gravels correlates with the Lowestoft Formation, as Bytham river sediments of this age are replaced, without interruption, by lacustrine sediments associated with the Scottish glaciation that over-rode the Bytham river valley and deposited the Lowestoft Till (Rose, 1989), and that the Bytham river valley was buried by deposits of the Lowestoft Glaciation throughout Midland and Eastern England (Rose, 1994). We also know that Bytham river sediments were deposited in a cool temperate climate in which the early Hominids occupied sites such as High Lodge (Ashton *et al.*, 1992; Rose 1995), and that this temperate interval occurred between the incision of the Bytham river below the Second Terrace and the final aggradation to the limit of the First Terrace. Thus, if we assume that major incision in the main rivers is a feature of temperate climate processes (Bridgland, 1994), then there are two temperate stages between the formation of the Second Terrace and the destruction of the Bytham river system. In this case, if the Anglian Glaciation and the deposition of the Lowestoft Formation date from OIS 12, and the temperate environment represented at High Lodge from OIS 13, then the earlier glaciation which deposited the Happisburgh Till of the Corton Formation must be predate an additional cold and temperate cycle and be pre-OIS 15. Furthermore, there is no good evidence for a major global glaciation in Europe in OIS 14, whereas global ice appears to be important in OIS 16 (Raymo, 1997). We therefore suggested that the first Scandinavian glaciation of Britain most likely occurred during OIS 16.

The uppermost of the glacial deposits in Northeast Norfolk (excluding that of the Devensian Glaciation), known traditionally as the Third Cromer Till, is the Overstrand Formation. The Hanworth Till Member is a sandy diamicton that clearly post-dates the Lowestoft Formation. It has traditionally been considered to be the youngest Scandinavian North Sea Drift formation in Norfolk (Perrin *et al.*, 1979; Rose, 1989; Lunkka, 1994). However, preliminary comparison of the mineralogy of this unit (Perrin *et al.*, 1979) with the mineralogy of the Welton Till in Lincolnshire (unpublished data) and the Basement Till of East Yorkshire (Catt and Penny, 1966; Madgett and Catt, 1978; Catt, 1991) suggest

that these units are equivalent. Also associated with these sediments, on the basis of palaeogeography, would be the outwash gravels of the Tottenhill member of the Nar Valley Formation in Norfolk (Gibbard *et al.*, 1991, 1992; Lewis and Rose, 1991). The age of these sediments is not yet known with confidence, although it is believed that they all predate OIS 5e, since Last Interglacial deposits apparently rest on the Basement Till in East Yorkshire (Catt and Penny, 1966), and since the gravels at Tottenhill retain palaeosol microstratigraphy which suggests a sequence of soil development that would extend back only to the Last Interglacial (Lewis and Rose, 1991). By comparison with the continent, the most recent glaciation to reach the Netherlands, and hence the part of the North Sea most adjacent to Britain (Oele and Schuttenhelm, 1967) is known to have occurred during OIS 6, because glacially-tectonised deposits include organic material dated to OIS 7 at Fransche Kamp and the glacially-tectonised material is buried by Eemian marine sediments (OIS 5e) (Ruegg, 1991). On the assumption that the ice sheet that reached the Netherlands also reached eastern England, then the Overstrand Formation, Tottenhill outwash sands and gravels, Welton Till, Basement Till and Warren House Gill Till should be attributed to OIS 6. They should not be called Wolstonian (Bowen, 1999) as the deposits at Wolston (Wolston Formation) are of pre-Anglian and Anglian age.

Also supporting the OIS 6 age of the Overstrand Formation in north Norfolk is the 'freshness' of the terrain within the region of this formation, and the presence of landforms such as the Blakeney esker, kames within the Glaven Valley, and the Cromer moraine ridge. These landforms that have the appearance of constructional geomorphological features, although detailed work has shown that all of these are substantially eroded and are residual around relatively resistant gravel lithologies. Constructional glacial landforms are not associated with Anglian deposits elsewhere in Britain. In the past, convoluted arguments have been put forward to explain the existence of these features (Straw, 1960; Sparks and West, 1964; Rose, in Banham *et al.*, 1975; Grey, 1997), but an origin during a glaciation between 188 ka and 130 ka (OIS 6, Martinsson *et al.*, 1987) would mean that the largest features may have a chance of surviving complete destruction by periglacial mass movement during the Last Glacial Stage and retain their relief to the present day. The reason no other landforms of this kind survive in Britain is that all other known locations where OIS 6 deposits occur have been over-ridden by Devensian ice. Similar large-scale, but heavily-eroded landforms of OIS 6 age survive in the Netherlands and Germany where they are beyond the limit of the Last Glacial Maximum (LGM).

The possibility that the Overstrand Formation is Devensian is not considered realistic, since the lithology is quite unlike the Devensian Holderness Formation

(Hunstanton Formation of Bowen, 1999), which can be seen in Norfolk between Hunstanton and Morston, west of Blakeney, and which crops out extensively north of the Wash (Madgett and Catt, 1975).

Discussion in the field during the QRA Easter Field Meeting indicated that there are arguments against our suggestion that the Corton Formation belongs to OIS 16, since this would imply that the Cromerian of Norfolk is wholly older than that stage. The problem is that deposits at Ostend and Sidestrand/Trimingham in North Norfolk contain *Arvicola t. cantiana* which is associated with deposits traditionally ascribed to a time after OIS 15 (Preece and Parfitt, 2000). However, several workers are currently studying the small mammal and mollusc faunas of the Cromerian, and we hope that a clearer picture will emerge in due course. At present it would appear that the OIS stage at which *Mimomys savini* is replaced by *Arvicola t. cantiana* is not known with confidence (Vandenberghe, 2000).

An alternative scenario, that the Corton and Lowestoft formations date respectively from OIS 12 and 10 needs consideration because evidence for a glaciation in OIS 10 is suggested from the Midlands (Sumbler, 1995, in press) and from west Norfolk (Rowe *et al.*, 1997). However, we reject this scenario for the following reasons:

- i) There is substantial evidence that the chalky till of East Anglia was deposited in OIS 12 prior to the deposition of organic deposits dated to OIS 11 (Bridgland, 1994; Rowe *et al.*, 1999; Grün and Schwarcz, 2000). Specifically, it is unlikely that the Lowestoft till overlying the Corton Formation at the type site could belong to OIS 10 when it is so close to, and in stratigraphic continuity with, identical till of demonstrated OIS 12 age at Hoxne.
- ii) If the Corton Formation is OIS 12 this would mean that all the deposits of the OIS 16 glaciation (represented by the Bytham Sands and Gravels at Leet Hill) will have been destroyed by later erosion (except at Leet Hill). Bearing in mind the extensive Cromerian soft sediments that survive in Norfolk, it is very unlikely that glacial deposits would not also have survived.

We do not reject the evidence for an additional glaciation in the Midlands and western East Anglia, but discussion of that topic is beyond the scope of this note.

Thus, we conclude that, including the Devensian, we have evidence for five glacial episodes in eastern and Midland England (bearing in mind the previous sentence), as follows:

OIS 16 - Scandinavian glaciation in Northeast Norfolk - Happisburgh Till of Corton Formation - responsible for the creation of a large lake in the southern North Sea, which overflowed to cut the Strait of Dover.

OIS 12 - Scottish glaciation throughout eastern England - Lowestoft Till/Walcott Till of Lowestoft Formation - responsible for final diversion of the Thames through London; Trias-rich Thrusington Till in Midlands.

OIS 10 - Scottish glaciation of Midland England - Oadby Till extending into Northwest Norfolk but not overtopping the Chalk escarpment into northeast Norfolk.

OIS 6 - Scandinavian glaciation of eastern England and as far south as north Norfolk - Overstrand Till/Welton Till/Basement Till/Warren House Gill Till. Ice reached the Netherlands on continental Europe.

OIS 2 (LGM) - Scottish Ice reached the Wash and Fen Basin - Skipsea and Withernsea tills of Holderness Fm.

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Although this note is just an elaboration of the issues raised by the authors at the Annual Field Meeting of the QRA in April 2000, we wish to draw attention to, and acknowledge the work of Holger Kessler and Steve Booth, both members of the BGS Northern East Anglia Project, who have contributed significantly to our understanding of East Anglian geology, and to Ian Candy and Jon Lee who have contributed significantly to the data collection and ideas underpinning the views outlined above. We would also like to thank Mike Sumbler and Tony Morigi for their constructive and helpful comments as BGS internal reviewers, and David Bridgland and Colin Whiteman who acted as reviewers for *QN* and whose comments have been noted and incorporated where appropriate. Richard Hamblin and Brian Moorlock publish with the permission of the Director of the British Geological Survey, NERC.

References

Ashton, N.M., Cook, J., Lewis, S.G. and Rose, J. (1992). *High Lodge: Excavations by G. de G Sieveking, 1962-8, and J. Cook, 1988*. British Museum Press, London.

Banham, P.H. (1968). A preliminary note on the Pleistocene stratigraphy of north-east Norfolk. *Proceedings of the Geologists' Association*, 79, 281-285.

Banham, P.H. (1988). Polyphase glaciotectionic deformation in the Contorted Drift of Norfolk. In: Croot, D.G.(ed) *Glaciotectionics; Forms and Processes*. Balkema, Rotterdam, 27-32.

Banham, P.H., Davies, H. and Perrin, R.M.S. (1975). Short field meeting in north Norfolk. *Proceedings of the Geologists' Association*, 86, 251-258.

- Bowen, D.Q. (1999). *A Revised Correlation of Quaternary Deposits in the British Isles*. Geological Society Special Report No. 23.
- Bridgland, D.R. (1994). *Quaternary of the Thames*. Chapman and Hall, London.
- Catt, J.A. (1991). Late Devensian glacial deposits and glaciations in eastern England and the adjoining offshore region. In: Ehlers, J., Gibbard, P.L. and Rose, J. (eds) *Glacial deposits in Britain and Ireland*. Balkema, Rotterdam, 185-191.
- Catt, J.A. and Penny, L.F. (1966). The Pleistocene deposits of Holderness, East Yorkshire. *Proceedings of the Yorkshire Geological Society*, 35, 375-420.
- Fish, P.R., Whiteman, C.A., Moorlock, B.S.P., Hamblin, R.J.O. and Wilkinson, I.P. (2000). The glacial history of the Weybourne area, north Norfolk: a new approach. *Bulletin of the Geological Society of Norfolk*, 50, 21-45.
- Gibbard, P.L., West, R.G., Andrew, R. and Petitt, M. (1991). Tottenhill, Norfolk. In: Lewis, S.G., Whiteman, C.A. and Bridgland, D.R. (eds) *Central East Anglia and the Fen Basin. Field Guide*. Quaternary Research Association, London, 131-143.
- Gibbard, P.L., West, R.G., Andrew, R. and Petitt, M. (1992). The margins of a Middle Pleistocene ice advance at Tottenhill, Norfolk, England. *Geological Magazine*, 129, 59-76.
- Gray, J.M. (1997). The origin of the Blakeney Esker, Norfolk. *Proceedings of the Geologists' Association*, 108, 177-182.
- Grün, R. and Schwarcz, H.P. (2000). Revised open system U-series/ESR age calculations for teeth from Stratum C at the Hoxnian Interglacial type locality, England. *Quaternary Science Reviews*, 19, 1151-1154.
- Hamblin, R.J.O. (2000). A new glacial stratigraphy for East Anglia. *Mercian Geologist*, 15, 59-62.
- Hart, J.K. and Boulton, G.S. (1991). The glacial drifts of northeastern Norfolk. In: Ehlers, J., Gibbard, P.L. and Rose, J. (eds) *Glacial deposits in Britain and Ireland*. Balkema, Rotterdam, 233-243.
- Lawson, T., and Allen, P. (2000). QRA Annual Field Meeting - Norfolk and Suffolk. *Quaternary Newsletter*, 91, 15-22
- Lewis, S.G. and Rose, J. (1991). Tottenhill, Norfolk. In: Lewis, S.G., Whiteman, C.A. and Bridgland, D.R. (eds) *Central East Anglia and the Fen Basin. Field Guide*. Quaternary Research Association, London, 145-148.
- Lunkka, J.P. (1994). Sedimentation and lithostratigraphy of the North Sea Drift and Lowestoft Till Formations in the coastal cliffs of northeast Norfolk, England. *Journal of Quaternary Science*, 9, 209-234.

Madgett, P.A. and Catt, J.A. (1978). Petrography, stratigraphy, and weathering of Late Pleistocene tills in East Yorkshire, Lincolnshire and north Norfolk. *Proceedings of the Yorkshire, Geological Society*, 42, 55-108.

Martinsson, D.G., Pisias, N.G., Hays, J.D., Imbrie, J., Moore, Jr., T.C. and Shackleton, N.J. (1987). Age dating of the orbital theory of the ice Ages: development of a high-resolution 0 to 300,000-year chronostratigraphy. *Quaternary Research*, 27, 1-29

Moorlock, B.S.P., Booth, S., Fish, P., Hamblin, R.J.O., Kessler, H., Riding, J., Rose, J. and Whiteman, C.A. (2000). A revised glacial stratigraphy of Norfolk. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk and Suffolk: Field Guide*. Quaternary Research Association, London, 53-54.

Oele, E. and Schuttenhelm, R.T.E. (1979). Development of the North Sea after the Saalian glaciation. In: *Quaternary History of the North Sea*, Acta Universitatis Uppsaliensis, Uppsala, 191-216.

Perrin, R.M.S., Rose, J., and Davies, H. (1979). The distribution, variation and origins of pre-Devensian tills in eastern England. *Philosophical Transactions of the Royal Society of London*, B287, 535-570.

Preece, R.C. and Parfitt, S.A. (2000). The Cromer Forest-bed Formation: new thoughts on an old problem. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds) *The Quaternary of Norfolk and Suffolk: Field Guide*. Quaternary Research Association, London, 1-27.

Raymo, M.E. (1997). The timing of major climate terminations. *Paleoceanography*, 12, 577-585.

Rose, J. (1989) Stadial type sections in the British Quaternary. In: Rose, J. and Schlüchter, Ch. (eds) *Quaternary Type Sections: Imagination or Reality?* Balkema, Rotterdam, 45-67.

Rose, J. (1994). Major river systems of central and southern Britain during the Early and Middle Pleistocene. *Terra Nova*, 6, 435-443.

Rose, J. (1995). Britain 'colonised via Bytham River'. *British Archaeology*, June 1995, 5.

Rose, J., Lee, J.A., Candy, I., and Lewis, S.G., (1999). Early and Middle Pleistocene river systems in eastern England: evidence from Leet Hill, southern Norfolk. *Journal of Quaternary Science*, 14, 347-360.

Rowe, P.J., Atkinson, T.C. and Turner, C. (1999). U-series dating of Hoxnian interglacial deposits at Marks Tey, Essex, England. *Journal of Quaternary Science*, 14, 693-702.

Rowe, P.J., Richards, D.A., Atkinson, T.C., Bottrell, S.H. and Cliff, R.A. (1997). Geochemistry and radiometric dating of a Middle Pleistocene peat. *Geochimica et Cosmochimica Acta*, 61, 4201-4211.

Ruegg, G.H.J. 1991. Geology and Archaeology of ice-pushed Pleistocene deposits near Wageningen (The Netherlands). *Mededelingen Rijks Geologische Dienst*, 46, 1-99

Shackleton, N.J. and Turner, C. (1967). Correlation between marine and terrestrial Pleistocene successions. *Nature*, 216, 1079-1082.

Sparks, B.W. and West R.G. 1964. The drift landforms around Holt, Norfolk. *Transactions of the Institute of British Geographers*, 35, 27-35.

Straw, A. (1960). The limit of the 'Last' Glaciation in north Norfolk. *Proceedings of the Geologists' Association*, 71, 378-390.

Sumbler, M.G. (1995). The terraces of the rivers Thame and Thames and their bearing on the chronology of glaciation in central and eastern England. *Proceedings of the Geologists' Association*, 106, 93-106.

Sumbler, M.G. (in press). The Moreton Drift: a further clue to glacial chronology in central England. *Proceedings of the Geologists' Association*.

Vandenberghe, J. (in press). A global perspective of the European chronostratigraphy for the past 650 ka. *Quaternary Science Reviews*.

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REPORTS

THE INQUA LOESS COMMISSION

1999 was a good year for the Loess Commission (LC). At the INQUA Congress in Durban in August we had two useful business meetings, elected many new members and made plans for the future. But the major 1999 event was the LoessFest in Heidelberg and Bonn in late March. This celebrated 175 years of 'loess' - 175 years since Karl Caesar von Leonhard invented the concept - and marked 30 years of the existence of the LC as a full INQUA Commission. The LoessFest demonstrated that the study of loess is in good shape and that we face the future with some confidence. The Fest was organised by Ed Derbyshire and Ludwig Zoeller. Ed is editing special issues of *Quaternary International* and *Earth Science Reviews* which will contain the presented papers and keynote addresses; these will provide a good start for loess publishing in the current inter-congress period.

This report summarises the nature and activities of the LC, past, present and future.

Past

The LC has two beginnings. At the 6th INQUA Congress in Poland in 1961 Julius Fink of the University of Vienna initiated the Sub-Commission on European Loess Stratigraphy as part of the main Commission on Stratigraphy. At the 8th Congress in Paris in 1969 this was upgraded in status to a full Commission. The initial aims were to elucidate the complex stratigraphy of the European loess (with some emphasis on material in East and Central Europe) and to prepare a loess map of Europe. Fink believed that the European loess had great significance to the Quaternary, and indeed great success was achieved when the loess was shown to record multiple events in the Quaternary. The famous 1977 *Quaternary Research* paper with George Kukla showed 17 interglacials since the Olduvai event.

Fink handed the Commission over to Marton Pecsí of the Hungarian Academy of Sciences at the 10th INQUA Congress in Birmingham in 1977, and Pecsí broadened the scope to take in a world view of loess. He also proposed that the Commission might start to focus on practical problems. At the 1977 Congress the Western Pacific Working Group was formed by Jim Bowler of ANU. This WPWG was remarkably successful, a model of how a working group should be organised. Bowler set reasonable, achievable targets and all were met very

efficiently. In particular, three conferences were held in Australia, China and New Zealand which did much for cooperation in the Western Pacific region. In addition, *Loess Letter* was started (and now celebrates 20 plus years of continuous publication).

At the 13th INQUA Congress in Beijing in 1991, Pecsí handed over leadership of the Commission to An Zhi-Sheng of the Chinese Academy of Sciences, and a move began back to a more project-orientated approach. The engineers became more obvious, and subsidence and hydroconsolidation were studied in addition to stratigraphy and palaeoclimatology. At the Beijing conference, there were more than 250 abstracts dealing with loess (in contrast to eleven loess papers at the 6th Congress in 1961). The great success of the LC was mainly in the detailing of the Quaternary and in exploiting some new methods such as thermoluminescence dating. The downside is the failure to complete the Loess Map of Europe, although this may still be achieved. During the 30 years, the focus has shifted from eastern Europe to China, but worldwide activity is steadily increasing.

Present

New officers of the LC were chosen at the Durban Congress: President - Ian Smalley (UK; smalley@loessletter.com); Vice-President - Andrei Dodonov (Russia) and Secretary- Zhou Liping (China; lpz10@cus.cam.ac.uk). Fifteen full members were chosen with a wide international spread; they are listed in *Loess Letter* 43. We are setting up *Loess Letter Online* (www.loessletter.com), to provide reports on conferences, a selection of recent references and discussions of current topics. It features some thoughts on Russian loess. We plan a long-term study of loess in Russia, and loess discussed in the Russian (FSU) literature. The aim is to provide a bridge between the vast Russian literature and that in other languages, largely English. The LC is an international body, and we need to identify and resolve problems of cooperation and interchange across national boundaries.

We identify two major global loess problems, (1) determining the climate over the past two million years, and (2) describing the structure of loess and determining the collapse mechanism. The major 'external' problem to which loess contributes is that of palaeoclimatic reconstruction. The major 'intrinsic' problem, inherent in the loess material and deposit nature, is that of structure formation and collapse.

We pursue projects in both of these fields of study. We are also committed to support the 'Dirtmap' project, an international project to study aeolian dust; see *Loess Letter* 42 for details or contact Karen Kohfeld in Jena ([45](mailto:kek@bgc-</p></div><div data-bbox=)

jena.mpg.de). Please note in your diary: Dirtmap meeting (mineral aerosols) 7-11 October in Jena.

Future

The LC will continue to organise and support meetings, and we will continue to publish *Loess Letter* and develop *Loess Letter Online*. There are moves to revisit the original Fink regions to investigate loess sedimentology and engineering problems rather than stratigraphy. The Danube basin is a very tempting area for international research and, with the international boundaries being so extensively redrawn, many research initiatives may be needed to restart loess studies in this region. A proposal has been published on *LLO*.

The LC supports the idea of a research journal devoted to loess. This idea is being discussed at present, and progress will be reported in *LL* and *LLO*.

We seek cooperation with other INQUA Commissions and with other bodies. The LC is working very closely with the 'Collapsing Soils Commission' of the International Association of Engineering Geology and the Environment (IAEG) and joint meetings and research projects are being proposed. We hope to have a strong presence at the Reno INQUA Congress in 2003. This location suggests that this might be a good moment to have a definitive symposium on 'desert loess', one of the enduring controversies in the loess world.

The UK contribution to global loess studies is surprisingly large. Over the years, QRA members have made huge contributions to loess research, and this is likely to continue. Even the modest loess in Britain is becoming more widely appreciated, and the news that the British Geological Survey is preparing a monograph on UK loess suggests that we have received an official seal of approval.

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FUTURE DIRECTIONS IN NEOTECTONICS: FOUR MORE YEARS FOR THE INQUA COMMISSION ON NEOTECTONICS

Neotectonics is the study of crustal movements that have occurred in the Earth's recent past and continue at the present day. These movements, which are driven directly or indirectly by global plate motions (tectonics), result in the vertical and horizontal warping, folding or faulting of the Earth's surface. Generally, plate motions give rise to the slow, progressive deformation of the Earth's outer shell that is detectable only by high-precision space-borne and land-based monitoring over years to decades. Where such movements occur abruptly, however, as during earthquakes or volcanic eruptions, they are readily detectable by humans. Human records of recent tectonic movements extend beyond the period of modern instrumentation (the last century) through historical and archaeological records, though the duration and quality of these records vary enormously between different regions. Before the records chronicled by humans, however, the incidence of tectonic movements must be reconstructed from the form of the Earth's landscape and from the sediment record. Although such geomorphological and geological evidence of past tectonic movements extend timescales of inquiry back several million years, the history they reveal is generally imprecise, ambiguous and selective. Nevertheless, to gain a full picture of the pattern of neotectonic movements for a particular region, high-resolution 'snapshots' provided by seismologists and geodeticists must be integrated with the low-resolution 'time exposures' provided by Quaternary scientists. This Quaternary perspective is essential in studying the regional - and continental-scale interactions between geodynamic and surficial process, such as in the linkage between tectonic, geomorphologic and climatic influences in the growth and denudation of mountain belts, and the implications to regional and global climate. Although INQUA's Commission on Neotectonics has long embraced the breadth and diversity of this multidisciplinary field of study, its core remains the application of Quaternary geology to neotectonic problems.

At the INQUA Congress in Durban in August 1999, it was agreed to direct the Commission's main activities at four key research themes during the present inter-congress period. These themes - Palaeoseismology, Mountain Building, Coastal Tectonics, and Tectonic Hazards - relate to the current working groups (and in one case, Subcommittee) of the Commission. In Durban, the committee of the Commission was renewed, with Iain Stewart (Brunel, UK) replacing the outgoing President Carlo Bartolini (Firenze, Italy), Jim McCalpin (Geo-Haz Consultants, USA) replacing Cliff Ollier (ANU, Australia) as Vice President,

and Koji Okumura (Hiroshima, Japan) taking over Iain Stewart's former role as Secretary. It was agreed that Maria Assunção Araújo (Porto, Portugal) would continue to act as Secretary of the Commission's web page (<http://www.lettras.up.pt/geograf/neotect.html>).

Palaeoseismology is concerned with studying the location, timing and size of prehistorical earthquakes. In recent years, the working group on this burgeoning research field has been one of the most active and productive within the Commission. Consequently, in Durban its status was elevated to that of a Subcommission, necessitating the election of its own co-ordinating officers (President: A. Michetti [Italy]; Vice President: F. Audemard [Venezuela] and Secretary: S. Marco [Israel]).

Palaeoseismological analysis rests on the premise that earthquakes produce permanent and recognisable effects on the land surface. Assuming that an earthquake fault has been active over a timespan of several tens of thousands of years, the fault is likely, depending on its style and rate of activity, to have generated repeated ground effects (e.g. surface rupture, ground elevation changes, liquefaction and mass-movement phenomena, groundwater- and river-flow fluctuations). The cumulative action of these recurring ground effects contributes to what Hancock & Michetti (1997) referred to as the 'seismic landscape'. Their interest to earthquake geologists stems from the assumption that landscapes characteristically affected by, for example, magnitude 7 (Intensity X) events will differ from those characteristically affected by magnitude 6 (intensity IX) events. The earthquake ground effects themselves are well known, but their 'fossil' expression in the geomorphological and geological record is less well defined. Furthermore, it is still largely unclear how the distribution, scale and nature of these effects relate to key earthquake parameters, such as magnitude, intensity or epicentral location of the causative quake. The identification and interpretation of seismic (or palaeoseismic) components of the landscape is problematic, particularly since features can be obliterated, masked or mimicked by climate-driven or human-induced geomorphological changes. The key to unravelling this interplay between anthropogenic, climatic and tectonic controls often lies within the surficial sediments that mantle the seismic landscape, since here often lies both the stratigraphical evidence for past tectonism and the chronological framework that permits its history to be reconstructed. As a consequence, an important emphasis in the Subcommission has been to establish links with INQUA's Palaeopedology Commission, via B. Van Vliet-Lanoe (France) and R. Amit (Israel), in order to consider the macro- micro-scale interactions between tectonic and soil processes. Developing a multi-proxy empirical database on earthquake ground effects that can be used by, and incorporated into, seismic-

hazard assessment practices, represents an important research challenge for the next decade, and serves as the primary goal of the Palaeoseismology Subcommission during this present inter-congress period.

In recent years, the Coastal Tectonics Working Group has pursued research into how late Quaternary coastal records can help to develop, test and refine tectonic models in a variety of different geodynamic settings (e.g. Stewart and Vita-Finzi, 1998). Much of this work has been in collaboration with other research agencies, particularly INQUA's Commission on Shorelines and the UNESCO-IUGS IGCP-367 project (Rapid Coastal Changes in the Late Quaternary). Over the period 1999-2003, this working group, under the new leadership of J. Clague (Canada), Y. Ota (Japan) and L. Ortlieb (France), will focus increasing research efforts on the coastal tectonic behaviour of subduction zones and other convergent plate margins. Much of the world's coastlines, and the bulk of global seismicity, coincide with convergent plate margins, and their high-rates of geodynamic activity make tectonism an important control on both short- and long-term coastal evolution. In the past, this tectonism has been largely revealed through the study of emergent shoreline features (e.g. raised marine terraces, elevated tidal notches), but recent studies along the Cascadia seaboard, western North America, show that coastal wetlands and marshes may also preserve valuable biostratigraphical records of tectonism, particularly abrupt earthquake subsidence and tsunami flooding. One of the challenges facing the Coastal Tectonics Working Group will be to refine the multi-proxy (geomorphological, sedimentological and palaeoenvironmental) 'earthquake stratigraphy' approach developed in Cascadia, and extend its application to other subduction-zone environments.

One of the main ongoing scientific debates concerns the 'chicken-and-egg' issue about mountain-building: is mountain uplift driven by climate-induced denudational change or does mountain growth force local and regional climatic change? The Commission on Neotectonics has long championed the importance of the regional interplay between geodynamics and global environmental change, and under its new leadership of X. Fang (China) and F. Dramis (Italy), its Mountain-Building Working Group will continue research into this field. During the present inter-congress period, there will be an emphasis in unravelling tectonic and climate signals in the Quaternary landscapes and depositional sequences in the Tibetan plateau, with the aim of improving understanding of the timing and mechanisms of mountain-building in high Asia. Research will continue to be pursued, however, into the interactions between tectonic and surface processes operating in other mountain belts.

The Commission's Working Group on Tectonic Hazards is spearheading the

challenge to integrate the principles and practices of Quaternary geology into mainstream geohazard assessment. Led by S. Pavlides (Greece), P. Silva (Spain) and T. Azuma (Japan), the main goals of this Working Group will be to apply neotectonics research to issues of important societal need and to bring neotectonicians together with practitioners from other 'communities', for example seismological, engineering and insurance (e.g. Pavlides and King, 1998). One of the key developments on this subject has been the establishment of a multidisciplinary research school, the latest of which will be the 'Winter School on Active Faulting' in January 2000 at Hokudan, Japan. A meeting on the 'Evaluation of the potential for large earthquakes in present-day low-seismic activity regions of Europe', to be held 13-16 March at Han-sur-Lesse (Belgium) will examine the specific question of how to use neotectonics research for seismic-hazard assessment.

With over 160 active members, the INQUA Commission on Neotectonics is a broad-based research group with interests in many fields additional to the four present research themes. As a result, much of the research ongoing under its auspices is not linked to a formal working group. One such area of research that has developed in this way, and that is likely to be of interest to many Quaternary scientists, is that of the interplay between ice sheets, crustal deformation and seismicity. This topic was the subject of a symposium at the Durban Congress, and a special issue of *Quaternary Science Reviews* (edited by I. Stewart, J. Sauber and J. Rose) is currently being prepared from papers arising from that meeting. In this respect, the Commission will continue to promote, facilitate and support research that is outside of its current main themes, recognising that these outlying research strands represent the potential working groups of future inter-congress periods.

References

- Hancock, P.L. and Michetti, A.M. (eds) (1997). *Paleoseismology: Understanding Past Earthquakes using Quaternary Geology*, *Journal of Geodynamics*, 24.
- Pavlides, S. and King, G.C.P. (eds) (1998). *The Results of the May 13, 1995 Kozani-Grevena earthquake (Greece) earthquake*. *Journal of Geodynamics*, 26, 323.
- Stewart, I. and Vita-Finzi, C. (eds) (1998). *Coastal Tectonics*. Geological Society, London, Special Publication, 146.

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THE QUATERNARY OF THE BANFFSHIRE COAST AND BUCHAN

QRA Short Field Meeting, 8-11 September 2000

Quaternary research in NE Scotland has a long and distinguished history, dominated by continuing debate on the age and significance of lithologically-distinctive glacial deposits that reflect competing ice movements from the Moray Firth to the north, Strathmore to the south and the Grampian Mountains to the south-west. The area contains evidence of glacial, periglacial and interglacial deposits that extend back to Oxygen Isotope Stage 8 (OIS 8) or earlier, together with remarkable deposits of weathered gravels of inferred Tertiary age that have survived over-running by successive Pleistocene ice sheets. NE Scotland was last visited by a QRA field meeting in 1984, and since then has been subject of continuing research that will culminate in a forthcoming memoir of the British Geological Survey (Merritt *et al.*, 2001). The field meeting was thus timely in that it allowed participants to revisit a number of classic exposures that have been placed in revised stratigraphic context, and also introduced a number of significant new sites.

The thirty or so participants included survivors from the excellent 1984 field meeting as well as representatives of a younger generation of Quaternary scientists and half a dozen overseas visitors fresh from the IPA/IGU/QRA Periglacial Workshop held at St Andrews. Those present at the 1984 meeting could detect a distinct change in emphasis. The concept of 'moraineless Buchan' - the notion that part of NE Scotland escaped Late Devensian glaciation - seems at last to have been laid to rest, even though a putative ice-free enclave continues to appear in recent ice-sheet models. Three foci of debate dominated discussion: the survival of ancient landscape elements under cold-based or polythermal ice masses, the possible role of ice sheets in the northern North Sea Basin in deflecting the Moray Firth and Strathmore ice streams, and a correlation of lithostratigraphic units proposed by Merritt *et al.* (2000, 2001) that forms a framework for future debate and revision as more dating evidence becomes available.

Friday 8th September

Day 1 commenced with a visit to the classic Teindland Interglacial site, where **Adrian Hall** and **Rodger Connell** lucidly explained the site stratigraphy and the implications of recent research, including luminescence ages that imply an OIS 5 age for the buried podzol. Significantly, none of the attending periglacialists seemed inclined to challenge the glacial origin of the overlying diamicton.

A visit to the Boyne Bay Limestone Quarry led by **Doug Peacock** and **Jon Merritt** engendered much discussion of the glaciotectionised Whitehills Glacigenic Formation, which separates a lower partly-weathered till of inferred pre-OIS 5 age from an upper till of inferred Late Devensian age. Discussion of this formation with its conspicuous rafts of sediment dredged from the Moray Firth continued after lunch at Gardenstown, where attention also focused on the anomalous lithology of the basal gravels in the local Quaternary sequence, and on the origin and implications of the glaciolacustrine deposits that cap the succession. The day concluded with a view of the local meltwater channel networks, formed on the lee (east) side of north-south trending bedrock ridges.

Saturday 9th September

Day 2 began with a visit led by **Adrian Hall** and **Rodger Connell** to the Howe of Byth Quarry, where a till and superjacent outwash sediments of inferred Late Devensian age overlie the thick gravels and intercalated diamicts of the Howe of Byth Gravel Formation. Luminescence ages indicate a Middle Devensian age for the latter, but weathering evidence suggests that this impressive deposit may be older. Discussion focused on competing interpretations of the intercalated diamicts as sediment-gravity flows of glacigenic or nonglacial (paraglacial?) origin, and on the possible significance of involuted (*sensu lato*) structures near the top of the gravels. The most lively debate of the day, however, was reserved for the interpretation of the spectacular rafts of Jurassic clay and sand in the till that overlies deltaic sands and gravels in the Oldmill Quarry. The till has been interpreted as representing the Whitehills Glacigenic Formation, inferred from the rafted sediments to have been emplaced by Moray Firth ice during an early phase of Late Devensian glaciation. The survival of far-travelled rafts of sand and clay gave rise to much discussion of the conditions under which bodies of poorly-consolidated sediment could be transported over long distances without being sheared into a more homogenous till.

Subsequent sites proved less controversial. **Rodger Connell** provided a convincing interpretation of the Sandford Bay sections south of Peterhead, broadly vindicating that proposed by T.F. Jamieson over a century ago: Late Devensian expansion of inland ice beyond the present coastline was followed by deposition of a glaciomarine or glaciolacustrine sequence, then onshore advance of Logie-Buchan ice from the south. The last-mentioned dammed substantial lakes in the North and South Ugie Valleys as the inland (Grampian) ice stream retreated. In the St Fergus area, **Doug Peacock** outlined the significance of the St Fergus Silt Formation, dated to c. 15 ka BP by radiocarbon dating of the molluscan fauna; the occurrence of the St Fergus silts at altitudes of up to 16 m OD indicates much greater glacio-isostatic depression than has

previously been assumed for the north-east coast of Scotland, and thus implies a thicker and more extensive cover of Late Devensian ice. The final site of the day, Ardglassie Quarry, triggered renewed speculation on the mode of transportation of ice-rafted sediment blocks against an audible rumbling of stomachs with the approach of dinner.

Sunday 10th September

The final day was devoted to visits to sites exhibiting outcrops of the Buchan Ridge Gravel Formation, comprising quartzite and flint gravels of probable pre-Pleistocene age. **Clive Auton** introduced the classic site at Windy Hills, which is dominated by a quartzite gravel sequence and locally overlain by a thin diamict containing allochthonous clasts, with strong evidence of clast erection by frost action in the uppermost 40 cm or so. Discussion centred around the age (Pliocene or earlier) and environment of deposition (fluvial or littoral) of the gravels, and interpretation of a massive sand unit (aeolian?) underlying the surface diamict. At an excavated trench on Skelmuir Hill, **David Bridgeland** gave a stimulating introduction to the characteristics of flint-bearing clastic deposits attributed to the Buchan Ridge Gravel Formation, which he attributed on the basis of the degree of flint rounding to deposition in a beach environment (Bridgeland *et al.*, 1997), and described the archaeological significance of the site in terms of Neolithic flint quarrying. Similar themes continued to dominate discussion at the Den of Boddam site, where research by Alan Saville, David Bridgeland and others has revealed some 458 Neolithic flint extraction pits. At this final site, just as an experienced QRA groupie was commenting on the fact that the field meeting had produced not a single pollen diagram, **Richard Tipping** emerged from behind a clump of Ericaceae to describe his analysis of Holocene pollen assemblages at the site, startling us with his observation that the pollen appeared to show no indication of Neolithic interference.

This was an enjoyable excursion in which the participants benefited from the expertise of a group of Quaternary researchers who have devoted many years of work to a fascinating area that has yielded its secrets only grudgingly. The detail presented in the accompanying field guide (Merritt *et al.*, 2000) is ample testament to the thoroughness and dedication of their work. **Jon Merritt** is due particular thanks for his overall organization of the field meeting, and all of those who gave site introductions and contributed to the field guide deserve the gratitude of participants. Like all good field meetings, some new ideas and initiatives emerged, notably the need for more luminescence dating to place the proposed regional lithostratigraphy on a more secure footing. I look forward to the next QRA field meeting in NE Scotland, possibly around 2015. By then we may have reached some consensus on the Buchan Ridge gravels, have tightened

up the chronostratigraphy and may even understand the behaviour of the Late Devensian ice streams. There is much still to be learnt about the drifts and rafts of supposedly 'moraineless' Buchan.

References

Bridgland, D.R., Saville, A. and Sinclair, J. (1997). New evidence for the formation of the Buchan Ridge Gravel, Aberdeenshire. *Scottish Journal of Geology*, 33, 43-50.

Merritt, J.W., Connell, E.R. and Bridgland, D.R. (eds) (2000). *The Quaternary of the Banffshire Coast and Buchan: Field Guide*. Quaternary Research Association, London.

Merritt, J.W., Auton, C.A., Connell, E.R., Hall, A.M. and Peacock, J.D. (2001). *The Cainozoic Geology and Landscape Evolution of North-East Scotland*. Memoir of the Geological Survey (Scotland), in press.

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REVIEWS

HOLOCENE LAND-OCEAN INTERACTION AND ENVIRONMENTAL CHANGE AROUND THE NORTH SEA

Edited by Ian Shennan and Julian Andrews

Geological Society, London

ISBN 1-86239-054-1, 2000.

Special Publication, 166, 326 pages. Price £79

Centered on the Durham - East Anglia axis, this volume synthesises work conducted on the English east coast, including the various river catchments and adjoining North Sea. The research findings gathered here stem from the Land-Ocean Evolution Perspective Study (LOEPS) and were funded through the Natural Environment Research Council (NERC) Land-Ocean Interaction Study (LOIS). The papers were originally presented at a meeting held at the Geological Society of London in September 1998.

The great thing about Geological Society Special Publications is the knowledge that they bring the reader up-to-date on the chosen subject. This volume does not disappoint and contains a wealth of carefully-collected analytical data, providing an excellent regional account of Holocene environmental change. The volume is well organised into 15 papers, providing the reader with a logical progression from techniques, site-specific papers to regional-scale analyses.

For those who enjoy acronyms, the first paper by **Shennan** and **Andrews** is a must, clarifying the role of LOEPS within the LOIS and beyond. However, this introductory paper is somewhat disappointing in terms of elucidating the wider implications of the research presented in this volume. The second paper, by **Ridgway *et al.***, provides a very useful review of techniques used in the Humber Estuary and is well placed in the volume in that many of the following papers avoid large methods sections. This paper will certainly serve as a useful reference for those conducting work on estuarine sediments. Continuing the techniques theme, **Horton *et al.*** explain methodological development in a paper which outlines the foraminiferal-based transfer function approach in sea-level reconstruction. Despite problems associated with AMS ^{14}C dating of calcareous foraminifera from intertidal sediments, it is encouraging to see the effort which is being made by this bright star of the Durham Environmental Research Centre to develop an alternative to bulk organic dating of such

sediments. The next two papers develop the important theme of dating minerogenic sediments, with two contrasting approaches to luminescence dating of Holocene coastal sediments. **Bailiff** and **Tooley**, comparing infra-red-stimulated luminescence (IRSL) ages on silt-sized fractions of water-laid deposits and calibrated radiocarbon ages from organic horizons within the same core, suggest that a chronological resolution of about 1 ka is possible by the IRSL method employed. **Clarke** and **Rendell** describe a methodology for luminescence dating based on the use and improved understanding of alkali feldspars which can be applied to freshwater and saltmarsh environments.

A series of papers on the Holocene sediments of the Humber follow. **Macklin** *et al.* briefly describe the Yorkshire Ouse catchment, suggesting that during the Holocene its sediment delivery to the Humber Estuary may have been relatively low. **Metcalfe** *et al.* provide a wealth of data in an attractive paper which describes the palaeogeographic evolution of the Humber from 8 to 3 cal.ka BP. **Rees** *et al.* continue this theme by exploring the character, volume and source of these sediments. One of the more interesting papers of the volume, by **Andrews** *et al.*, details one of the first well-constrained Holocene organic carbon budgets for a temperate estuary. In contrast to the pre-reclamation system, which acted as a large sediment sink, the modern managed estuary has lost much of its brackish-freshwater wetlands and saltmarshes during the past 300 years. As a result, suspended sediments and associated organic carbon and sulphur are currently bypassing former (Holocene) storage areas and are now presumably impacting North Sea biogeochemical cycles.

The paper on the Tees Estuary by **Plater** *et al.* extends the records beyond the Holocene and includes an intriguing record of what are described as Late Glacial laminated silts and clays, thought to have formed in an ice-dammed Lower Tees lake basin. I found the correlation figure of total varve thickness with the GISP $\delta^{18}\text{O}$ record from the interval 16.5-18 ka BP, constrained by a single luminescence age of $18,365 \pm 10,015$ a BP, to be highly questionable. To infer a climate control on varve thickness where "much of the laminated sediment has a turbiditic or waning flow origin" seems overly ambitious and detracts from what, otherwise, seems to be a well-argued paper. **Orford** *et al.* describe dune initiation in Northumberland at 4 cal. ka BP, with some evidence to suggest dune development during the Little Ice Age. **Andrews** *et al.* describe the north Norfolk barrier coastline, which contrasts with the numerous estuarine sites and provides a debate about coastal management. A thorough characterization of Holocene sediment accumulation in the Fenland is given by **Brew** *et al.*

Two papers from **Shennan** *et al.* stand out as the major achievements of the

volume, synthesising sea-level data collection from the early 1980's. One of the successes of LOEPS, as stressed by **Shennan *et al.***, has been the spatial improvement of the sea-level data set and its extension towards the earlier Holocene. Perhaps the highlight of this volume is the final paper by **Shennan *et al.***, which includes a far-reaching attempt to model the palaeogeographies and associated tidal changes of the western North Sea during the Holocene. These regional-scale modelling exercises, in collaboration with **Kurt Lambeck**, exemplify the importance in Quaternary Science of long-term data gathering, synthesis and management.

To conclude, this volume is an excellent regional synthesis of work on the English east coast, providing a very strong UK perspective. The collected papers work nicely together but, inevitably there are some weaker elements here, some of which would not stand well alone. This is a useful reference volume, although the title is somewhat misleading, with little coverage of the North Sea itself. I would certainly recommend it as a valuable reference for library collections and highly challenging to those who would contemplate further the complex relationships that exist in land-ocean interaction. Finally, it was good to read the salute to **Gill Harwood** and **Robin Wingfield**, both of whom died before the completion of this volume - this is indeed a fitting memorial to them.

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**GEOLOGY OF THE READING DISTRICT:
SHEET EXPLANATION (268)**

S. J. Mathers and N.J.P. Smith

ISBN 0 85272 362 8 (0 7518 3288 X folded and cased map)30pp

GEOLOGY OF THE BIRMINGHAM AREA: MEMOIR (168)

J.H. Powell, B.W. Glover and C.N. Waters

ISBN 0 11 884545 4 (0 7518 3041 0 folded and cased map)132pp

England and Wales 1:50,000 sheets

Published by : British Geological Survey 2000

Birmingham Memoir £45 and Reading Sheet Explanation £9 or with a folded copy of the cased 1:50,000 map in a tough clear plastic wallet £15. Individual 1:50,000 maps cost £9.95, with 25 % academic discount when ordered from: **Sales Desk, British Geological Survey, Keyworth, Nottingham NG12 5GG** Tel : 0115 - 936 3100 Fax : 0115 - 936 3200 (prices exclusive of post and packing).

Both publications straddle the transition from the traditional British Geological Survey (BGS) memoir to the sheet explanation that accompanies newly-surveyed 1:50,000 geological maps. Sheet memoirs have been produced for over a century and originally described in detail a newly-mapped one-inch to the mile (1:63,630) sheet. However, in recent years they have often appeared long after the publication of the map, and the essential costs of writing up a survey have been transferred to increasingly expensive memoirs. Thus, apart for the occasional special publications to cover classic geological areas, the memoirs will be replaced by sheet explanations; the latter are published as A5 booklets (21 x 15 cm), about 30 pages long, at the same time as the map, and presented with the folded edition in a clear plastic wallet. This is similar to the long-standing Bureau de Recherches Géologiques et Minières (BRGM) 1:50,000 map and memoir series, except that the French folded sheet is uncased and often only has a geological key around its margin; since the late 1980's the booklet has become a small (22 x 12 cm) but detailed memoir with an extensive reference list that can exceed a hundred pages in length (see *Quaternary Newsletter*, 91, 52-54).

The Reading sheet explanation details the subsurface geology, Upper Cretaceous Chalk and unconformity with overlying Palaeogene deposits, the structure, applied geology and the Quaternary deposits in this part of the Thames Valley, on the southern edge of the Chilterns dip slope. Due to the complex nature of the alluvial deposits derived from the catchments of the ancestral Thames and its Kennet, Loddon and Blackwater tributaries, the Quaternary takes up about a third of the concisely-written text. The Introduction outlines the topography and geological history of the area, and the final three paragraphs place the Quaternary events into the wider context of climate and sea-level change. The development of such inland drainage systems is being considered in terms of the easterly downwarping of Britain since the late Pliocene (Foster *et al.*, 1999). Hence the relative uplift of the Reading area in relation to the subsiding southern North Sea Basin is now taken for granted. This very significant change in approach by the BGS over the last few years seems to have occurred without reference to any seminal publications.

The bulk of the section on the Quaternary comprises a detailed and revised description of the complex alluvial deposits which, due to their different and changing catchments, contain pebbles with distinct provenances. The text is complemented by a diagram of the relative height, thickness, chronology and correlation of the terraces belonging to the main river systems and the level of their present floodplains. This admirable diagram could have been improved by indicating the positions of the Loddon-Blackwater and Kennet confluences on the Thames and the approximate downstream distances along the present rivers. Unfortunately, the text lacks a diagram placing the diverse Quaternary deposits into a chronology based on warm and cold climate cycles related to oceanic oxygen-isotope stratigraphy, as a number of recent memoirs (i.e. Fortrose in Scotland and Worcester in England) have done quite successfully. To do this, the modified version of a published cross-section across the Kennet valley at Woolhampton could have been inserted on the margin of the map beside an insert showing the distributions of the main gravel compositions. The nature of periglacial deposits such as head gravel and clay-with-flints is also outlined, and certain Quaternary aspects, in terms of mineral workings, local cambering and slope stability, are related to the applied geology of the area. Given their limited length, two pages of information sources, including national data-bases and maps, along with the repetition of memoirs already listed amongst the 71 references, cannot be justified. However, this is considerably more than those listed at the end of the adjacent sheet explanation for Windsor and Bracknell district (1999) to the east.

Considering that a complex series of Quaternary (Drift) deposits, including buried glacial channels, covers three quarters of the area shown by the Birmingham sheet, it is surprising that less than a sixth of this otherwise excellent memoir is devoted to this topic; the memoir mainly deals with Cambrian to Jurassic (Solid) rocks. However, the longer and better-illustrated applied geology chapter, which is important in such a heavily-mined and industrialised district, provides some additional information about the area's superficial deposits. These consist mainly of glaciofluvial, lacustrine and till deposits, mostly from the Anglian or Wolstonian glaciations, with some pockets of interglacial material, including classic Hoxnian successions. In addition, there are restricted river terraces derived from glacial material, and small, scattered areas of postglacial landslips, peat and head.

The revision of the complex Quaternary deposits has been aided by numerous site-investigation boreholes used to generate a map of drift thickness. This map locates buried channels whose restricted length and central low points suggest that they were not pre-existing valleys but may have formed by subglacial scour, water in ice-marginal plunge pools or, more probably, by water flowing under the confining pressure of overlying ice. The borehole data have also been plotted to indicate bedrock levels below central Birmingham and to illustrate the nature of the deposits associated with the key Hoxnian sites at Nechells Green and Quinton. Unfortunately, the data were not used to generate further diagrams that may have improved the reader's understanding of these varied and often abruptly-changing spreads of glacial and glacially-derived material.

The text is supplemented by stratigraphic tables. One table outlines the alternative ages assigned to some of the Quaternary deposits, another their depositional environments and main lithologies. However, no attempt has been made to relate the stratigraphy to the oxygen-isotope record (Foster *et al.*, 1999), and so there are no references to papers such as that by Funnell (1995). Thus this interpretation is dated and can give the impression that there were only two warm stages and a Wolstonian cold phase between the Anglian and Devensian glaciations instead of three cold and four warm stages making up the intricate pattern of intervening global climate changes. Also, the few quoted radiocarbon dates appear to be uncalibrated, and the text does not mention that such ages are often significantly younger than absolute calendar dates.

Even with an uninspired Quaternary chapter the Birmingham memoir contains vastly more information than can a replacement sheet explanation. Memoirs often contain diagrams and information that cannot be found elsewhere, and in some cases these are based on otherwise confidential data held by the BGS. While these new sheet explanations are clearly written, well presented and

accessible to a wider readership, it can only be hoped that they will normally be supplemented by longer sheet descriptions with an expanded reference list. These are relatively cheap, produced in a larger A4 (30 x 21 cm) format and printed to order by the BGS (to reduce costs, the mainly colour figures are expanded and reproduced at the back of the report accompanying the photographs).

References

Foster, S.S.D., Morigi, A.N. and Browne, M.A.E. (1999). *Quaternary geology - towards meeting user requirements*. British Geological Survey, Keyworth, Nottingham.

Funnell, B.M. (1995). Global sea-level and the (pen-)insularity of late Cenozoic Britain. In: Preece, R.C. (ed) *Island Britain: a Quaternary Perspective*. Geological Society, London. Special Publication 96, 3-13.

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ABSTRACTS

PALYNOLOGY OF LATE PLEISTOCENE MARINE SEDIMENTS IN NORTH DENMARK

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This thesis examines the pollen and spore content of marine sediments in two cores from north Jutland (Nørre Lyngby 2 and Skagen 3) and one from the island of Anholt, Kattegat (Anholt II/III).

The main aim of the thesis was to resolve the controversy over the relative dating of the sequences. While foraminiferal analysis and optically-stimulated luminescence dating have given an Eemian age for the interglacial sections of the Nørre Lyngby and Skagen sequences, amino-acid dating suggests that the sediments may correlate with Oxygen Isotope Stage 11. Similar analyses suggested an Eemian age for the Anholt sequence, and it was hoped that pollen analysis of this core might provide a useful comparison to the results from Nørre Lyngby and Skagen.

The pollen assemblages obtained from Nørre Lyngby and Skagen record a transition from interglacial to glacial conditions, followed by, in the case of Nørre Lyngby, two periods of boreal-forest expansion attributed to interstadial conditions. While the Nørre Lyngby and Skagen sequences are broadly similar and can be correlated with each other, there are significant differences from the pollen assemblages that characterise the interglacials of the Middle-Late Pleistocene.

Although the Skagen sequence reflects only the expansion of *Picea*, the presence of low percentages of thermophilous tree taxa in the Nørre Lyngby sequence raises two main possibilities for the relative dating of both sequences:

- 1) The interglacial section of the Nørre Lyngby core reflects a complete interglacial with an early immigration of *Picea* (e.g. the Holsteinian). The low proportions of thermophilous tree taxa relative to terrestrial records of interglacials of this type result from taphonomic bias in the marine environment.
- 2) The interglacial section of the Nørre Lyngby core reflects the latter part of an interglacial with a relatively late immigration of *Picea* (e.g. the Eemian). The early part of the interglacial is missing, presumably due to erosion or non-deposition.

While both hypotheses may explain the relative lack of thermophilous taxa, the possibility that they represent a background population of reworked taxa is also considered.

In contrast to the sequences from Nørre Lyngby and Skagen, that from Anholt can be correlated relatively firmly with the latter part of zone 4 and the beginning of zone 5 of the Eemian interglacial. Much higher proportions of thermophilous taxa are recorded at Anholt, which seems to discount the possibility that, if the Nørre Lyngby and Skagen sequences are Eemian, the low values of thermophilous pollen result from taphonomic bias.

The lower part of sub-biozone NL-1b of the Nørre Lyngby core records a slight decline in thermophilous taxa. This is interpreted as the terrestrial response to the cooling inferred from the foraminiferal record at the same point. While the occurrence of climatic oscillations in the Eemian has been widely accepted, the fact that the pollen record has shown that the age of the sequences cannot presently be resolved, raises the important possibility that climatic oscillations may also have occurred in earlier interglacials.

Although the pollen sequences from Nørre Lyngby and Skagen resemble most closely those from the latter part of the Eemian interglacial, this correlation cannot be demonstrated unequivocally. It is therefore proposed that local stratigraphic terminology is used, and that the interglacial period represented in the Nørre Lyngby and Skagen sequences should, for the time being, be referred to as the 'Skagerrak interglacial'.

HOLOCENE FLOODPLAIN VEGETATION DYNAMICS IN THE LOWER AIRE VALLEY, YORKSHIRE

Jason Robert Kirby (Doctor of Philosophy)
Department of Geography, University of Hull

Perimarine river valleys are a rich palaeoecological resource which may provide information about catchment and sea-level change. This thesis reconstructs the Holocene environmental history of the lower Aire valley, and investigates the factors influencing floodplain and vegetational development.

Reconstruction of environmental change in the lower Aire valley in the mid- to late-Holocene is based on lithological and palaeoecological records from three sites in the upper, middle and lower parts of the study reach. Techniques used include pollen, diatom, wood macrofossil, loss on ignition and radiocarbon analyses.

Paludification of the valley floor was time transgressive, probably due to gradually rising sea level. Paludification began at c. 7,000 BP (c. 8,000 to c. 7,600 cal. yrs BP) at the lowermost site, whereas conditions were not wet enough for preservation of organic sediment in the upper reach until c. 4,200 BP (c. 5,000 to c. 8,500 cal. yrs BP). Accumulation of floodplain peat was interrupted by the deposition of finely-laminated humic clays some time after c. 7000 BP (c. 8,000 to c. 7,600 cal. yrs BP) in the lower tract of the Aire valley, near Goole, suggesting a change to lagoonal conditions. This was apparently caused by the ponding of freshwater against the rising estuary. It is also possible that drainage was impeded, associated with widespread deposition of organic sediment in the lower valley areas, which may have contributed to the creation of a lagoonal environment. The lagoon had silted up by c. 6,000 BP (c. 7,200 to c. 6,600 cal. yrs BP), probably due to an increase in tidal asymmetry and range, which resulted in a net surplus of sediment in the floodbasins and enabled the re-invasion of fen carr onto the site.

The main period of organic sedimentation lasted for several millennia at each of the study sites, during which time *Alnus glutinosa* fen carr communities dominated the backswamp areas of the floodplain. During mid-Holocene times, the surrounding dryland was colonised by a mixed woodland, with *Tilia*, *Ulmus*, *Quercus*, and probably *Corylus avellana* and *Fraxinus excelsior*. *Pinus sylvestris* was also prevalent in the region.

Alnus carr was progressively replaced by fen meadow communities, and then saltmarsh or freshwater reedswamp communities, as water levels rose due to rising sea level recorded throughout the lower Aire valley between c. 4,600 and c. 2,700 BP (c. 5,500 to c. 2,700 cal. yrs BP). Remnants of a possible upper peat unit and diatom evidence from the upper clastic sediment is tentatively interpreted as indicating the contraction of estuarine conditions and a phase of falling sea level at some time during the late Iron Age.

NOTICES

1. MILLENNIAL-SCALE EVENTS IN THE NORTH ATLANTIC REGION DURING TERMINATION 1 INTERNATIONAL CONFERENCE AND ASSOCIATED FIELD MEETING

University of Ulster, Northern Ireland, 13-18 June 2001

Oral and poster contributions are invited for an international conference on millennial-scale events. The conference will focus on evaluating the timing, signatures and correlation of high-frequency hemispheric-scale climate and environmental changes during Termination 1 (last deglaciation) in the North Atlantic region, as deduced from ice-core, marine-core, and terrestrial (glacial, peat, lake) records. Papers presented at the conference are invited for submission to an associated volume, most likely a Geological Society Special Publication, edited by Marshall McCabe and Jasper Knight.

Paper sessions based at the University of Ulster (days 1-3) will be followed by a field meeting (days 4-6) examining onshore field evidence for Heinrich event 1 in Ireland. This is the only known dated site where ice advance associated with H1 is demonstrated in the NE Atlantic region. A field guide will accompany this part of the meeting.

Conference details and registration forms are available from:
www.ulst.ac.uk/termination1.html

Deadline for statements of interest: 1 October 2000

Deadline for abstracts: 1 January 2001

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<http://www.ulst.ac.uk/faculty/science/crg/home.htm>

2 ENGLISH QUATERNARY SSSI/GCR SITES

Concerns about Quaternary SSSI/GCR sites in England will be welcomed by Dr Chris Gleed-Owen at the NCC for England (English Nature). Dr Gleed-Owen is covering for Natalie Bennett, who is on maternity leave until January 2001.

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QUATERNARY RESEARCH ASSOCIATION

The Quaternary Research Association is an organisation comprising archaeologists, botanists, civil engineers, geographers, geologists, soil scientists, zoologists and others interested in research into the problems of the Quaternary. The majority of members reside in Great Britain, but membership also extends to most European countries, North America, Africa, Asia and Australasia. Membership (currently c. 1,000) is open to all interested in the objectives of the Association. The annual subscription is £15 with reduced rates (£5) for students and unwaged members and an Institutional rate of £25.

The main meetings of the Association are the Annual Field Meeting, usually lasting 3-4 days, in April, and a 1 or 2 day Discussion Meeting at the beginning of January. Additionally, there are Short Field Meetings in May and/or September, while Short Study Courses on techniques used in Quaternary work are also occasionally held. The publications of the Association are the *Quaternary Newsletter* issued with the Association's *Circular* in February, June and October; the *Journal of Quaternary Science* published in association with Wiley, incorporating *Quaternary Proceedings*, with eight issues per year, the Field Guide Series and the Technical Guide Series.

The Association is run by an Executive Committee elected at an Annual General Meeting held during the April Field Meeting. Current officers of the Association are:

President: *Professor M.J.C. Walker*, Department of Geography, University of Wales, Lampeter, Dyfed, SA48 7ED (e-mail: walker@lamp.ac.uk)

Vice-President: *Dr R.C. Preece*, Department of Zoology, University of Cambridge, Downing Street, Cambridge, CB2 3EJ. (e-mail: r.c.preece@zoo.cam.ac.uk)

Secretary: *Dr C.A. Whiteman*, School of the Environment, University of Brighton, Cockcroft Building, Lewes Road, Brighton, BN2 4GJ (e-mail: C.A.Whiteman@brighton.ac.uk)

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All questions regarding membership are dealt with by the **Secretary**, the Association's publications are sold by the **Publications Secretary** and all subscription matters are dealt with by the **Treasurer**.

QRA home page on the world wide web at: <http://www.qra.org.uk>



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