REPORT

New developments on the Quaternary of Norfolk

David Keen's excellent talk to the Society on the Quaternary of the Midlands will no doubt have reminded members of a Foundation Lecture which one of us (RJOH) gave three years ago on the Quaternary of Norfolk. Since then certain developments have occurred which affect the dating of the Norfolk deposits and their correlation with those described by Professor Keen.

At the time of the Foundation Lecture (Hamblin, 2000), Oxygen Isotope Stages for the Norfolk glacial sequence were suggested as in Table 1. Uncertainty as to the date of the Lowestoft Formation has now been largely resolved by further work on material from the Hoxnian type section at Hoxne (Grün and Schwarcz, 2000). This places the interglacial deposits at Hoxne in Stage 11, in which case the immediately underlying Lowestoft Till is almost certainly Stage 12. This was already a difficult conclusion to avoid since the Lowestoft glaciation extended the farthest south of any glaciation in south-east England, and has long been believed to have accounted for the diversion of the River Thames. Evidence from the terraces of the Thames placed that diversion in OIS 12 (Bridgland, 1994).

The Corton Formation has been re-named the Happisburgh Formation, partly because a more complete sequence is exposed at Happisburgh than at Corton, and partly to avoid confusion since Corton is also the type site of the Anglian Stage. Important evidence for the dating of the formation has been found at the Leet Hill pit near Bungay in the Waveney Valley (Rose et al, 2000; Hamblin et al, 2000). Boulders of basic volcanic rocks, high-grade metamorphic rocks and Carboniferous limestone, many of them with angular edges, were found in fluvial gravels of the Bytham Formation (Fig. 1). They do not resemble the erratic suite of the Lowestoft Formation, but do suggest a correlation with the Happisburgh Formation. This interpretation is supported by the presence of clasts of sandy till, similar to that of the Happisburgh Till (Lee et al, 2002). Since the Lowestoft glacial advance overran a terrace of the Bytham Formation that post-dates by at least one warm period the terrace gravels in which the Happisburgh marterial

Formation	*Member*	*OIS*
Overstrand	Briton's Lane Sand and Gravel	6
Overstrand	Hanworth Till	6
Lowestoft	Walcott Till	10 or 12
Corton	Happisburgh Till	12 or 14

Table 1. The earlier concept of the stratigraphy.

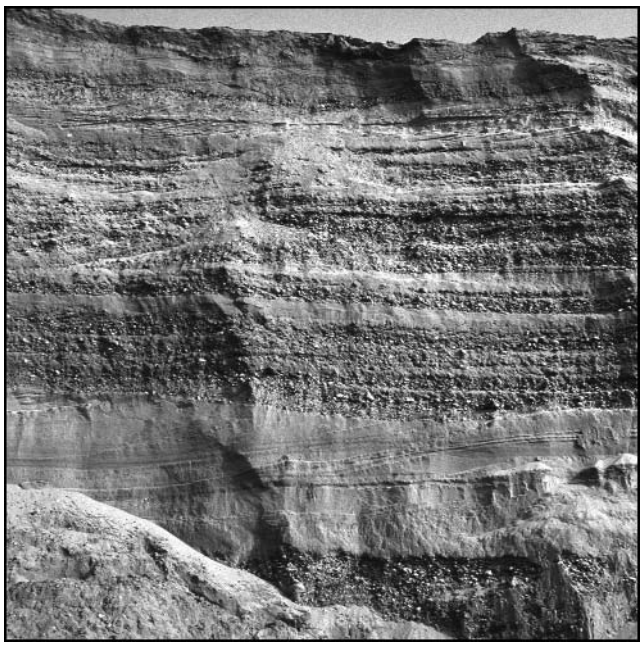

Figure 1. Bytham Formation terrace gravels at Leet Hill. These contain glacial erratics and till balls, indicating a glaciation earlier than OIS 12.

was found, the Happisburgh and Lowestoft are clearly separate glaciations. Since the Lowestoft glaciation dates from OIS 12, and there is no good evidence for a global glaciation in Europe in OIS 14, whereas global ice appears to be important in OIS 16 (Raymo,1997), we suggested (Hamblin et al, 2000) that the Corton (now Happisburgh) Formation dates from OIS 16.

The above developments occurred in time to be demonstrated at the QRA field meeting at Norwich in April 2000, at which we proposed (Moorlock *et al*, 2000; Hamblin *et al*, 2000) that Norfolk had been subjected to three pre-Devensian glaciations, in OIS 16, 12 and 6. However, further work cast doubt on the relationships of the members of the Overstrand Formation. We had proposed that the Hanworth Member till and the Briton's Lane Sand and Gravel belonged to the same glaciation because both were believed to be of Scandinavian derivation, but whilst this is undoubtedly true of the Briton's Lane Sand and Gravel, Jonathan Lee's clast analyses of the tills failed to demonstrate a Scandinavian connection in the Hanworth Till. Indeed, a letter to Quaternary Newsletter (Moorlock *et al*, 2001) failed to elicit any evidence for Scandinavian erratics in any deposits older than the Briton's Lane Sand and Gravel.

This discovery suggests that the Hanworth and Briton's Lane members belong to different glaciations, and this is indeed in accord with their relationships, since the latter is found draped over an eroded surface cut in the former, with no interdigitation. Further, the Briton's Lane Member exhibits constructional geomorphology in the form of the Blakeney Esker and the kames of the Glaven

Formation	*Member*	*OIS*
Overstrand	Briton's Lane Sand and Gravel	6
Beeston Regis	Hanworth and Bacton Green	10?
Lowestoft	Walcott Till	12
Happisburgh		16

Table 2. Revised pre-Devensian stratigraphy in Norfolk.

Valley, whilst the Hanworth Till has no such appearance of constructional topography. We have thus raised a new formation, the Beeston Regis Formation, to include the Hanworth Member, whilst the Briton's Lane Member remains in the Overstrand Formation. Also, we have divided the tills of the Beeston Regis Formation into the Hanworth Member, which lies south of the Cromer Ridge and is not glacially deformed, and the Bacton Green Member, which occurs north of the Cromer Ridge and demonstrates impressive soft-sediment deformation - the "contorted drift" of the traditional sequence.

In view of its constructional appearance and Scandinavian origin we are satisfied that the Briton's Lane Member is OIS 6 as originally proposed, but the Beeston Regis Formation is likely to be older: OIS 8 is unlikely as this was not a very cold period, so OIS 10 and 12 are possible, although we do not believe that OIS 12 is likely since there is no obvious relationship between the Beeston Regis and Lowestoft formations, with the former resting on an eroded surface of the latter. The most likely age would appear to be OIS 10, particularly since Rowe *et al*. (1997) record a peat of OIS 9 age resting upon a till of believed OIS 10 age at Tottenhill, NW Norfolk. There would thus appear to have been no less than five glaciations in Norfolk, in OIS 16, 12, 10, 6 and 2 (Devensian), and we would suggest correlation of the Lowestoft (OIS 12) and Beeston Regis (OIS 10) formations with the Thrussington and Oadby tills of the East Midlands as described by David Keen (p242 in this journal). Our new pre-Devensian stratigraphy is thus as in Table 2.

Finally, the realisation that the OIS 6 glaciation is the only Scandinavian glaciation to reach Norfolk has interesting repercussions in the geology of the North Sea and English Channel. It has long been believed that the Strait of Dover was cut during the Anglian (assumed OIS 12) glaciation, by the overflow of a pro-glacial lake that formed when British and Scandinavian ice joined to block the northern outlet of the North Sea (Gibbard, 1988, 1995, Hamblin *et al*, 1992). However, palaeontological evidence on the isolation of Britain during interglacial stages, such as would occur after cutting the Strait, imply that isolation did not occur before the Ipswichian (OIS 5e) (Meier and Preece, 1995; Stuart, 1995; Sutcliffe, 1995). Most recently, Ashton and Lewis (2002) cite the likely cutting of the Strait in OIS 6 as an important factor in explaining the absence of human populations from England in OIS 5. The inevitable prognosis of the cutting of the Strait in OIS 6 is that at no time before then was the North Sea blocked by the convergence of British and Scandinavian ice, which is in accord with our findings in Norfolk.

Acknowledgements

Richard Hamblin and Brian Moorlock publish with the permission of the British Geological Survey (NERC).

References

Ashton, N, and Lewis, S., 2002. Deserted Britain: declining populations in the British Late Middle Pleistocene. *Antiquity*, **76**, 388-396.

Bridgland, D.R., 1994. *Quaternary of the Thames*. Geological Conservation Review Series 7. Chapman & Hall, London. 441pp

Gibbard, P.L., 1988. The history of the great northwest European rivers during the last three million years. *Phil. Trans. Royal Society*, **318B**, 559-602.

Gibbard, P.L., 1995. The formation of the Strait of Dover. *Geol. Soc. Spec. Publ.*, **96**, 15-26.

Grün, R. & Schwarcz, H.P., 2000. Revised open-system U-series/ESR age calculations for teeth from Stratum C at the Hoxnian Interglacial type locality, England. *Quat. Sci. Rev*., **19**, 1151-1154.

Hamblin, R.J.O., 2000. A new glacial stratigraphy for East Anglia. *Merc. Geol*., **15**, 59-62.

Hamblin, R.J.O., Crosby, A., Balson, P.S., Jones, S.M., Chadwick, R.A., Penn, I.E., & Arthur, M. J., 1992. *United Kingdom offshore regional report: the geology of the English Channel*. British Geological Survey, HMSO, London.

Hamblin, R.J.O., Moorlock, B.S.P., & Rose, J., 2000. A new glacial stratigraphy for eastern England. *Quat. Newsl*., 92, 35-43.

Lee, J.R., Rose, J., Riding, J.B., Moorlock, B.S.P. & Hamblin, R.J.O., 2002. Testing the case for a Middle Pleistocene Scandinavian glaciation in Eastern England: evidence for a Scottish ice source for tills within the Corton Formation of East Anglia, UK. *Boreas*, **31**, 345-355.

Meier, T., & Preece, R.C., 1995. Malacological evidence relating to the insularity of the British Isles during the Quaternary. *Geol. Soc. Spec. Publ*., **96**. 89-110.

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

Moorlock, B.S.P., Hamblin, R.J.O, Rose, J., & Lee, J.R., 2001. The occurrence of rhomb-porphyry within diamictons in north-east Norfolk. *Quat. Newsl*., **95**, 49-50.

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

Rose, J., Moorlock, B.S.P. & Hamblin, R.J.O., 2000. Lithostratigraphy and palaeoenvironments of the pre-Anglian sand and gravels of East Anglia. In: Lewis, S.G., Whiteman, C.A. and Preece, R.C. (eds), *The Quaternary of Norfolk and Suffolk: Field Guide*. Quaternary Research Association, London, 35-46.

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

Stuart, A.J., 1995. Insularity and Quaternary vertebrate faunas in Britain and Ireland. *Geol. Soc. Spec. Publ*., 96. 111-125.

Sutcliffe, A.J., 1995. Insularity of the British Isles 250,000-30,000 years ago: the mammalian, including human, evidence. *Geol. Soc. Spec. Publ*., 96. 127-140.

Richard Hamblin, Brian Moorlock,
British Geological Survey, Nottingham;
James Rose, Jonathan Lee,
Royal Holloway College, London University