THE PLEISTOCENE EPOCH IN EAST ANGLIA*

By R. G. West
(The Botany School, University of Cambridge)

ABSTRACT. The sequence of Pleistocene deposits in East Anglia is tabulated. The following aspects of the Pleistocene are discussed and summarized: boundaries of the Pleistocene, glacial and preglacial, ice advances, interglacials, glaciations, marine horizons, climate and periglacial features. Correlations are given between the Pleistocene deposits of East Anglia and the continent.

ZUSAMMENFASSUNG. Die zum Pleistozän gehörigen Ablagerungen in East Anglia sind in Tabellen aufgestellt. Die folgenden Aspekte des Pleistozän werden besprochen und zusammengefasst: Die Grenzlinien des Pleistozän, die glazialen und präglazialen Ablagerungen, das Vordringen des Eises, die Interglacialzeiten, die Vereisungen, die Marinehorizonte, das Klima und die periglazialen Verhältnisse. Die Beziehungen, die zwischen den zum Pleistozän gehörigen Ablagerungen in East Anglia und auf dem europäischen Festland bestehen, werden besprochen.

BOUNDARIES OF THE PLEISTOCENE

Boswell [1] has dealt fully with the question of where to draw the Plio-Pleistocene boundary in East Anglia. Criteria used to determine the boundary include the presence of a stratigraphical break, marked increase of the proportion of northern forms of marine molluscs, indicative of a refrigeration of the climate, and the first arrival of elephant and horse. Such criteria seem best satisfied by placing the boundary between the Coralline and Red Crags. The correlation of this boundary with the continental Plio-Pleistocene boundary has been summarized by Voorthuysen.[2]

The Pleistocene-Holocene (Recent) boundary may be taken at the transition between the Late- and Post-glacial Periods, between Zones III and IV of the north-west European pollen zonation. The youngest Pleistocene deposits considered here are those of the most recent glaciation in East Anglia, although Late-glacial deposits are known in East Anglia.[3]

GLACIAL AND PRE-GLACIAL

Although far-travelled erratics occur in the Crags, the oldest true glacial deposits in East Anglia are the tills of the North Sea Drift. Thus the Pleistocene deposits in East Anglia may be divided broadly into a "glacial" series, including the North Sea Drift and younger deposits, and a "pre-glacial" series, including the *Leda-myalis* Bed, Cromer Forest Bed Series and older deposits. These terms are naturally of local significance only; what is pre-glacial in East Anglia is not necessarily so on the continent. As the correlations in the table suggest, the early Pleistocene glaciations of the continent [4] do not appear to be represented by glacial deposits in East Anglia. Instead there is the extensive sequence of the marine and estuarine Crag deposits. There is not yet sufficient evidence to make any detailed correlation of these deposits with the continental early Pleistocene glacial and interglacial deposits.

ICE ADVANCES

Tills of a number of ice advances have been distinguished in East Anglia. The earliest tills are those of the North Sea Drift, including the Cromer Till and the Norwich Brickearth. It is possible that the tills of this age in north-east Norfolk may have been formed by more than one advance.[5] The direction of movement of the ice which laid down the North Sea Drift, the Cromer Advance,[6] appears to have been from the north-west. The next ice advance to be distinguished is the Lowestoft Advance,[6] which deposited Baden-Powell's [7] Lowestoft Till, a chalky boulder clay. Evidence from erratics and stone orientation measurements of this

* Substance of a lecture given to the British Glaciological Society at the University of Birmingham, 8 November 1957.

till suggest that the ice which deposited it moved across East Anglia from west to east. An upper chalky boulder clay, the Gipping Till of Baden-Powell [7] is the youngest widespread till-sheet in East Anglia. The till was deposited during the Gipping Advance.[6] Both erratics and stone orientation measurements suggest a north to south movement for this advance.

There is some evidence of a final ice advance in north Norfolk, where certain features of the landscape described by West [8] suggest a recent, Newer Drift, glaciation, in contrast to the Older Drift formed by the previous ice advances. Possibly this ice advance also deposited the Hunstanton Brown Boulder Clay, supposed by many [5, 7] to be younger than the chalky boulder clays.

Interglacials

Professor van der Vlerk [9] has pointed out that the wealth of information about fauna, flora and climate provided by fossiliferous interglacial* sediments makes such deposits more significant than glacial deposits for subdividing the Pleistocene. This is certainly true in East Anglia. The classification of the glacial deposits has been simplified by the identification of three distinct richly fossiliferous interglacial horizons, each of which appears to have a characteristic vegetational development. The oldest, the Cromerian, is represented by the Cromer Forest Bed Series. A pollen diagram from this deposit [11] shows a lower coniferous phase, a middle mixed oak forest phase, and an upper coniferous phase, a type of sequence which is indicative of climatic amelioration and then deterioration and is characteristic of interglacial deposits. The pollen diagram differs from those of both the younger interglacial periods in various ways, principally in the low values of *Corylus*, and from the pollen diagram of the Hoxnian Interglacial in the absence of any quantity of *Abies* pollen.

In the sense that there are no glacial deposits below the Cromer Forest Bed Series, the deposit may be considered "pre-glacial". However, the typical interglacial sequence mentioned above, and the fact that early continental glaciations are supposed to have occurred before the Cromerian,[4] suggests that the Cromer Forest Bed Series was deposited in an interglacial period.

The middle interglacial horizon, the Hoxnian, includes deposits at Hoxne,[12] Clacton [13] and several other sites in East Anglia. The pollen diagrams from this interglacial period are different from those from the earlier and later interglacials, notably in the slow rise of *Corylus* to a maximum long after the rise to dominance of the mixed oak forest and in the presence of rather high percentages of *Abies* pollen in the latter part of the interglacial.

The youngest interglacial, the Ipswichian, with deposits at Cambridge [14] and Ipswich,[15] gives pollen diagrams with an early high percentage of *Corylus*, with low values of *Alnus* and a distinct *Carpinus*-dominant zone, all features apparently absent from the older interglacials.

Glaciations

If the three interglacial horizons already described are taken as limiting glaciations, then evidence for two, and possibly three, glaciations can be distinguished in East Anglia. The first, the Lowestoft Glaciation,[6] is between the Cromerian and Hoxnian Interglacials; the second, the Gipping Glaciation,[6] is between the Hoxnian and Ipswichian Interglacial; a third, later than the Ipswichian Interglacial, is possibly represented by the fresh drift features, and perhaps by the Hunstanton Brown Boulder Clay, of the north Norfolk coast.

Marine Horizons

The "pre-glacial" Pleistocene deposits, confined to the eastern part of East Anglia, are, apart from the freshwater beds of the Cromer Forest Bed Series, predominantly marine and estuarine. Two series of Crag deposits can be distinguished: the Red Crag, and the Icenian

* The term interglacial is used here in Jessen and Milthers' [10] sense of the word; a climatic amelioration at least equivalent to the Post-glacial amelioration of the climate in the area in question is implied.

Crag, which includes the Norwich Crag, Chillesford Beds and Weybourne Crag. The Red Crag is a shore deposit, while the Icenian Crag is supposed to have been deposited in "a shallow open sea that lay near the estuary of a large northward-flowing river that was probably a forerunner of the Rhine".[16] Alterations in the conditions of deposition and the changes of sediment type in these Crag deposits suggest changes of relative land- and sea-level during Crag times.[16] These changes are not known in any great detail, but it appears that they were superimposed upon a relative depression of the land, part of the general Pleistocene subsidence in the southern part of the North Sea basin.[17]

Reid[18] described a middle estuarine bed of the Cromer Forest Bed Series. The exact position of this horizon in the interglacial sequence shown by the pollen diagram is not known. A further comparatively unknown marine deposit is the *Leda-myalis* Bed, lying above the Cromer Forest Bed Series, but below the glacial deposits.

A series of sands, the Corton Beds of Baden-Powell and Reid Moir,[19] lies between the North Sea Drift and the Lowestoft Till. These sands contain a fauna of marine molluscs described by Baden-Powell.[20] It is not certain to what extent the fauna is contemporary with the deposit. No organic deposits are known from the interval between the North Sea Drift and the Lowestoft Till, and there appears to be no evidence from the Corton Beds of the kind that shows the Cromerian and Hoxnian deposits to be interglacial and that would merit the characterization of the Corton Beds as interglacial, except in a strictly stratigraphical sense.

A comparison of the pollen diagrams from the interglacial beds at Hoxne[12] and Clacton[13] indicates that the estuarine deposits of the Clacton Channel were formed during a phase of declining warmth within the Hoxnian Interglacial. It appears that during this interglacial relative land- and sea-level changes in East Anglia resulted in a transgression relatively later in the interglacial, compared with the earlier transgression in the Eemian Interglacial.[21]

The March Gravels, a marine horizon described by Baden-Powell,[22] have been tentatively correlated with the Eemian (=Ipswichian) Interglacial.[11] This seems the most probable correlation in view of the fact that these gravels lie in the Fenland basin apparently undisturbed by a glacial advance, and thus later than the latest widespread advance in the Fenland, the Gipping Advance.

Solomon[5] described a raised beach deposit beneath Hunstanton Brown Boulder Clay at Morston, on the north Norfolk coast. If this till is of Last Glaciation age, then possibly the raised beach was formed during the Ipswichian Interglacial.

Climate

The increasing proportion of species of northern marine mollusca in the Pleistocene Crags suggests a gradual refrigeration of the climate during their deposition.[1] The pollen diagram from the Cromer Forest Bed Series shows an amelioration of the climate from a basal boreal phase to a middle temperate phase, and then a deterioration to an upper boreal phase. The Arctic Freshwater Bed, described by Reid[18] from between the Cromer Forest Bed Series and the North Sea Drift, contains dwarf birch, *Betula nana*, and an arctic willow, *Salix polaris*, indicators of cold conditions. The climatic cycle shown by the interglacial deposits at Hoxne has been described by West.[12] There is a sequence from cold conditions at the base through a temperate phase back to a cold periglacial climate at the top. A similar sequence is known from the Eemian Interglacial on the continent, but in the Ipswichian deposits only the amelioration of the climate at the beginning of the interglacial at Ipswich,[15] and zones somewhat later in the interglacial at Cambridge,[14] have so far been recorded. A comparison between the pollen diagrams of the Hoxnian and Ipswichian Interglacials suggests that the climate became warmer, and the vegetation more open, during the temperate phase of the latter interglacial.

Indications of a periglacial climate with frozen ground phenomena during the Late Pleistocene are described in the next section.

Periglacial Features

Features indicative of a periglacial climate are abundant in East Anglia. Disturbance of the deposits is frequently seen near the surface in sections in the East Anglian drifts. In the Breckland magnificent stone stripes have been identified by Watt,[23] and these are often associated with large-scale polygon-type surface patterns. Paterson [24] has given an account of frost phenomena seen in gravels near Cambridge. Periglacial valleys have been described from the eastern part of the Cromer Ridge by West.[8]

It is evident that severe periglacial conditions were present in East Anglia at some time later than the Gipping Advance, possibly during the Last Glaciation, since many of these features disturb the deposits of this advance.

Correlations

The correlations with the continental sequence made in the table (p. 215) are those suggested by West [15, 25] and by various authors in the symposium on Pleistocene correlations between the Netherlands and adjacent areas conducted by van der Vlerk.[26]

MS. received 16 December 1957

REFERENCES

1. Boswell, P. G. H. The Plio-Pleistocene boundary in the east of England. *Proceedings of the Geologists' Association*, Vol. 63, Part 4, 1952, p. 301-12.
2. Voorthuysen, J. H. van. The Plio-Pleistocene boundary in the North Sea basin. *Geologie en Mijnbouw*, N.S., 19e Jaarg., No. 7, 1957, p. 263-66.
3. Tallantire, P. A. Studies in the post-glacial history of British vegetation. XIII. Lopham Little Fen, a late-glacial site in central East Anglia. *Journal of Ecology*, Vol. 41, No. 2, 1953, p. 361-73.
4. Zagwijn, W. H. Vegetation, climate and time-correlations in the early Pleistocene of Europe. *Geologie en Mijnbouw*, N.S., 19e Jaarg., No. 7, 1957, p. 233-44.
5. Solomon, J. D. The glacial succession on the north Norfolk coast. *Proceedings of the Geologists' Association*, Vol. 43, Part 3, 1932, p. 241-71.
6. West, R. G., *and* Donner, J. J. The glaciations of East Anglia and the East Midlands: a differentiation based on stone-orientation measurements of the tills. *Quarterly Journal of the Geological Society of London*, Vol. 112, Part 1, 1956, p. 69-91.
7. Baden-Powell, D. F. W. The Chalky Boulder Clays of Norfolk and Suffolk. *Geological Magazine*, Vol. 85, No. 5, 1948, p. 279-96.
8. West, R. G. Notes on a preliminary map of some features of the drift topography around Holt and Cromer, Norfolk. *Transactions of the Norfolk and Norwich Naturalists' Society*, Vol. 18, Part 5, 1957, p. 24-29.
9. Vlerk, I. M. van der. The significance of interglacials for the stratigraphy of the Pleistocene. *Quaternaria*, Vol. 2, 1955, p. 35-43.
10. Jessen, K., *and* Milthers, V. Stratigraphical and palaeontological studies of interglacial fresh-water deposits in Jutland and north-west Germany. *Danmarks Geologiske Undersøgelse*, 2 Raekke, No. 48, 1928.
11. Woldstedt, P. Das Vereisungsgebiet der Britischen Inseln und seine Beziehungen zum festländischen Pleistozän. *Geologische Jahresberichte*, Bd. 65, 1950, p. 621-40.
12. West, R. G. The Quaternary deposits at Hoxne, Suffolk. *Philosophical Transactions of the Royal Society of London*, Series B, Vol. 239, No. 665, 1956, p. 265-356.
13. Pike, K., *and* Godwin, H. The interglacial at Clacton-on-Sea, Essex. *Quarterly Journal of the Geological Society of London*, Vol. 108, Part 3, 1953, p. 261-72.
14. Walker, D. The interglacial deposits at Histon Road, Cambridge. *Quarterly Journal of the Geological Society of London*, Vol. 108, Part 3, 1953, p. 273-82.
15. West, R. G. Interglacial deposits at Bobbitshole, Ipswich. *Philosophical Transactions of the Royal Society of London*, Series B, Vol. 241, No. 676, 1957, p. 1-31.
16. Chatwin, C. P. *East Anglia and adjoining areas. Third edition*. London, H.M.S.O., 1954. (G.B. Geological Survey and Museum. British Regional Geology.)
17. Voorthuysen, J. H. van. Crustal movements of the southern part of the North Sea basin during Pliocene and early Pleistocene times. *Geologie en Mijnbouw*, N.S., 16e Jaarg., No. 6, 1954, p. 165-72.
18. Reid, C. The Pliocene deposits of Britain. *Memoirs of the Geological Survey of the United Kingdom*, 1890.
19. Baden-Powell, D. F. W., *and* Moir, J. R. On a new Palaeolithic industry from the Norfolk coast. *Geological Magazine*, Vol. 79, No. 4, 1942, p. 209-19.
20. Baden-Powell, D. F. W. Field meeting in the Lowestoft district. *Proceedings of the Geologists' Association*, Vol. 61, Part 3, 1950, p. 191-97.
21. Brelie, G. von der. Transgression und Moorbildung im letzten Interglazial. *Mitteilungen aus dem Geologischen Staatsinstitut in Hamburg*, 23, 1954, p. 111-18.

(*Continued on page 216*)

TABLE I

		East Anglia: Deposits: Marine and estuarine	East Anglia: Deposits: Continental	East Anglia: Glaciations and Interglacials	Correlation with the continental sequence [26]	
Pleistocene	"glacial" series		? Fresh glacial features on north Norfolk coast; Hunstanton Brown Boulder Clay?	Hunstanton Glaciation	Weichsel Glaciation	
		March Gravels; Morston Raised Beach?	Interglacial deposits at Ipswich and Cambridge	Ipswichian Interglacial	Eemian Interglacial	
			Gipping Till	Gipping Glaciation	Saale Glaciation	
		Estuarine deposits of Clacton channel	Interglacial deposits at Hoxne, Clacton and Saint Cross, Southelmham	Hoxnian Interglacial	Hoxnian Interglacial (=Holstein Interglacial of N. Germany) (=Needian Interglacial of Netherlands)	
		Corton Beds	Lowestoft Till North Sea Drift	Lowestoft Glaciation	Elster Glaciation	
	"pre-glacial" series	*Leda-myalis* Bed Cromer Forest Bed Series: estuarine bed	Arctic Freshwater Bed Cromer Forest Bed Series: freshwater beds	Cromerian Interglacial	Cromerian Interglacial	
					Marine	*Continental*
		Icenian Crag: Weybourne Crag; Chillesford Beds; Norwich Crag			Icenian	Menapian Glaciation Waalian Interglacial Eburonian Glaciation Tiglian Interglacial
		Red Crag			Amstelian	Praetiglian Glaciation
Pliocene		Coralline Crag				Reuverian

22. Baden-Powell, D. F. W. On the marine gravels at March, Cambridgeshire. *Geological Magazine*, Vol. 71, No. 839, 1934, p. 193-219.
23. Watt, A. S. Stone stripes in Breckland, Norfolk. *Geological Magazine*, Vol. 92, No. 2, 1955, p. 173-74.
24. Paterson, T. T. The effects of frost action and solifluxion around Baffin Bay and in the Cambridge district. *Quarterly Journal of the Geological Society of London*, Vol. 96, Part 1, 1940, p. 99-130.
25. West, R. G. The glaciations and interglacials of East Anglia; a summary and discussion of recent research. *Quaternaria*, Vol. 2, 1955, p. 45-52.
26. A symposium on Pleistocene correlations between the Netherlands and adjacent areas. *Geologie en Mijnbouw*, N.S., 19e Jaarg., No. 7, 1957, p. 229-316.

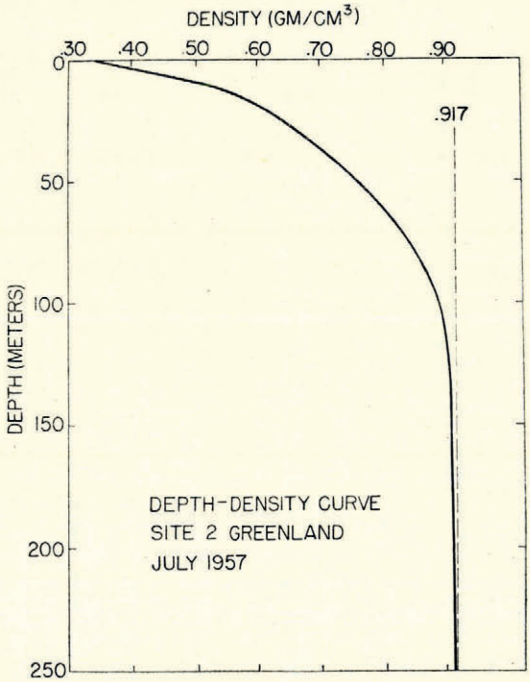

Fig. 1

https://doi.org/10.3189/S0022143000024266 Published online by Cambridge University Press