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THE CRAG AT BRAMERTON, NEAR NORWICH, NORFOLK

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WITH THREE APPENDIXES

I. SYSTEMATIC NOTES ON THE FORAMINIFERA

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II. MOLLUSCA AT WROXHAM HALL

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III. THE VERTEBRATE FAUNA OF BRAMERTON

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CONTENTS

PAGE
1. Introduction 490
2. Stratigraphy 492
   (*a*) Bramerton Common section 492
   (*b*) Blake's Pit section 494
3. Palynology at Blake's Pit 494
   (*a*) Pollen diagram 494
   (*b*) Taphonomy 496
   (*c*) Vegetational history 496
   (*d*) Comparisons and correlations 497
4. Foraminifera 497
   (*a*) Systematics 497
   (*b*) Bramerton Common section 499
   (*c*) Blake's Pit section 500
   (*d*) Comparisons and correlations 500
5. Mollusca 501
   (*a*) Bramerton Common section 502
   (*b*) Blake's Pit section 514
   (*c*) Facies and notes on Mollusca 514
6. Associated gravels 516

PAGE
7. CONCLUSIONS AND CORRELATIONS 516
(*a*) Relation to gravels 516
(*b*) Relation to the 'Bure Valley Beds' 517
(*c*) Relation to the Norfolk coastal sequence 518
(*d*) Relation to Ludham and the southern crag 518
(i) Pollen 518
(ii) Mollusca 518
(iii) Foraminifera 519
(*e*) A synthesis 520

REFERENCES 521

APPENDIX I. SYSTEMATIC NOTES ON THE FORAMINIFERA 522

APPENDIX II. MOLLUSCA AT WROXHAM HALL 530
(*a*) Stratigraphy 530
(*b*) Mollusca 530

APPENDIX III. THE VERTEBRATE FAUNA OF BRAMERTON 531

Mollusc, foraminifer and pollen assemblages from sections at Bramerton, near Norwich, the type locality of the Norwich Crag, are described. It is shown that the marine sediments were deposited first under temperate conditions and later under colder conditions. The faunas and floras are compared with those elsewhere in the East Anglian crag and it is concluded that the temperate stage represented at Bramerton must be regarded as a new stage in the East Anglian Pleistocene succession, here named the Bramertonian, while the subsequent cold stage is equivalent to the Pre-Pastonian *a* substage of the Norfolk coast. It is likely that the Bramertonian stage also includes the Norwich Crag faunas of Suffolk at Chillesford, Aldeburgh, Thorpe Aldringham and Sizewell, together with the Westleton Beds. The first influx of quartz–quartzite–flint gravels in the Norwich area is shown to have occurred later than the deposition of the Bramertonian crag.

1. INTRODUCTION

The pit at Bramerton Common, near Norwich, Norfolk (TG 2951 0601) (figure 1), has frequently been regarded as the type-section for the Norwich Crag (Reid 1890), and was referred to the Upper Division of the Norwich Crag by Harmer (1900).

It was first described by Taylor (1823). Taylor recognized, and illustrated by means of an elegant etching, ten strata:

	stratum	thickness	
13.41–14.94 m	1	5 ft	sand without organic remains
13.11–13.41 m	2	1 ft	gravel
11.89–13.11 m	3	4 ft	loamy earth
11.43–11.89 m	4	1½ ft	red, ferruginous sand containing, occasionally, hollow ochreous nodules
10.97–11.43 m	5	1½ ft	coarse white sand, with a vast number of *Crag-shells*
10.52–10.97 m	6	1½ ft	gravel, with fragments of shells
5.94–10.52 m	7	15 ft	brown sand, in which is a seam of minute fragments of shells, 6 in thick

	stratum	thickness	
4.88–5.94 m	8	3½ ft	coarse white sand with *Crag-shells*, similar to stratum 5; the Tellinae and Murices are the most abundant
0.30–4.88 m	9	15 ft	red sand, without organic remains
0.00–0.30 m	10	1 ft	loamy earth, with large stones and *Crag-shells*
$\overline{0.30}$–0.00 m	11	1 ft	large irregular black flints, crowded together *in situ*, in the chalk; adhering to these flints are echini, terebratulae, inocerami, and belemnites
$\overline{4.88}$–$\overline{0.30}$ m	12	15 ft	chalk, excavated to the level of the river adjacent

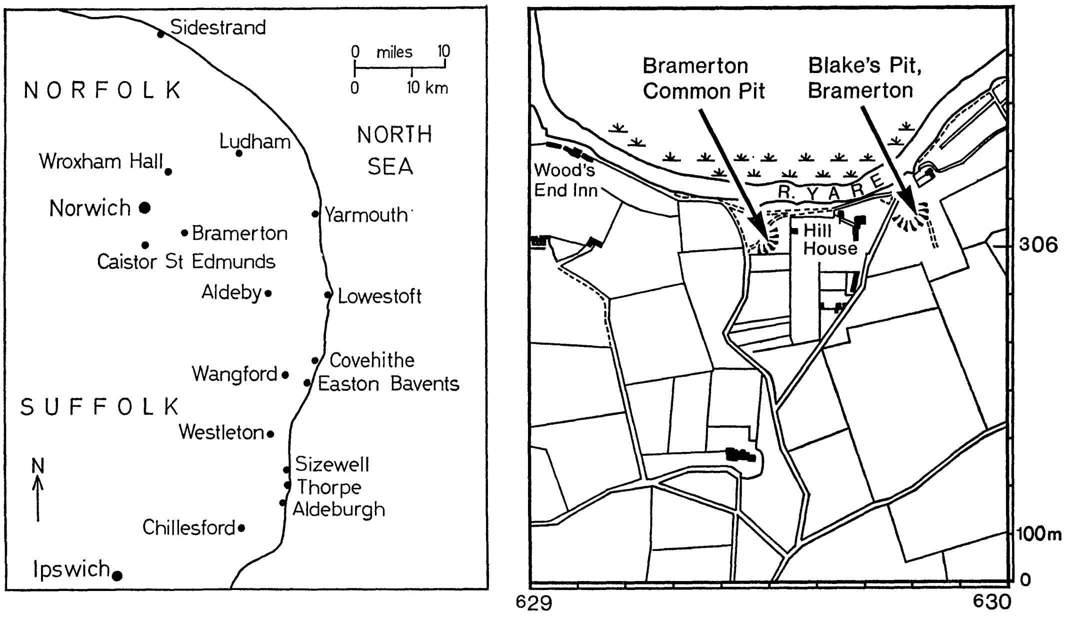

FIGURE 1. Maps of East Anglia showing the position of the Bramerton sites and of other crag sites.

Later descriptions of the Bramerton Common pit were published by Wood Jr (1865), Wood Jr & Harmer (1872) and Woodward (1881).

The section was re-excavated, described and sampled for foraminifers, molluscs and pollen in 1958 with the aid of a grant from the Gloyne Excavation Fund of the Geological Society of London (Funnell 1961 *a*, *b*). Norton (1967) described mollusc assemblages from the same samples.

Blake's Pit, Bramerton (TG 2982 0608), first had attention drawn to it by Reeve in 1870. It was noted, and the molluscs from it recorded separately, by Woodward (1881). It has been re-opened and sampled for pollen, molluscs and foraminifers several times in the last few years. It was first cleaned and sampled by Cambridge and his colleagues in 1974. Subsequently, P.E.P.N. recleaned the section and sampled it for molluscs and pollen in September 1975. In March 1977 a further series of pollen samples was taken, after again cleaning the section. The 1975 mollusc samples have also been examined for foraminifers.

The present paper provides new palaeontological data on the type Norwich Crag at Bramerton, integrating the first pollen diagram from this crag with the faunal succession of foraminifer and mollusc assemblages. This new data is collated with results of previous studies of the Bramerton faunas and the mollusc fauna of the Norwich district, with the object of providing a comprehensive account of the palaeontology and environmental history of the type Norwich Crag.

2. STRATIGRAPHY

Figure 2 summarizes the sections at Bramerton Common and Blake's Pit, showing also the positions of samples for analysis of foraminifers, molluscs and pollen.

(*a*) *Bramerton Common section*

This section has previously been briefly described and illustrated by Funnell (1961 *a*, *b*).

The full section, showing the positions of samples taken for examination of the molluscs and foraminifers, was as follows:

12.10–12.30 m		loamy sand passing up into sand, with soil above
11.55–12.10 m		brown silty clay
11.20–11.55 m		dark brown gravel with fragments of ferruginous concretions
11.15–11.20 m		black sand
9.75–11.15 m		light yellow fine sand with mica (*f*B19 at 10.60 m; *m* 170 cm at 10.60 m barren)†
9.70–9.75 m		pebbly sand
8.25–9.70 m		brown-grey clay, more grey towards the base where there are sandy partings; base undulating between 8.20 and 8.30 m (*m* 290 cm at 9.40 m barren)
7.60–8.25 m		yellow loamy sand with a clay band (20 mm thick) at 7.60 m (*f*B30 at 7.60 m barren; *m* 440 cm at 7.90 m barren)
7.45–7.60 m		black sand
7.35–7.45 m	upper shell bed	sand with shells
7.10–7.25 m		very shelly sands (*m* 500 cm at 7.30 m)
6.60–7.10 m		yellow sands: to the south, the upper part of the yellow sands was replaced by shelly sands with clay bands to 6.60 m. *Mya* is common as single valves at the base
6.40–6.60 m		yellowish sands with clay streaks at 6.40 and 6.50 m (*m* 580 cm at 6.50 m)
6.00–6.40 m		gradation to white sand complete at 6.25 m; clay layer at 6.00 m (*f*B78 at 6.10 m; *m* 620 cm at 6.10 m)
5.60–6.00 m		white sand
5.05–5.60 m		as above; shell fragments fairly common below 5.60 m; clay streak at 5.05 m (*m* 710 cm at 5.20 m)
4.65–5.05 m		as above; clay streak at 4.65 m (*m* 740 cm at 4.90 m)
3.90–4.65 m		as above (*f*B84 at 4.60 m)
3.45–3.90 m		as below; but more orange in colour (*m* 860 cm at 3.70 m)
2.50–3.45 m		pale whitish sand with discontinuous, horizontal orange bands with sporadic shell fragments (*f*B3 at 3.10 m; *m* 920 cm at 3.10 m)
2.40–2.50 m	lower shell bed	shelly crag (*m* 980 cm at 2.50 m)
2.25–2.40 m		brown clay bands, five or six in all, individual bands being up to 20 mm thick
1.50–2.25 m		shelly crag with small flints scattered throughout (*f*B6 at 1.60 m; *m* 1070 cm at 1.60 m)
1.15–1.50 m		whitish shelly crag
1.05–1.15 m		two bands of clay with orange-yellow crag on either side and in between; lower clay layer 20 mm thick, brown with tendency to a grey centre
0.75–1.05 m		white shelly crag, with more finely comminuted shells than above
0.70–0.75 m		two brown clay bands, each about 10 mm thick and separated by a similar amount of shelly crag
0.50–0.70 m		shelly crag with pebbles and stones (small rounded flint and quartz pebbles, *ca.* 10 mm diameter), overlying clay; beneath this are more pebbles, becoming increasingly large towards 0.50 m, and consisting of large sub-angular flints with common quartz pebbles (*m* 1160 cm at 0.70 m)
0.25–0.50 m		pale yellow sands
0.10–0.25 m		shelly crag
0.00–0.10 m		grey clay, 50 mm thick overlying basement flints or 100 mm thick in between; basement flints usually resting directly on the surface of the Chalk which is slightly irregular 0.00 to 0.05 m (*f*B15 at 0.10 m, *f*B14 at 0.05 m; *m* 1220 cm at 0.10 m)
		CHALK (surface at 3.3 m O.D.)

† *f*, *m* and *p* refer to foraminifer, mollusc and pollen samples respectively.

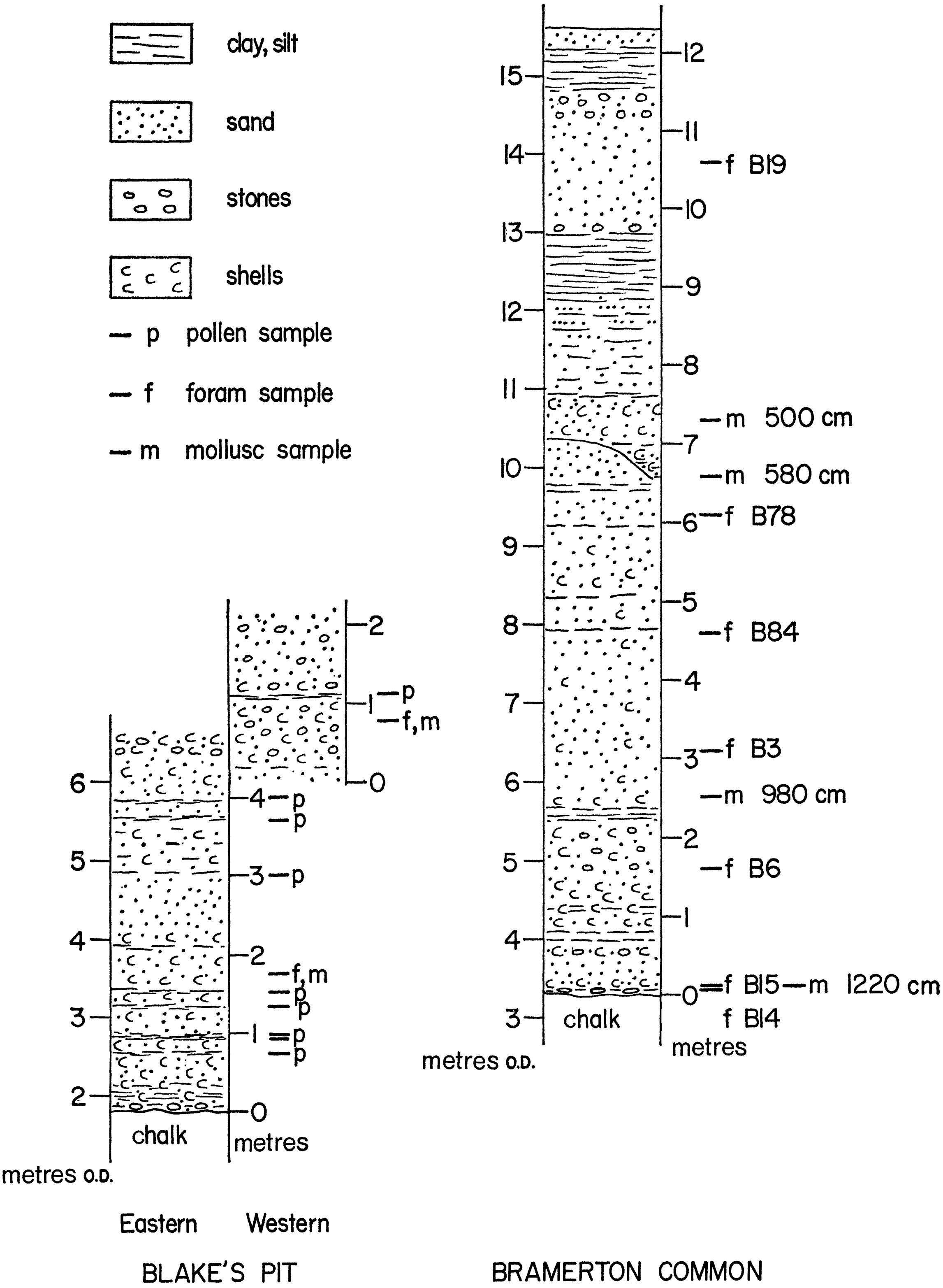

FIGURE 2. Crag stratigraphy at Bramerton Common and Blake's Pit.

(*b*) *Blake's Pit sections*

This section was dug in two parts, an upper western section and a lower eastern section, about 10 m apart.

Western section

1.30–2.30 m	brown, followed by buff stony loam going up into soil
0.50–1.30 m	grey or oxidized stony crag, shells forming a multilayered pavement, here and there interrupted by discontinuous sand or silty layers; brown silty clay seam at 1.10 m (5.30 m above Chalk) (*f* and *m* at 0.75–0.90 m = 4.95–5.10 m above Chalk; *p* at 110 cm)
0.30–0.50 m	brown sand with stones and shell fragments
0.00–0.30 m	brown loamy sand (0 cm appears to be equivalent to *ca.* 4.20 m of Eastern section)

Eastern section

4.51–4.81 m	upper shell bed: multilayered pavement of broken shells inclined about 18° E: bivalves on sides: some flat stones, gastropods
3.76–4.51 m	brown and buff loamy sand, with seams of silt (3.96 m); shell fragments in bands, forming lenses, elsewhere at 3.11–3.21 m; some pebbles above 4.46 m (*p* at 396 cm)
3.76 m	brown silty clay seam (*p*)
3.41–3.76 m	brown loamy sand with shell fragments, especially 3.46–3.56 m
3.01–3.41 m	buff sand, with inclined bedding; above 3.21 m, bedded brown and buff sand, inclined about 15° E
3.00–3.01 m	grey-brown silty clay with ferruginous boundaries (*p* at 300 cm)
2.22–3.00 m	buff sand
2.18–2.22 m	grey shelly sand
2.10–2.18 m	irregular brown silty sand
1.70–2.10 m	shelly sand with irregular bands of buff sand towards top (*f* and *m* at 1.70–1.80 m)
1.56–1.70 m	grey shelly sand
1.56 m	grey silty clay seam (*p*)
1.35–1.56 m	grey shelly sand
1.35 m	grey silty clay seam (*p*)
1.10–1.35 m	grey sand, shelly from 115 cm up
1.00–1.10 m	grey and brown mottled sand
0.98–1.00 m	grey silty clay (*p* at 98 cm, 100 cm)
0.65–0.98 m	grey shelly sand, silty clay seam at 75 cm (*p* at 75 cm)
0.30–0.65 m	grey and brown silty sand, occasional shells
0.25–0.30 m	grey-brown silty clay, shells
0.19–0.25 m	laminated grey-brown silty clay, bedding disturbed
0.12–0.19 m	grey-brown silty clay, shells
0.00–0.12 m	rounded flints in red-brown silty clay matrix, shells
	CHALK (surface at 1.8 m O.D.)

3. PALYNOLOGY AT BLAKE'S PIT

(*a*) *Pollen diagram*

Nine samples of silty clay within the sequence of shelly sands were found to contain pollen in quantity at the levels shown in the section description and pollen diagram (figure 3).

The pollen diagram is divisible into two pollen assemblage biozones (p.a.b.):

530 cm (110 cm)	*Pinus*–Ericales–Gramineae pollen assemblage biozone
75–400 cm	*Alnus*–*Quercus*–*Carpinus* pollen assemblage biozone

The characteristics of these biozones are as follows:

Alnus–Quercus–Carpinus p.a.b.

This biozone shows 76–86 % tree pollen (a.p.). Deciduous trees predominate, with the thermophilous genera *Quercus* and *Carpinus* well represented, accompanied by *Ulmus*, *Betula* and *Alnus*,

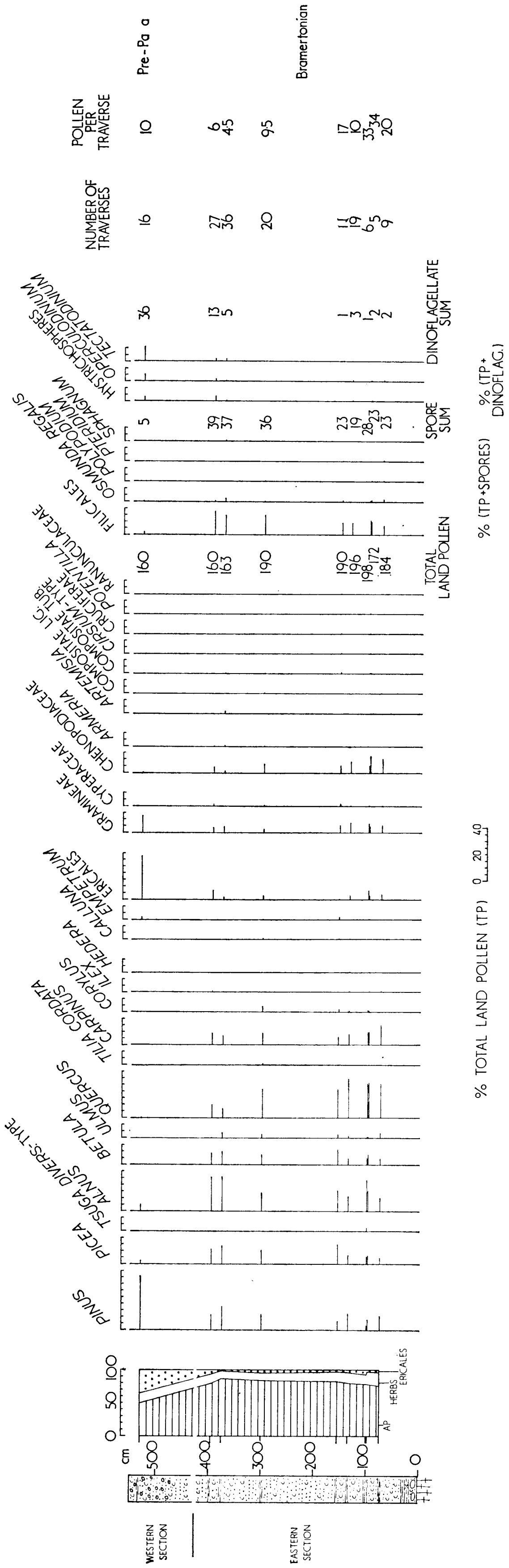

FIGURE 3. Pollen diagram from Blake's Pit.

and very low frequencies of *Tilia cordata*, *Corylus*, *Ilex* and *Hedera*. *Pinus* and *Picea* show lower frequencies (totalling 10–16 %) near the base of the biozone than in the upper part (totalling 21–32 %). A single grain of *Tsuga diversifolia* type occurred at 100 cm. Low frequencies of non-tree pollen (n.a.p.) are provided by the taxa Ericales, Gramineae and Chenopodiaceae, in that order of increasing frequency. *Calluna*, *Empetrum*, Cyperaceae, *Armeria*, *Artemisia*, Compositae, Cruciferae, *Potentilla* and Ranunculaceae pollen is recorded much more sparsely. The spores are predominantly Filicales, with low frequencies of *Osmunda regalis*, *Polypodium*, *Pteridium* and *Sphagnum*. Low (0.5–8 %) frequencies of dinoflagellate cysts are recorded in the biozone.

Pinus–Ericales–Gramineae p.a.b.

This single pollen spectrum shows a nearly equal representation of a.p. and n.a.p. The a.p. is mostly *Pinus* with low frequencies of *Picea* and *Alnus*. The n.a.p. is mostly Ericales and Gramineae, with low frequencies of pollen of *Empetrum*, Chenopodiaceae and Compositae. The low frequency of spores is composed mainly of Filicales, with *Osmunda regalis* occurring. Dinoflagellates (three taxa counted) are better represented (18 %) than in the lower biozone.

(*b*) *Taphonomy*

The sediments in the section are all of inshore marine origin. Pollen was recorded in sufficient quantities to count from silty clay seams within the sands, but not from the more massive silty clays at the base of the section above the Chalk. Bioturbation and weathering seen in these lowest sediments may account for this difference. The pollen assemblages are likely to be largely derived from an influx of pollen from the neighbouring basin via the river drainage, and must represent the flora and vegetation of a reasonably large area. Problems of differential transport and deposition at the time of the origin of the assemblages and of post-depositional changes from weathering in sandy marine sediments make for difficulties in interpretation of the assemblages. These difficulties have been summarized by West (1961) and discussed at a greater length by West (1979). In spite of these difficulties, the pollen assemblages seem to have a clear meaning in regional vegetation terms and to show a meaningful distinction between themselves.

(*c*) *Vegetational history*

Alnus–*Quercus*–*Carpinus* p.a.b.

This assemblage indicates regional temperate forest with *Quercus* and *Carpinus*. The relatively high Chenopodiaceae frequencies, with *Armeria*, are characteristic of the inshore marine environment. Otherwise n.a.p. taxa are poorly represented, which is surprising, since in river catchments n.a.p. is usually well represented by reason of the presence of herb communities in riverine situations.

Pinus–Ericales–Gramineae p.a.b.

This assemblage shows that an abrupt change in vegetation occurred in the sediments higher than 396 cm. There is no evidence for temperate forest, *Pinus* being very well represented, with *Picea* and *Alnus* less frequent. Such a change from the lower spectra is hardly likely to be produced by post-depositional changes such as weathering, since, if it were, *Picea* pollen is likely to have been as well represented as *Pinus*, as in the lower spectra. The frequencies of Ericales and Gramineae pollen, especially the former, have risen, and Chenopodiaceae pollen frequencies have fallen. These changes are consistent with a climatic deterioration causing a disappearance of temperate forest, and the opening of the forest and its partial replacement by heath and herbaceous communities.

(*d*) *Comparisons and correlations*

The vegetational history of the Blake's Pit section shows that the sediments belong to a part of a climatic cycle, a part extending from a temperate substage to a cold, perhaps 'early glacial', substage. In terms of the pollen assemblages, the *Alnus–Quercus–Carpinus* p.a.b. of the temperate substage is similar to assemblages from Pastonian II in the coastal pre-glacial sequence (West 1979), to the Lp 5† pollen assemblage biozone at Ludham (West 1961), and to the Chillesford pollen assemblage described by West & Norton (1974). In the latter paper, a tentative correlation of the Chillesford pollen assemblage with the Pastonian was made, but further work on the coastal pre-glacial sequence (West 1979) has indicated that the Chillesford pollen assemblage is very probably older than the Pastonian.

The *Pinus*–Ericales–Gramineae p.a.b. resembles in its high frequencies of *Pinus* and Ericales the pollen assemblages of the Lp 4c substage at Ludham (West 1961), 16.6 km to the northeast (see figure 1 for locations of correlated sites), and of the Pre-Pa *a* substage of the coastal pre-glacial sequence, as at Sidestrand (West 1979). In the latter work, Pre-Pa *a* is correlated to Lp 4c because of the similarity of the pollen assemblages. The assemblage differs from Lp 4b (Baventian) assemblages in its much higher frequencies of *Pinus*.

We may note that no *Pinus*–Ericales–Gramineae pollen assemblage has been recorded in a marine sediment later than the Pastonian in the coastal pre-glacial sequence. This suggests that the *Alnus–Quercus–Carpinus* p.a.b. may be older than Pre-Pa *a*, that is, it belongs to a temperate stage older than the Pastonian.

Since this pollen assemblage lacks the high frequencies of *Tsuga* found in the pre-Lp 4b substage at Ludham (Antian), and in the pre-Baventian marine sediments at Easton Bavents (Funnell & West 1962), it seems probable that we are dealing with a hitherto unknown temperate stage at Bramerton, one which may either intervene between Lp 4c and Lp 4b in the Ludham borehole, or be equivalent to Lp 5 in that borehole, and one which may also include those marine sediments of southeast Suffolk which contain the Chillesford pollen assemblage (at Chillesford, Aldeburgh, Thorpe Aldringham and Sizewell: see West & Norton 1974), and also the Westleton Beds of Hey (1967). The evidence justifies the erection of a new temperate stage, which may be termed the Bramertonian, with a type site at Blake's Pit giving evidence of molluscs, foraminifers and pollen. These correlations are shown in table 5.

4. FORAMINIFERA

(*a*) *Systematics*

Although the foraminiferal species found in the Bramerton Common section were fully listed by Funnell (1961*a*, *b*), they have not previously been described. With two exceptions, all the identifiable specimens can be allocated to living species of foraminifer, illustrations and

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[†] Faunal and flora biozones are presented according to the pattern: initial capital letter(s) indicates locality; lower case letter indicates biological group (f, foraminifers; m, molluscs; p, pollen), and arabic numeral indicating number of biozone.

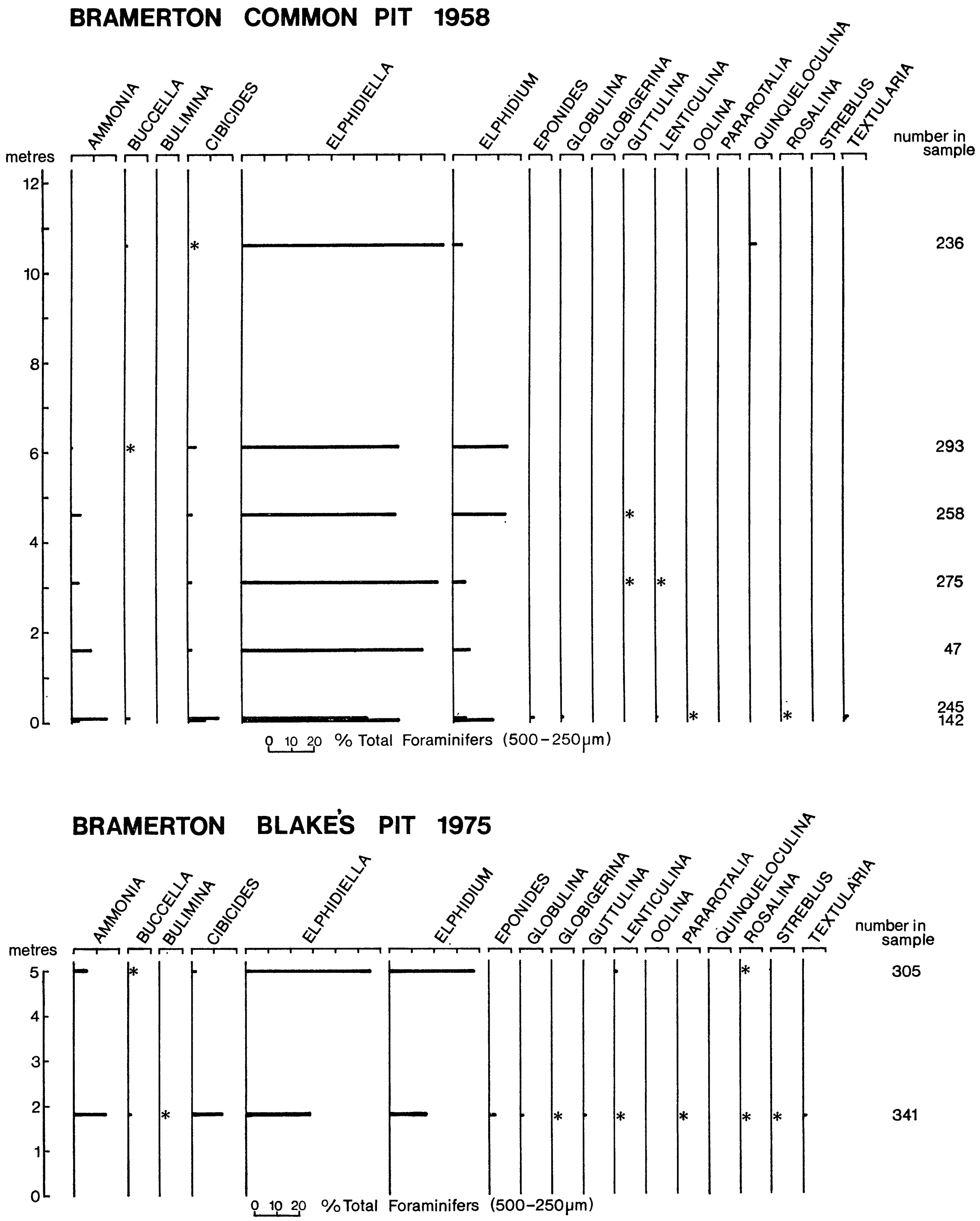

Figure 4. General composition of foraminiferal assemblages at Bramerton Common and Blake's Pit.

Table 1. Foraminifera from Bramerton

	Bramerton Common							Blake's Pit	
no. in sample ...	142	245	47	275	258	293	236	341	305
height in section (m) ...	0.05	0.10	1.60	3.10	4.60	6.10	10.60	1.70–1.80	4.95–5.10
sample no. ...	14	15	6	3	84	78	19		
Ammonia beccarii	4	16	9	4	5	1	—	14	6
Buccella frigida	—	—	—	—	—	—	0	0	—
B. inusitata	—	2	—	—	—	0	0	0	0
Bulimina sp.	—	—	—	—	—	—	—	0	—
Cibicides lobatulus	7	9	2	1	2	4	0	6	2
C. lobatulus var. *grossa*	—	2	—	—	—	—	—	1	—
C. pseudoungerianus	1	2	—	—	—	—	—	4	—
C. subhaidingerii	—	1	—	—	—	—	—	3	—
Cibicides sp.	—	—	—	1	—	—	—	—	—
Elphidiella hannai	70	56	81	88	69	70	90	47	56
E. crispum	—	1	—	—	—	—	—	0	0
E. excavatum clavatum	4	1	—	1	1	0	—	3	2
E. excavatum selseyense	—	1	—	0	1	—	—	0	0
E. frigidum	4	0	2	0	4	7	0	1	7
E. macellum var. *granulosum*	6	1	—	0	3	—	—	—	6
E. orbiculare	—	—	—	0	—	0	—	—	1
E. pseudolessonii	4	1	4	3	15	17	3	11	20
E. williamsoni	—	0	2	0	—	0	0	1	1
Eponides repandus	—	2	—	—	—	—	—	2	—
Globulina gibba	—	0	—	—	—	—	—	0	—
G. aff. *G. myristiformis*	—	0	—	—	—	—	—	0	—
Globigerina bulloides	—	—	—	—	—	—	—	0	—
Guttulina lactea	—	—	—	0	0	—	—	1	—
Lenticulina rotulata	—	1	—	0	—	—	—	0	1
O. williamsoni	—	0	—	—	—	—	—	—	—
Pararotalia serrata	—	—	—	—	—	—	—	0	—
Quinqueloculina seminulum	—	—	—	—	—	—	3	—	—
Rosalina parisiensis	—	0	—	—	—	—	—	0	0
Streblus perlucida	—	—	—	—	—	—	—	0	—
Textularia sagittula	1	1	—	—	—	—	—	1	—
T. cf. *T. truncata*	—	1	—	—	—	—	—	1	—

(0 indicates less than 0.5 %).

descriptions of which are available in the literature on modern forms. For the sake of necessary comparisons, however, we provide (in appendix I), systematic notes on the more common species occurring in the Bramerton sections.

(*b*) *Bramerton Common section*

Foraminifers from the Bramerton Common section have previously been listed by Funnell (1961*b*, pp. 352 *et seq.*). They are re-expressed here in figure 4 and table 1, in which the opportunity has been taken to up-date some of the original taxonomy.

The dominant species throughout is *Elphidiella hannai* (56–90 %). This is typical of inner sublittoral environments in the early Pleistocene of the southern North Sea.

At the base of the section (0.05 m) with *Elphidiella hannai* recording 70 %, the next most common species are *Cibicides lobatulus* (7 %) and *Elphidium macellum* var. *granulosum* (6 %), followed by *Ammonia beccarii*, *Elphidium excavatum*, *Elphidium frigidum* and *Elphidium pseudolessonii* (each at 4 %). These species suggest a shallow sublittoral or intertidal temperate environment.

They are accompanied by 1% each of *Cibicides pseudoungerianus* and *Textularia sagittula* of possibly more southern and deeper water affinities. In immediately overlying sediment (0.10 m) *Elphidiella hannai* is reduced to 56%, followed by *Ammonia beccarii* (16%), *Cibicides lobatulus* (9%), and a number of other species at 2% or less. These latter include *Elphidium macellum* var. *granulosum*, *Elphidium excavatum clavatum*, *Elphidium frigidum* and *Elphidium pseudolessonii* as seen in the underlying sample. They also include *Cibicides pseudoungerianus* and *Textularia sagittula* as seen in that sample, with, in addition to *Cibicides lobatulus* var. *grossa*, *Cibicides subhaidingeri*, *Elphidium crispum*, *Eponides repandus*, *Globulina* spp., *Lenticulina* sp., *Oolina* sp., *Rosalina parisiensis* and *Textularia* sp. All of these latter taxa are typical of most of the Red Crag and the Ludham Crag, and, taken together, give the impression of a warm temperate association. In the top sample from the lower shell bed (at 1.60 m) this warm temperate association is absent again, and an *Elphidiella hannai* (81%) dominated assemblage, followed by *Ammonia beccarii* (9%), *Elphidium pseudolessonii* (4%) and *Cibicides lobatulus*, *Elphidium excavatum selseyense* and *Elphidium frigidum* (each at 2%), reappears.

In the samples taken between the two shell beds, i.e. between 2.50 and 6.75 m, *Elphidiella hannai* maintains a high proportion (69–88%) followed initially by *Ammonia beccarii* (at 4%) and later by *Elphidium pseudolessonii* (at 15–17%). *Cibicides lobatulus*, *Elphidium excavatum clavatum*, and *Elphidium frigidum* continue to be consistently present at up to a few per cent of the assemblages. It is noticeable that the level of *Ammonia beccarii* is significantly lower between 4.60 and 6.10 m, and that *Elphidium pseudolessonii* is especially important at those two levels.

Well above the upper shell bed, at 10.60 m, a sample yielded a foraminiferal assemblage totally dominated by *Elphidiella hannai* (90%) accompanied by *Elphidium pseudolessonii* and *Quinqueloculina seminulum* (each 3%) and specimens of *Buccella frigida*, *Buccella inusitata*, *Cibicides lobatulus*, *Elphidium excavatum selseyense* and *Elphidium frigidum*.

(*c*) *Blake's Pit section*

Foraminifers from the Blake's Pit section have only recently been examined. The assemblages are also listed in figure 4 and table 1. They were examined from sub-samples of the samples obtained by Norton and examined by him for molluscs for the forthcoming Institute of Geological Science's Memoir on the Norwich district. These sub-samples were obtained in September 1975 from the lower sample (1.70–1.80 m above the base), and from the upper sample shell bed of the west section (at 4.95–5.10 m above the Chalk).

As far as the foraminifers are concerned, the lower sample is almost identical with sample B15 (at 0.10 m) taken from the Bramerton Common section, and the upper sample compares well with the B84 (at 4.60 m) and B78 (at 6.10 m) samples from the Bramerton Common section.

(*d*) *Comparisons and correlations*

The foraminiferal assemblages of the Bramerton sections are clearly of a post-Red Crag, post-Ludham Crag aspect overall. *Elphidiella hannai* dominates the 500–250 μm fraction (47–90%), and diversities are low (generally 8–14 species in counts of more than 100).

Secondly, there is clear evidence of climatic deterioration in the sections from the bottom upwards. This is mainly seen in the reduction and eventual elimination of *Ammonia beccarii*, together with the rise in dominance of *E. hannai* and overall reduction of diversity.

Detailed correlation with other Norwich Crag formation localities (figure 1) is not easily achieved on the basis of the foraminifers. There is nothing to preclude correlation of the lower part of the Bramerton sections with the Chillesford Crag, the crag of Thorpe Aldringham, Sizewell (Rifle Range), Easton Bavents or the Lf 3 (≡ Lp 1b) or Lf 5 (≡ Lp 3) assemblage biozones of Ludham. All reflect temperature conditions not dissimilar to those of the present day.

The increase in *Elphidium pseudolessonii*, with concomitant high *E. hannai* and reduced *A. beccarii*, in the 4.60 and 6.10 m levels of the Common pit and the 4.95–5.00 m level of Blake's Pit, resemble the Lf 4 (≡ Lp 2) assemblage biozone at Ludham, except that *Elphidium haagensis* does not feature at Bramerton. The upper part of the Bramerton sections (more closely resembles the Lf 6 (≡ Lp 4b) and Lf 7 (≡ Lp 4c) assemblage biozones of Ludham, where the Arctic forms *Elphidium orbiculare* and *Elphidium bartletti*, almost totally replace *pseudolessonii* as the characteristic *Elphidium* species, as in the crag at Sidestrand.

A point of particular interest at the 0.10 m level in the Common pit and at the 1.70–1.80 m level in Blake's pit is the occurrence of numerous species such as *Cibicides pseudoungerianus*, *C. subhaidingerii*, *Eponides repandus*, *Globulina* aff. *myristiformis*, agglutinating species other than *Textularia sagittula*, and *Pararotalia serrata*, which are characteristic of the Red Crag and the Ludham Crag and do not occur elsewhere in the Norwich Crag formation. These species are likewise accompanied by spines of both regular and irregular echinoids and bryozoans, as in the Red Crag and the Ludham Crag. It is almost impossible to resolve whether these species are from a contemporary deeper water facies or are totally derived. They could represent a resurgence of Lusitanian influences during the temperate period represented in the lower part of the Bramerton sections, but, as some of the specimens have their chambers infilled with glauconite, a derivative origin seems more likely.

A definitive conclusion on the correlation of the Bramerton sections based on the foraminifers is therefore not available. Funnell (1961*b*) suggested a correlation of the lower part of the Common section with the Lf 5 (≡ Lp 3) assemblage biozone, and of the upper part with the Lf 6 (≡ Lp 4b) and Lf 7 (≡ Lp 4c) assemblage biozones of Ludham. Although such a correlation is still possible, an earlier Lf 2/3 (≡ Lp 1a/b) to Lf 4 (≡ Lp 2) equation is not completely ruled out, and a later post-Lf 7 (≡ Lp 5) age is also quite possible. Unfortunately, facies control of Norwich Crag foraminiferal assemblages leads to recurrent patterns and it is not yet possible to identify reliably any distinctive features in the faunas that characterize individual temperate or cold periods in the early Pleistocene succession. It is possible that better knowledge of the range (in relation to the pollen sequence) of certain species, especially among the Elphidiidae, will enable such distinctions to be made in the future (see also §7 (*d*) (iii)).

5. Mollusca

The crags of the Norwich district, including the one at Bramerton, though rich in Mollusca, have been regarded as containing fewer species than the crags to the south. Many 19th century collectors contributed to monographs of the crag Mollusca (Wood 1848–79; Harmer 1914–25), but there is no recent assessment of their work. The synoptical table, table 2, lists records of the Mollusca of the crag of the Norwich district, following re-examination of available museum collections, and specifies which records are only in literature and which are supported by specimens. Table 2 thus includes recent work as well as acting as a guide to the 19th century collectors and the specimens preserved by them. In this previous work there was a tendency to overspecification (particularly in the work of Harmer), and towards description of species and varieties on the basis of unique specimens, some of which would nowadays be regarded merely as monstrosities. Frequencies ('very common', 'not rare', 'very rare' etc.) were often ascribed. Attempts were made to describe the palaeoecological conditions represented by the Mollusca, e.g. the lower shell bed fauna at Bramerton Common was described as 'Fluviomarine' and the upper shell bed as 'more northern and deeper water'.

In the last century Reid (1890) suggested some correlations, e.g. between the clay unit (Woodward 1881, unit 3) at Bramerton Common and the 'Chillesford Clay' (vigorously opposed by Woodward) and between the pebbly and shelly 'Bure Valley Beds' (said to contain *Macoma balthica*), the 'Weybourne Crag' and the 'Pebbly Beds' of the Norwich district (Woodward 1881, unit 4). The more recent studies of the crag of the Norwich district have not up to now yielded pollen, and as correlations have not been firmly established from Mollusca or Foraminifera, it has remained impossible to test these earlier correlations and this difficulty has been compounded by lack of a clear understanding of the extent and composition of the stratigraphical units mentioned above. The discovery of pollen in the sediments of the Blake's Pit section has, however, now made it possible to suggest the correlations detailed elsewhere in this paper, and it is timely to reassess the palaeoecological evidence from Norwich Crag assemblages as a whole.

Mollusca from the Bramerton sections are listed in table 2 and abstracted in table 3. These tables also contain results from Wroxham Hall, a site described in appendix II. The positions of the samples analysed for molluscs are shown in figure 2 and §2.

(*a*) *Bramerton Common section*

The following summarizes the account by Norton (1967).

(i) 1220 cm sample (at 0.10 m, lower part of 'lower shell bed'). *Abra alba* 46 %, *Calyptraea chinensis* 18 %, *Hydrobia ulvae* 8 %, *Mytilus edulis* 4 %. The assemblage appears to reflect inner sublittoral marine conditions. The shells were not deposited *in situ*. *Abra alba* indicates presence of a silty seabed, *Calyptraea chinensis* the presence of rocks and silt in the sublittoral. *Hydrobia ulvae* suggests the presence of a brackish or wadden-area type intertidal province. *Mytilus edulis* and *Littorina littorea* would also exist in those intertidal conditions.

(ii) 980 cm sample (at 2.50 m, upper part of 'lower shell bed'). *Hydrobia ulvae* probably 58 %, *Cerastoderma edule* 16 %, *Macoma* sp. 8 %. The assemblage appears to reflect brackish-water estuarine or wadden-area conditions with silty sand containing *Cylichna* and *Cerastoderma edule* and some stones supporting groups of *Littorina littorea* and *Thais lapillus*. The 19th century 'fluviomarine' concept was apparently sound.

(iii) 580 cm sample (at 6.50 m, lower part of 'upper shell bed'). *Cerastoderma edule* 16 %, *Macoma* sp. 23 %, *Macoma calcarea* 13 %, *M. obliqua* 9 %, *M. praetenuis* 7 %, *Mya arenaria* 5 %, *Spisula subtruncata* 4 %. Inner sublittoral and littoral conditions are almost equally suggested by this assemblage. The littoral conditions were apparently sandy and silty with no exclusively brackish-water species. By comparison with the 'wadden-area' facies interpreted from the 980 cm sample, we appear to have open-coast conditions here. The sublittoral appears to have been a region of muddy sand, with stones or algae supporting *Hiatella arctica*. That the infaunal *Macoma calcarea*, which today occurs in muddy sand and is a subarctic species, is found here together with *Yoldia* (2 %) suggests that conditions were colder by the time this sample was deposited. The 19th century collectors also thought that the fauna of this bed represented colder climatic conditions.

TABLE 2. SYNOPTICAL TABLE OF MOLLUSCA OF THE CRAG OF THE NORWICH DISTRICT

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
GASTROPODA																		
Patella vulgata L.	vr	—	—	—	—	—	—	—	N	—	—	—	—	—	—	—	—	—
Patina pellucida (L.) ?	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	? *acmaea* sp.
Acmaea virginea (Müller)	vr	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
A. parvula Woodward	—	—	—	—	—	H	—	—	N	—	—	—	—	—	—	—	—	—
Calliostoma zizyphinum L.	—	—	—	—	vr	H	—	—	—	—	—	—	—	—	—	—	—	! *Calliostoma* sp. Reeve Colln
Eumargarita groenlandica (Martini & Chemnitz)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Gibbula tumida Montagu	r	r	—	—	r	H	—	—	N	—	—	M	M	M	—	—	—	—
G. conuloides Lamarck	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
G. occidentalis Mighels & Adams	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
G. noduliferens (S. Wood)	M	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Viviparus medius (Woodward)	vr	—	—	—	—	H	—	X	H	—	H	—	M	M	—	—	—	—
V. glacialis (Wood)	—	—	—	—	—	—	—	—	—	H	M	—	—	—	M	—	M	—
Valvata piscinalis (Müller)	X	[vr]	—	—	P	H	—	—	—	—	—	—	—	—	—	—	—	—
V. cristata (Müller)	[vr]	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
V. leucostoma	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Littorina littorea L. + vars	vc	[c]	—	X	vc	H	X	M	N	M	M	N	M	M	—	N	R	! Monstrosities, N.C.M. type Colln
L. rudis Maton + vars	r	—	—	—	r	H	—	M	H	M	H	—	—	M	—	P	M	—
L. obtusata L.	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Lacuna crassior Montagu	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
L. vincta Montagu	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
L. divaricata Fabricius	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Hydrobia stagnalis Basterot	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
H. ulvae Pennant + vars:	vc	—	—	—	P	H	X	H	—	—	—	—	—	—	—	—	—	—
‘*subumbilicata*’	[vc]	[r]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
‘*ventrosa*’	[r]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
‘*minuta*’	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
‘*obtusa*’	—	—	X	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
H. reevei Kennard & Woodward	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
H. pendula (Wood)	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—
Bithynia tentaculata (L.)	vr	—	—	—	vr	H	—	—	—	—	—	—	—	—	—	—	—	—
Rissoa striata Adams	vr	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
R. obsoleta Wood	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
R. curticostata Wood	vr	—	—	—	P	H	X	—	—	—	—	—	—	—	—	—	—	(*semicostata* Woodward auctt.)
Cingula semicostata (Montago)	—	—	—	—	P	—	X	—	—	—	—	—	—	—	—	—	—	—
Assiminea grayana Leach	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—	—	—	—
Turritella incrassata Sowerby	c	M	—	—	c	H	—	M	N	—	—	—	M	M	—	—	—	—
T. terebra Wood	c	M	—	—	c	—	—	M	M	—	—	M	M	M	—	—	—	—
T. communis Risso	—	—	—	(*)	—	H	—	—	I	—	—	—	—	—	—	—	—	—
Caecum mammilatum Wood	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
C. glabrum Montagu	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—

TABLE 2 (*cont.*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
GASTROPODA (*cont.*)																		
Scalaria groenlandica Chemnitz	c	r	—	—	X	H	—	M	M	M	M	—	—	—	M	M	—	—
S. similis Sowerby	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	N	—	—
S. clathratulus minutus Sowerby	—	—	—	—	P	—	—	—	H	—	—	—	—	M	—	—	—	—
S. trevelyana Leach	[r]	—	—	—	—	H	—	—	N	—	—	—	M	M	—	—	—	—
S. trevelyana var. *cragtrevelyana* Sacco	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
S. aldebiana Sacco	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Eulima polita (L.)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Capulus ungaricus L.	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Calyptraea chinensis L.	r	—	—	—	P	H	X	M	—	—	—	M	—	—	—	—	—	—
Natica clausa Broderip & Sowerby	c	r	—	—	P	—	—	—	N	—	M	M	M	M	M	P	—	—
N. affinis (Gmelin)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. groenlandica Wood	vr	—	—	—	—	—	—	N	—	—	—	—	M	—	—	—	—	—
N. catena (da Costa)	vc	c	—	—	c	H	—	(*)	M	M	M	M	—	—	—	M	H	—
N. hemiclausa (Sowerby)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. helicoides Wood	vr	vr	—	—	X	—	—	—	—	M	M	M	—	—	—	—	M	[? = *Amauropsis islandica* (Gmelin)]
Amauropsis islandica (Gmelin)	—	—	—	—	—	H	—	—	H	—	H	—	—	—	—	—	—	—
Velutina undata Brown	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
V. laevigata Pennant	vr	—	—	—	—	H	—	H	H	—	—	—	—	—	—	—	—	—
Erato laevis Donovan	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Trivia europaea (Montagu)	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—
Cassidaria bicatenata (Sowerby)	M	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Ovula spelta (L.)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Trophon actoni Wood	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
T. clathratus (L.)	—	—	—	—	—	H	—	—	H	—	—	—	—	—	—	—	—	—
T. clathratus var. *gunneri* Lovén	—	—	—	—	—	H	—	—	H	—	—	—	—	—	—	—	—	—
T. scalariformis Wood	M	—	—	—	r	—	—	M	—	—	—	—	—	—	—	—	—	(? = *T. clathratus*)
T. altus Wood	M	—	—	—	—	—	—	M	M	—	—	—	—	—	—	—	—	—
Cerithiopsis tuberculatus (Montagu)	vr	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Potamides tricinctus Brocchi var. *icenica* Harmer	c	c	—	—	P	H	X	M	N	—	M	M	—	—	—	—	—	—
Bittium reticulatum (da Costa)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. reevei (Harmer)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
C. greeni (=? *C. reevei* Wood)	—	—	X	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Cerithium derivatum Wood	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Thais lapillus (L.) & vars (! monstrosities)	vc	c	X	—	P	H	X	M	N	N	—	N	M	—	—	R	I	—
Ocinebra erycinacea (L.)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
O. tortuosa (J. Sowerby)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Volutopsius norvegica Chemnitz	—	—	—	—	—	H	—	—	H	—	—	—	—	—	—	—	—	—
Liomesus dalei (J. Sowerby)	—	—	—	—	—	H	—	N	—	—	—	—	—	—	—	—	—	—
Sipho gracilis de Costa	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—

S. tortuosus Reeve	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Neptunea antiqua L.	c	N	—	—	—	H	X	N	N	N	M	N	—	M	M	M	M	—
N. antiqua var. *subtornata* Harmer	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. antiqua var. *striata* Wood	—	—	X	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. antiqua var. *carinatus contortus*	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. ambigua var. *ornatus*	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
N. despecto L.	—	X	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. despecto var. *curtispira*: also nine	—	—	X	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
other 'varieties' *q.q.v.* Harmer	—	—	X	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. ignota Harmer	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	unique
N. contraria L.	M	M	—	—	—	—	—	M	M	—	M	—	—	M	M	M	M	—
Buccinum undatum L.	nc	c	—	—	nc	—	—	N	M	N	M	—	M	—	—	—	M	—
B. undatum var. *coerulea* Sars	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. meridionale Harmer var. *icenica* Harmer	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. groenlandicum Chemnitz	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Nassarius reticosus (Sowerby)	—	—	—	—	—	—	—	H	H	—	—	—	—	—	—	—	—	—
N. incrassatus Ström	r	[vr]	—	—	r	H	—	—	M	—	—	—	—	—	—	—	—	—
N. pusillinus (Wood)	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. propinquus (Sowerby)	vr	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
N. cuvieri Jeffreys	—	—	—	—	r	—	—	—	—	—	—	M	—	—	—	—	—	(? = *N. pusillinus* Wood)
Voluta lamberti J. Sowerby (?)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Admete viridula (Fabricius)	vr	—	—	—	—	H	—	H	—	—	—	—	—	—	—	—	—	—
Haedropleura rufa (Montagu)	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—
Bela pyramidalis Ström var. *semiplicata* Sars	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. bicarinata (Couthouy)	vr	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
B. trevelyana (Turton)	—	vr	—	—	vr	H	—	—	N	—	M	—	—	—	—	—	—	(? = *B. borealis* Reeve)
B. turricula (Montagu)	[r]	—	—	N	r	H	—	—	N	—	M	—	—	—	—	—	—	—
B. exarata (Müller)	—	—	—	X	—	H	—	H	—	—	—	—	—	—	—	—	—	—
B. rugulata Troschel var. *bergensis* Friele	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. decussata Couthouy var. *conoidea* Sars	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. mitrula (Louén)	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
B. scalaris (Müller)	—	—	—	—	—	H	—	H	H	—	—	—	—	—	—	—	—	—
B. violacea (Mighels)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Philbertia linearis (Montagu)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Actaeon tornatilis (L.)	r	—	—	C	vr	H	—	M	—	—	H	M	—	—	—	—	—	—
A. noae Sowerby	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—	—
Ringicula ventricosa (Sowerby)	r	vr	—	—	vr	H	—	—	—	—	—	M	—	—	—	—	—	—
Cylichna alba Kanmacher	[r]	vr	—	—	P	H	X	M	H	—	—	—	—	—	—	—	—	(*C. obtusa*, *C. regulbiensis* auctt.)
C. cylindracea (Pennant)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Utriculus lajonkaireanus Basterot	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Odostomia reevei (Wood)	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 2 (*cont.*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
GASTROPODA (*cont.*)																		
O. conoidea Brocchi	vr	—	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	—
O. (*?*) *derivata* (Wood)	—	—	X	—	—	—	—	—	—	—	—	—	M	—	—	—	—	—
O. plicata (Montagu)	—	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Turbonilla internodula (Wood)	vr	—	—	—	vr	H	—	—	—	—	—	—	M	—	—	—	—	—
T. internodula var. *conica* Harmer	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
T. internodula var. *ligata* (Reeve)	—	—	X	I	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Menestho derivata Wood	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Leuconia fusiformis (A. Bell)	—	—	—	—	—	H	—	H	—	—	—	—	—	—	—	—	—	—
Alexia myosotis (Drapernaud)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
A. reevei Harmer	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Carychium minimum Müller	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Melampus pyramidalis (Sowerby)	—	—	—	—	r	H	—	H	N	—	—	M	—	—	M	N	—	—
Limnaea palustris (Müller)	vr	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	M	—
L. palustris var. *butleyensis* Kennard & Woodward	—	—	—	—	c	H	—	—	H	H	—	—	—	—	—	—	—	—
L. auricularia L.	N	—	X	—	—	H	—	—	—	—	—	—	—	—	—	—	—	(? = *L. peregra*)
L. harmeri Kennard & Woodward	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
L. peregra (Müller)	—	—	—	—	X	H	—	—	—	—	M	—	—	—	—	—	—	—
L. woodi Kennard & Woodward	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Acroloxus lacustris (L.)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Aghardia edentulum (Draparnaud)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Planorbis spirorbis (Müller)	vr	—	—	—	vr	H	—	—	—	—	M	—	—	—	—	—	—	—
P. ?complanatus	—	—	—	—	vr	—	—	—	—	—	—	—	—	—	—	—	—	—
P. praecursor Kennard & Woodward	—	—	—	—	—	H	—	—	—	H	—	—	—	—	—	—	—	—
Pupa marginata	—	—	—	—	vr	—	—	—	—	—	—	—	—	—	—	—	—	(? = *P. edentula* Draparnaud)
Jaminia muscorum (L.)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
J. cylindracea (Da Costa)	—	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Succinea elegans Müller	—	—	—	—	—	—	—	—	—	H	—	—	—	—	—	—	—	—
S. oblonga Draparnaud	—	—	—	—	vr	H	—	—	—	M	—	—	—	—	—	—	—	(? = *S. putris*)
Vallonia pulchella (Müller)	vr	—	—	—	—	H	—	—	—	—	—	—	—	—	—	—	—	—
Trichia hispida L.	vr	—	—	—	nr	H	—	—	H	R	H	—	—	—	—	P	—	—
Helicigona arbustorum (L.)	—	—	—	—	—	—	—	(*)	—	H	—	—	—	—	—	—	—	—
BIVALVIA																		
Acila cobboldiae Sowerby	nc	[r]	—	nr	—	W	—	M	W	M	M	R	—	—	—	M	M	—
Nucula nucleus L.	—	M	—	—	P	—	—	—	—	—	—	—	—	—	—	—	—	—
N. tenuis Montagu	r	r	—	—	M	W	—	N	—	—	—	M	—	—	—	M	—	—
Leda pernula Müller	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—	—
Yoldia myalis Couthouy	c	c	—	—	c	W	X	W	M	M	M	R	—	—	M	M	M	(! = *Y. oblongoides* Wood)
Y. lanceolata Sowerby	vr	—	—	—	vr	W	—	—	—	—	—	—	—	—	—	—	—	—
Glycymeris glycymeris variabilis L.	vr	—	—	—	nr	W	—	—	N	—	—	—	M	M	—	—	—	—

Mytilus edulis L.	vc	[vc]	—	—	vc	W	X	M	N	M	M	N	M	M	—	M	N	—
Modiolus modiolus L.	—	—	—	—	—	—	—	W	M	—	—	M	—	M	—	—	—	—
Pecten princeps var. *pseudoprinceps* Wood	M	—	—	—	—	W	—	—	M	—	—	—	—	—	—	—	—	—
Chlamys opercularis L.	vr	r	—	—	M	W	X	—	N	M	—	N	—	M	—	N	—	—
C. tigerinus Müller	—	vr	—	—	—	—	—	—	—	—	—	—	—	—	—	R	—	—
C. pusio Pennant	—	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Hinnites cortessi Defrance	—	—	—	—	—	—	—	—	W	—	—	—	—	—	—	—	—	—
Ostrea edulis L.	M	—	—	—	—	W	—	—	W	—	—	—	—	—	—	—	—	—
Anomia ephippium L. (incl. var. *aculeata* Müller)	r	c	—	—	c	W	—	N	—	—	—	M	—	—	—	M	—	—
A. patelliformis L.	r	[r]	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—
A. squamula L.	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Astarte burtinea de la Jonkaire	M	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—
A. montagui Dillwyn	r	c	—	—	nc	W	X	—	W	M	M	R	—	M	—	M	R	(! = *A. compressa*)
A. semisulcata Leach	r	c	—	—	—	W	—	M	(*)	N	M	R	—	M	M	N	N	(! = *A. borealis* Chemnitz, auctt.)
A. sulcata de Costa	[r]	r	—	—	—	W	—	M	M	—	—	M	—	M	—	—	—	—
A. elliptica Brown	M	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—
A. omalii de la Jonkaire	M	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—
A. galeotti Nyst	—	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Sphaerium corneum (L.)	vr	—	—	—	—	H	—	—	N	—	—	—	—	—	—	—	—	—
Pisidium supinum Schmidt	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
P. casertanum (Poii)	—	—	—	X	—	H	—	—	—	—	—	—	—	—	—	—	—	—
P. pusillinum Turton	[vr]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
P. amnicum (Müller)	vr	—	X	—	—	H	—	—	N	—	—	—	—	—	—	—	—	—
P. astartoides Sandberger	—	—	X	—	—	H	—	—	H	—	—	—	—	—	—	—	—	—
Cyrena consobrina Caillaud	—	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	(? = *Corbicula fluminalis* Müller)
Corbicula fluminalis Müller	—	—	—	—	—	H	—	H	M	M	—	—	—	—	—	—	R	—
Arctica islandica L.	c	[c]	—	—	N	—	—	M	N	N	M	N	—	M	M	N	N	—
Diplodonta astartea Nyst	M	—	—	—	vr	W	—	—	N	—	—	—	—	—	—	—	—	—
D. dilatata Wood	—	—	—	—	—	—	—	—	M	—	—	—	—	—	—	—	—	—
Lucinoma borealis (L.)	r	c	—	—	vc	W	—	W	W	M	M	M	M	M	—	M	M	—
Divaricella divaricata (L.)	[r]	—	—	—	nr	W	—	—	W	—	—	M	—	—	—	—	—	(? = *D. juttingae* Spaink)
D. juttingae Spaink	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Lepton nitidum Turton	r	—	—	—	P	W	X	—	—	—	—	—	—	—	—	—	—	—
Mysella bidentata Montagu	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Kellia pumila Montagu	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Cerastoderma edule (L.)	vc	vc	—	—	vc	W	X	M	N	N	N	M	M	M	M	N	R	—
Cardium angustatum Sowerby	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	M	—
Serripes groenlandicus Brugière	[vr]	[r]	—	—	r	—	—	—	M	—	—	—	M	M	—	—	M	—
Parvicardium scabrum Montagu	—	—	—	—	—	—	X	—	—	—	—	—	—	—	—	—	—	—
Cardium parkinsoni Sowerby	—	—	—	—	—	—	—	—	W	—	—	—	—	—	—	—	—	—
Venerupis aurea (Gmelin)	M	—	—	—	X	W	—	—	—	—	—	—	—	—	—	—	—	—
V. virgineus Maton & Rackett	—	—	—	—	X	W	—	—	—	—	—	—	—	—	—	—	—	—
Venus fasciata da Costa	r	—	—	—	nr	W	X	—	(*)	—	—	—	—	—	—	P	—	—

TABLE 2 (*cont.*)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
BIVALVIA (*cont.*)																		
Spisula elliptica Brown	vr	r	—	—	c	W	—	(*)	M	M	M	N	M	—	M	—	M	(! = *S. ovalis* auctt. partim)
S. subtruncata (da Costa)	vc	[c]	—	—	P	W	X	(*)	(*)	—	—	M	—	—	—	M	—	—
S. solida (L.)	vc	c	—	—	M	W	—	—	M	—	—	M	—	—	—	M	—	—
S. arcuata Sowerby	—	—	—	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—
Mactra stultorum L.	[vr]	—	—	—	—	W	—	M	—	—	—	—	—	—	—	—	—	(? = *M. corallina* Wood)
M. corallina L.	[vr]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	(‘*M. corallina* L.’ Wood)
Siliquaria parva Speyer	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scrobicularia plana (da Costa)	vr	vr	—	vc	W	—	—	—	M	—	M	—	—	—	—	—	M	—
Abra alba (Wood)	M	M	—	—	P	—	X	—	W	—	—	M	M	—	—	—	—	—
A. obovalis (Wood)	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—	—
A. prismatica (Montagu)	—	—	—	—	—	—	—	—	—	—	—	R	—	—	—	—	—	—
Macoma calcarea (Chemnitz)	M	c	—	—	vc	W	X	M	M	M	M	M	—	M	M	M	M	(! = *M. lata* auctt.)
M. praetenuis Leathes	[vc]	c	—	—	vc	W	X	N	N	N	M	N	M	—	M	N	M	—
M. obliqua Sowerby	vc	vc	—	—	vc	—	X	M	N	N	R	R	M	M	M	N	R	—
M. balthica L.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	N	N	N	(! many specimens *M. praetenuis* etc.)
Tellina fabula (Gronovius)	M	—	—	—	vr	vr	—	—	—	—	M	—	—	—	—	—	—	—
T. crassa Pennant	M	—	—	—	—	—	—	(*)	W	—	—	—	—	M	—	—	—	—
Donax vittatus (da Costa)	[vr]	—	—	—	P	W	—	M	—	—	M	—	—	—	—	P	M	—
Ensis siliqua (L.)	r	—	—	—	r	W	—	—	M	—	—	N	—	—	—	—	—	—
Hiatella arctica L.	r	M	—	—	r	W	X	—	N	—	—	—	—	—	—	P	M	—
Panopaea norvegica Spengler	M	—	—	—	—	W	—	—	—	—	—	—	—	—	—	—	—	—
Mya arenaria (L.)	c	[c]	—	—	vc	W	X	N	N	N	M	M	M	M	M	N	N	—
M. truncata L.	c	—	—	—	P	—	X	M	—	—	M	M	—	—	—	—	—	—
Corbula gibba Olivi	r	c	—	—	nr	—	—	—	M	M	N	—	—	M	M	—	R	—
C. contracta (?) Say	[vr]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	P	—	—
Zirfaea crispata (L.)	M	M	—	—	—	—	—	M	—	—	—	—	—	M	—	—	M	—
Thracia papyracea Solander	vr	M	—	—	—	—	—	—	—	—	—	M	—	—	—	—	—	—

Explanation of synoptical table

Bramerton	Bramerton	Bramerton	Bramerton	Bramerton	Bramerton	Bramerton													
Common Pit	Common Pit	Common Pit	Common Pit																
(1) 'lower bed'	(2) 'upper bed'	(3) 'lower bed'	(4) bed unrecorded	(5) Blake's Pit	(6) Pit unspecified	(7) Common Pit	(8) Postwick	(9) Thorpe by Norwich	(10) Coltishall	(11) Horstead	(12) Brundall	(13) Kirby Bedon	(14) Whitlingham	(15) Rackheath	(16) Wroxham	(17) Belaugh			note
vc	vc	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	very common	Reeve Colln; Norwich Castle Museum (incl. Reeve material donated to I.G.S. London)	2
c	c	—	—	c	—	—	—	—	—	—	—	—	—	—	—	—	common		
nc	nc	—	—	nc	—	—	—	—	—	—	—	—	—	—	—	—	not common (nr not rare)		
r	r	—	—	r	—	—	—	—	—	—	—	—	—	—	—	—	rare (nu not uncommon)		
vr	vr	—	—	vr	—	—	—	—	—	—	—	—	—	—	—	—	very rare		
X	X	—	—	X	—	—	—	—	—	—	—	—	—	—	—	—	present		
[ ]	[ ]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	[ ] I.G.S. London only: frequencies as above		
—	—	—	—	—	—	—	—	—	R	R	R	—	—	—	R	R	Reeve Colln other sites than above		
—	—	X	X	—	—	—	—	—	—	—	—	—	—	—	—	—	type and figured collection		
N	N	—	N	N	—	—	N	—	N	N	N	—	—	—	N	N	collns other than above (if additional)		
—	—	—	(*)	—	—	—	(*)	(*)	—	—	—	—	—	—	—	—	I.G.S. London collns other than above (where additional)		4
—	—	—	—	—	H	—	H	H	H	H	—	—	—	—	—	H	Harmer 'Pliocene Mollusca' (where additional excl. col. 6)		3
—	—	—	—	—	W	—	W	W	—	—	—	—	—	—	—	—	Wood 'Crag Mollusca' (excl. where repeated in Harmer, Woodward)		
M	M	—	—	M	M	—	M	M	M	M	M	M	M	M	M	M	Woodward (1881) *q.v.* frequencies		1
—	—	—	—	P	—	X	—	—	—	—	—	—	—	—	P	—	Norton (1967) and herein where additional *q.v.* levels and frequencies. Specimens preserved		
—	—	—	I	—	—	—	—	I	—	—	—	—	—	—	—	I	City Museum Ipswich		

Notes: (1) Records in Woodward are only quoted where additional to sources listed above in table, but do not include Wood's records in column 6, 8, 9.
(2) Norwich Castle Museum '*Guide to Collections*' is in preparation.
(3) Sedgwick Museum Cambridge holds Harmer Collection: computer cataloguing in progress.
(4) I.G.S. London holds resurvey collections, cataloguing in progress.
(5) Nos 3–4 may introduce additional records.

TABLE 3. ANALYSIS OF MOLLUSCA FROM BRAMERTON COMMON, BLAKE'S PIT AND WROXHAM HALL

	Bramerton Common			Blake's Pit		Wroxham		
	580	980	1220	75–90W	170–180E	130–150	191–214	
1 Archaeogastropod sp.	7	1	3	5	3	2	—	—
2 *Patella* sp.	—	—	—	0	—	—	—	—
3 *Gibbula* sp.	1	1	1	0	1	—	—	—
4 *Valvata piscinalis* (Müller)	—	—	—	1	—	—	—	—
5 *Littorina littorea* L./*L. littorea carinata* 5a	0/0	1	2	1/1	4	1	—	= *var. carinata* auctt.
6 *L. rudis* Maton	—	—	—	1	1	3	—	—
7 *L.* sp.	—	—	—	3	4	2	—	—
8 *Hydrobia ulvae* Pennant/? *H. ulvae* 8a	—	37/21	8	63	2	—	—	= *Minuta subumbilicata* and *ventrosa* auctt.
9 *H.* sp.	0	—	—	—	7	—	—	—
10 *Rissoa obsoleta* Wood	—	—	1	—	—	—	—	—
11 *R. curticostata* Wood	—	—	0	1	—	—	—	—
12 *R.* sp.	—	—	0	1	—	—	—	—
13 *Cingula semicostata* (Montagu)	—	—	—	0	—	—	—	(cf. *C.s. semicostata*)
14 *Caecum glabrum* (Montagu)	—	—	F	—	—	—	—	—
15 *C. mammilatum* Wood	—	0	—	—	—	—	—	—
16 *Clathrus clathratulus minutus* (Sowerby)	—	—	—	—	1	—	—	—
17 *Calyptraea chinensis* L./cf. *Calyptraea* sp. 17a	—	—	17/1	0	4	—	—	—
18 *Natica clausa* Broderip & Sowerby/*Natica* sp.	—	—/1	—	2/0	—	—/1	—	(*Natica* sp. 18a)
19 *Turritella* sp.	—	—	—	0	2	—	—	—
20 Cerithiopsid sp.	—	—	0	—	—	—	—	—
21 *Potamides tricinctus icenicus* Harmer	—	—	—	0	0	—	—	—
22 *Thais lapillus* (L.)/cf. *T. lapillus* 22a	0	2	—/1	2	2	—	F	*T. l. vulgaris* Wood? parasitized
23 *Sipho* sp.	—	—	1	—	—	—	—	—
24 *Neptunea antiqua* L.	—	—	F	—	—	—	—	—
25 *Buccinum undatum* L.	—	—	—	0	—	—	—	thin 'northern' form or var.
26 *Nassarius* sp.	—	—	—	0	—	—	—	—
27 *Cylichna alba* Kanmacher	—	2	—	1	—	—	—	(= *C. obtusa* auctt.?)
28 *Cylichna* sp.	2	2	—	—	1	—	—	—
29 *Odostomia* sp.	—	—	F	—	—	—	—	—
30 *O. conoidea* (Brocchi)	—	—	—	—	0	—	—	—
31 *Turbonilla internodula* (Wood)	—	—	—	—	F	—	—	—
32 Pulmonate sp.	—	—	—	0	—	—	—	—
33 *Limnaea* sp.	—	—	—	—	1	—	—	—
34 *Melampus pyramidalis* (Sowerby)	—	—	—	0	—	—	—	—
35 *Planorbis* sp.	—	—	—	—	0	—	—	—
36 *Trichia hispida* (L.)	—	—	—	—	1	1	—	—
37 Bivalve sp.	—	1	3	0	2	4	7	—
38 *Nucula* cf. *nucleus* (L.)	—	—	—	—	0	—	—	—
39 *Glycymeris glycymeris* L.	—	—	—	—	0	—	—	—
40 Nuculanid sp.	0	—	—	—	—	—	—	—
41 *Yoldia myalis* Couthouy.	—	—	0	—	0	—	—	(incl. *Y. oblongoides* Wood)

42 *Y.* sp.	2	0	0	0	3	1	*2*		—
43 *Mytilus edulis* L.	3	1	4	0	8	3	*6.5*		—
44 *Chlamys opercularis* L.	F	—	1	—	0	—	—		—
45 *Anomia* sp.	—	—	—	0	2	—	—		—
46 *Astarte* cf. *montagui* Dillwyn	—	—	—	—	—	—	*1.5*		—
47 *A. semisulcata* Leach	—	—	—	—	—	—	*0.5*		—
48 *A.* sp.	—	—	—	—	1	—	—		—
49 *Arctica islandica* (L.)	—	—	—	—	—	0	—		—
50 *Lucinoma borealis* (L.)	—	—	—	—	0	—	—		—
51 *Divaricella juttingae* Spaintz	—	—	0	—	—	—	—		—
52 *Diplodonta astartea* (Nyst)	—	—	—	—	0	—	—		—
53 *D.* sp.	—	0	1	—	—	—	—		—
54 *Lepton nitidum* Turton	1	—	—	0	0	—	—		—
55 *Montacuta* sp.	—	—	0	—	—	—	—		—
56 *Cerastoderma edule* (L.)	16	12	0	8	5	30	—		—
57 *Parvicardium* cf. *scabrum* (Philippi)	—	—	F	—	—	—	—		—
58 *Acanthocardium tuberculatum* (L.)	—	—	—	—	F	—	—		—
59 *Cardium* (sens. lat.) sp.	—	2	1	—	0	—	—		—
60 *Venerupis* sp.	—	—	—	—	0	—	—		—
61 *Venus* sp.	—	—	0	—	1	—	—		—
62 *V. fasciata* Da Costa/*V.* cf. *fasciata*	—	—	—/0	—	—	—	F	(*V.* cf. *fasciata* 62a)	
63 *Spisula* cf. *elliptica* (Brown)	—	—	—	—	0	—	—		—
64 *S. subtruncata* (Da Costa)/*S.* cf. *subtruncata* 64a	4	1	0/0	0	—/0	—	—/*1.5*		—
65 *S.* sp.	0	1	1	1	3	0	—		—
66 *Scrobicularia plana* (Da Costa)	—	—	—	0	2	—	—		—
67 *Abra alba* (Wood)	0	0	46	0	25	—	—		—
68 *A.* sp.	0	—	—	—	—	—	—		—
69 *Macoma calcarea* (Gmelin/*M.* cf. *calcarea* 69a	13	0	0	0	—	—/1	—		—
70 *M. obliqua* (Sowerby)/*M.* cf. *obliqua* 70a	9	0	1	0	1	5	*1/1*		—
71 *M. praetenuis* (Leathes)	7	1	0	1	3	3	—		—
72 *M.* sp.	23	8	2	4	3	19	*4*		—
73 *Donax vittatus* (Da Costa)	—	—	—	—	—	5	—		—
74 *Hiatella arctica* (L.)	4	0	2	1	3	0	*2.5*		—
75 *Mya arenaria* (L.)/*M.* cf. *arenaria* 75a	5	1	—	—/0	0	5	*3.5*		—
76 *M. truncata* L./*M.* cf. *truncata* 76a	—	0	1	—/0	—	—	—		—
77 *M.* sp.	2	0	1	0	1	5	F		—
78 *Corbula gibba* (Olivi)	—	—	—	1	1	7	—		—
79 *Thracia* sp.	—	—	—	0	—	—	—		—
total	249.5	281.5	192	2533	395.5	116	30		
sample weight (g)	770	304	334	1017	1006	989	1120		

Conventions: Frequencies in % (to nearest %) or actual numbers of individuals (*italic*): 0, less than 1%; F, fragments; —, absent.

Table 4. Palaeoecological interpretation of Mollusca from Bramerton Common, Blake's Pit and Wroxham Hall

	Bramerton Common			Blake's Pit		Wroxham	
	580	980	1220	75–90W	170–180E	130–150	191–214
freshwater and terrestrial, nos 4, 32, 33, 35, 36	0	0	0	1.5% *Valvata piscinalis* 1%	2.5% *Limnaea* sp. 1% *Trichia hispida* 1%	1% *Trichia hispida* 1%	0
rocky intertidal nos 5, 5*a*, 6, 22, 43	4.5% *Mytilus edulis* 3%	5% *Littorina littorea* 2% *Thais lapillus* 2%	7% *Littorina littorea* 2% *Mytilus edulis* 4%	5.5% *Littorina littorea* 2% *Thais lapillus* 2%	15% *Littorina littorea* 4% *Thais lapillus* 2% *Mytilus edulis* 8%	7% *Littorina rudis* 3% *Mytilus edulis* 3%	*6.5* *Mytilus edulis 6.5*
sandy intertidal nos 8, 8*a*, 13, 27, 56, 73, 75, 75*a*, 76*a*	21% *Cerastoderma edule* 16% *Mya arenaria* 5%	73.5% *Hydrobia ulvae* 37% ?*H. ulvae* 21% *Cerastoderma edule* 12% *Cylichna alba* 2%	10% *Hydrobia ulvae* 8%	73% *Hydrobia ulvae* 63% *Cerastoderma edule* 8%	8.5% *Hydrobia ulvae* 2% *Cerastoderma edule* 5%	40% *Cerastoderma edule* 30% *Donax vittatus* 5% *Mya arenaria* 5%	*3.5* *Mya arenaria 3.5*
total intertidal	25.5%	78.5%	17%	78.5%	23.5%	47%	*10*
sublittoral							
muddy silty: infauna: nos 41, 49, 50, 64, 64*a*, 67, 52, 69, 69*a*	17.5% *Macoma calcarea* 13% *Spisula subtruncata* 4%	2%	48% *Abra alba* 46%	1.5%	26.5% *Abra alba* 25%	1.5%	*1.5*
muddy coarse nos 14, 38, 46, 58, 78	0	0	F	1%	1.5%	7% *Corbula gibba* 7%	*1.5*
coarse clean: infauna: nos 54, 57, 62, 62*a*, 63	1%	0	0.5%	0.5%	1%	0	F
epifauna: nos 17, 17*a*, 44, 74	4% *Hiatella arctica* 4%	0.5%	21% *Calyptraea chinensis* 18% *Hiatella arctica* 2%	1.5%	7.5% *Calyptraea chinensis* 4% *Hiatella arctica* 3%	0	*2.5* *Hiatella arctica 2.5*
total sublittoral	22.5%	2.5%	69.5%	4.5%	36.5%	8.5%	*5.5*
extinct spp. nos 10, 11, 21, 31, 39, 51, 70, 70*a*, 71	16% *Macoma obliqua* 9% *M. praetenuis* 7%	1.5%	2.5%	3%	5% *Macoma praetenuis* 3%	8% *Macoma obliqua* 5% *M. praetenuis* 3%	*2*

not fully determinable: nos. 1, 2, 3, 9, 12, 18, 19, 20, 23, 26, 28, 29, 37, 40, 42, 45, 48, 53, 55, 59, 60, 61, 72, 77, 79	38 % Archaeogastropod 7 % *Cylichna* sp. 2 % *Yoldia* sp. 2 % *Macoma* sp. 23 % *Mya* sp. 2 %	17 % *Cylichna* sp. 2 % *Cardium* sp. 2 % *Macoma* sp. 8 %	15.5 % Archaeogastropod 3 % Bivalve 3 % *Macoma* sp. 2 %	18 % Archaeogastropod 5 % *Macoma* sp. 4 %	28 % Archaeogastropod 5 % *Hydrobia* sp. 2 % *Turritella* sp. 2 % Bivalve sp. 2 % *Yoldia* sp. 3 % *Anomia* sp. 2 % *Spisula* sp. 3 % *Macoma* sp. 3 %	32 % Archaeogastropod 2 % Bivalve 4 % *Macoma* sp. 19 % *Mya* sp. 5 %	*13* Bivalve *7* *Yoldia* sp. *2* *Macoma* sp. *4*
‘informative’	48 %	81 %	86.5 %	84.5 %	62.5 %	56.5 %	*15.5*
‘uninformative’	56 %	18.5 %	18 %	21 %	33 %	40 %	*15*

0, absent; F, fragments. Species scored at ‘0’ in table 3 count 0.5 % in this table. Frequencies in percentages or (italic) actual numbers of individuals.

(iv) 500 cm sample (at 7.30 m). *Spisula subtruncata* 20 %, Tellinid sp. 13 %, *Lepton nitidum* 5 %, *Mya arenaria* 3 %, *Calyptraea chinensis* 3 %, Gastropod sp. and *Gibbula* sp. 3 % each. Compared to the 580 cm sample there is a much smaller percentage of intertidal shells, a much larger percentage of sublittoral shells and more individuals of species now extinct. The littoral was apparently of sandy type, with no *Hydrobia ulvae*. The sublittoral region appears to have included sandy mud and stones with silt, with other bottom types poorly represented. Only 30 % of the assemblage is properly identifiable and belongs to ecologically informative species. The latter suggest, from the comparisons above, that deposition took place in deeper water than the 580 cm sample and the lack of *Macoma calcarea* may even suggest warmer water.

(*b*) *Blake's Pit section*

(i) 1.70–1.80 m sample (Eastern section). *Abra alba* 25 %, *Mytilus edulis* 8 %, *Cerastoderma edule* 5 %, *Littorina littorea* 4 %, *Calyptraea chinensis* 4 %. The assemblage appears to reflect littoral and inner-sublittoral conditions (littoral species 23.5 %, sublittoral species 36.5 %), the sublittoral being silty with *Abra alba* infauna, and with stones and silt (populations of *Calyptraea chinensis*) and maybe algae (*Hiatella arctica*). The littoral appears to have been sandy (infauna of *Cerastoderma edule*) with stones (*Littorina*, *Thais*, *Mytilus*) and with brackish-water or freshwater influx bringing non-marine shells into the deposits (*Limnaea*, *Trichia*) and supporting a population of *Hydrobia ulvae*. Here, as in the Bramerton Common 980 cm sample, the assemblage appears 'fluviomarine', though much less markedly, there being a much greater sublittoral component, which recalls the Bramerton Common 1220 cm sample.

(ii) 0.75–0.9 m sample (Western section). *Hydrobia ulvae* 63 %, *Cerastoderma edule* 8 %, Gastropod sp. (unid) 5 %, *Macoma* sp. 4 %. This assemblage appears to represent littoral brackish, sheltered 'wadden-area' or semi-estuarine conditions, with non-marine shells being carried in. The littoral included sandy areas (with *Hydrobia* and *Cerastoderma*) and rocks or stones on which lived *Littorina* and *Thais*: the latter at the present feeds on barnacles which may grow upon molluscs, so that it is not essential to argue that rocks were present. *Mytilus* (less than 1 %) forms self-supporting clumps in modern sheltered intertidal areas; *Thais* and *Littorina* associate with these clumps. The sample strongly recalls the Bramerton Common 980 cm sample, the percentages of various ecological groupings being similar.

(*c*) *Facies and notes on Mollusca*

The above accounts of the samples show that a number of different marine facies are interpreted from the assemblages, as follows:

(*d*) open coast, more subarctic facies with littoral and sublittoral provinces, as represented at Bramerton Common 580 cm at 6.50 m;

(*c*) boreal 'fluviomarine' facies reflecting brackish sheltered tidal flat conditions with *Hydrobia ulvae*, as at Blake's Pit W 0.75–0.90 m (≡ E 4.95–5.10 m) and Bramerton Common 980 cm at 2.50 m;

(*b*) boreal littoral or inner-sublittoral facies with few brackish-water littoral shells deposited, as at Blake's Pit E 1.70–1.90 m; this facies resembles both (*c*) and (*a*) and could be regarded as intermediate;

(*a*) inner-sublittoral muddy-bottom facies with littoral, brackish, tidal-flat conditions as represented at Bramerton Common at 0.10 m.

If the equivalences suggested above are accepted, then these facies also show a succession in the order (*a*)–(*b*)–(*c*)–(*d*) since there is superposition of (*a*), (*c*) and (*d*) at Bramerton Common. Referred to O.D., the levels are approximately:

level	sample	facies
9.8 m O.D.	Bramerton Common 580 cm	*d*
6.8 m O.D.	Blake's Pit W 0.75–0.90 m	*c*
5.8 m O.D.	Bramerton Common 980 cm	*c*
3.5 m O.D.	Blake's Pit E 1.70–1.80 m	*b*
3.4 m O.D.	Bramerton Common 1220 cm	*a*

Comparing with the 1881 Memoir (Woodward 1881), we see that facies (*d*), (*c*) and perhaps (*b*) were discriminated by the Bramerton collectors.

Although the closest mollusc facies equivalence is found between the Blake's Pit sample taken at 6.8 m O.D. and a Bramerton Common sample taken at 5.8 m O.D., it should be noted that the mollusc assemblage biozone Bm 1 extends up to 9.4 m O.D. (Norton 1967; Funnell & West 1977). There is therefore no absolute contradiction between the equivalences of the two pits based on the molluscs and that suggested by the foraminifers, where the 6.8 m O.D. sample from Blake's Pit is compared with samples at 7.9 and 9.4 m O.D. in the Bf 2 foraminiferal assemblage biozone which ranges from 5.8 to above 9.4 m O.D. (Funnell 1961 *a*, *b*; Funnell & West 1977).

Distorted specimens of *Littorina littorea*, *L. rudis* and *Thais lapillus* are abundant and characteristic in the Bramerton sections, occurring in both beds in both pits. Many unique shells form holotypes of Harmer's varieties, but are apparently merely monstrosities. The figured specimen of *Littorina littorea* var. *distorta* Harmer (figure 16, plate LII of Harmer 1914–25), for example, has a barnacle on the inner lip. Apparently, the rapid growth of the barnacle caused the *Littorina* to alter its growth, becoming almost sinistral; Harmer does not refer to the barnacle. Distorted *Thais* and *Littorina* specimens are often found to be barnacle-encrusted in the sutures. Clearly, the normal action of the mantle in removing epizoites from the mouth of the shell was impaired, allowing barnacle cyprids to become established and then covered by the advancing suture, distorting it. It has been suggested that the Mollusca were enfeebled by conditions of low salinity or of ice, which persisted late into the spring, up to the time of cyprid settlement (this occurs in late March or early April in Boreal regions at present). Parasites might have affected the molluscs in a similar way. *Thais lapillus lapillus* (the Bramerton specimens are usually *T. lapillus vulgaris* Wood, thought to be extinct) is oviparous, and the young hatch throughout the year in the barnacle zone (Fretter & Graham 1962). *Littorina littorea* has pelagic eggs and veliger larvae; these settle sublittorally and migrate slowly up to the intertidal zone (Smith & Newell 1955). Thus the ice or low salinity conditions should not have been too severe or veligers could not have survived. Many of the *Littorina* specimens show no abnormality of sutures in the initial two or three whorls, whereas the *Thais* (which are also rougher and would therefore more readily attract cyprid settlement) are parasitized from the apex. This may result from the differences in development. Carination also occurs, usually without distortion, and is said to be a response to rough water conditions.

Spisula specimens, especially from the Arminghall '*Mactra solida*' (Woodward 1881, pp. 72) pit and in the working pit at Caistor St Edmunds (figure 1), also show characteristic aberrations. They are usually labelled in collections as *Mactra solida* or *M. ovalis*. An example was described by Wood (1848–79, vol. 2, p. 246). On re-examination most of the material has proved to be

S. subtruncata ('thick type' according to van Urk (1959)) with some *S. elliptica*, some *S. solida* and one *S.* aff. *constricta* Wood from Arminghall. The prodissoconch is often very much tilted, the teeth longer than in *S. solida* but not as long as in typical *subtruncata*; the shape is, however, incorrect for *S. constricta* Wood. The shells are very large and thin. Similar *Spisula* are found at Postwick, Bramerton Common and Blake's pit.

The presence of these unusual and local shell forms is interpreted as an indication that the shell deposits formed in a restricted marine basin and in a chronologically terminal situation where the gene pool had become isolated; this was followed by the local extinction of the molluscs. The shell deposits most likely include shells winnowed out and redeposited from patches of aberrant forms. In the modern North Sea, *Spisula subtruncata* forms dense but limited patches, several square kilometres in extent and lasting only for one generation (Davis 1923). The shell deposits may therefore contain only a few (or even a single) generations of shells. Similarly, the environmental or genotypic conditions which accompanied them may have been of very short duration and of limited extent.

6. Associated gravels

Overlying the shelly crag deposits in the vicinity of Bramerton are a series of gravels containing abundant quartz and quartzite pebbles. These were described from the Yare valley and Bramerton area by Funnell (1961 *b*), and similar quartz and quartzite-rich gravels have subsequently been investigated over a wide area of East Anglia by Hey (1976). It seems highly probable that the gravels in the vicinity of Bramerton are simply part of the extensive spread of quartz and quartzite-bearing gravels investigated by Hey, and tentatively attributed by him (through association with pollen-bearing deposits on the north Norfolk coast) to the Baventian (now recognized as Pre-Pastonian) to Beestonian stages. Six kilometres from Bramerton, at Caistor St Edmunds, near Norwich (TG 240047) the quartz–quartzite–flint gravels are again well developed, overlying fossiliferous sands and pebbly flint gravel of the Norwich Crag formation. At Caistor St Edmunds there is even a well developed reddened horizon, at the top of the quartz–quartzite gravels, similar to that recorded by Rose & Allen (1977) in the quartz and quartzite-bearing Kesgrave Sands and Gravels described by them from SE Suffolk and Essex. On the Norfolk coast, the quartz–quartzite–flint gravels occur widely in early Pastonian sediments and, once, in Pre-Pastonian *a* sediments. Thus they are associated with the earliest gravels lying on the chalk at Beeston (site BKF, West (1979)), which are Pre-Pastonian *a* in age, and with Pastonian sediments in other parts of the coastal section (Hey 1976). The time of their introduction into Norfolk thus appears to be between the Bramertonian and early Pastonian.

7. Conclusions and correlations

The correlations discussed in this section are summarized in table 5.

(*a*) *Relation to gravels*

The fossiliferous Bramerton sections pre-date the quartz–quartzite–flint gravels in the Norwich area. Thus an analysis by Dr R. W. Hey of pebble composition from gravels associated with the upper shell bed at Blake's Pit shows a very low quartz–quartzite content. The present evidence and the revision of the Norfolk coast stratigraphy (West 1979), taken together with evidence of gravel composition on the Norfolk coast (Hey 1976), indicate that the quartz–

Table 5. Correlation

Norfolk coast†	Norwich district (Bramerton)	Ludham borehole	Suffolk
3 Pastonian			
2 Pre-Pastonian *a* 1 (Sidestrand Crag)	*Pinus*–Ericales–Gramineae p.a.b.	(Lp 4c)‡	
	Bramertonian (Norwich Crag) *Alnus*–*Quercus*–*Carpinus* p.a.b.	Lp 5	Chillesford pollen assemblage Westleton Beds
		Lp 4b–c (Lp 4b)‡	Baventian (Lp 4a–b)

† 1, *Macoma balthica* present; 2, quartz and quartzite pebbles present; 3, quartz and quartzite pebbles abundant.

‡ If the Bramertonian does not equate with Lp 5 of the Ludham borehole, it may be equivalent to a stage between Lp 4b and Lp 4c not seen at Ludham. This alternative solution has been entered in the table in parentheses.

quartzite–flint gravels first appeared in post-Bramerton time, but before the end of the Pre-Pastonian *a* cold substage on the Norfolk coast.

(*b*) *Relation to the 'Bure Valley Beds'*

Knowledge of the molluscs and the extent and correlation of the 'Bure Valley Beds' is scanty. Few exposures remain available. The original definition, based on the presence of *Macoma balthica* in pebbly sand and gravels (original definition by S. V. Wood Jr in S. V. Wood Sr 1866, p. 547; see also Reid 1890, p. 114), needs clarification, as no stratotype has been proposed. The 'Bure Valley Beds' include the quartz–quartzite–flint gravels already referred to. According to Woodward (1881, pp. 31, 32) the 'Bure Valley Beds' are equivalent to his unit 4 of the Norwich area, which includes sands and gravels with quartz pebbles. According to Dr R. W. Hey, the composition of the gravels of this horizon is variable and suggests the presence of more than one sedimentary unit.

Appendix II describes the stratigraphy and mollusc fauna of an exposure regarded as 'Bure Valley Beds' at Wroxham Hall (Woodward 1881, p. 63). The interpretation of facies mentioned in the appendix suggest boreal open-coast conditions, based on the 1.30–1.50 m sample, upper section, with an O.D. of *ca.* 8.4 m O.D. *Macoma balthica* was not recorded in this section, but has recently been found by Mr P. Cambridge in a nearby excavation at Dobb's Plantation, Crostwick (TG 273158) (Cambridge 1978).

Thus the relation of the Bramerton Crag to 'Bure Valley Beds' is not clarified by the molluscan analyses, and the relative position of the Wroxham Hall shell bed remains uncertain. Woodward reported opinions that, based on the *Macoma balthica* recorded from it and other 'Bure Valley Bed' sites, it was younger than any at Bramerton. The correctness of this record, which is important, has been checked as follows.

Macoma balthica specimens from the 'Bure Valley Beds', as identified by Wood and others, are preserved at Norwich Castle Museum and in the I.G.S. collections (see the synoptical table, table 1). Mr G. Spaink and P. E. P. N. have examined all that are available and found that many are juvenile forms, difficult to identify, but in their opinion *Macoma balthica* (L.) was found at

Belaugh. This species, when juvenile, is easily confused with *M. praetenuis* and other *Macoma* species (Spaink & Norton 1967).

(*c*) *Relation to the Norfolk coastal sequence*

As discussed in §3 (*d*), the *Pinus*–Ericales–Gramineae pollen assemblage in the upper part of the Blake's Pit section resembles assemblages included in the Pre-Pastonian *a* substage of the coastal sequence (West 1979). Sediments of this substage at Sidestrand contain a mollusc fauna with *Macoma balthica* as described below.

Comparison of the molluscan assemblages at Bramerton with those of the Norfolk coastal sequence, on the basis of those described from Sidestrand (Norton 1967), gives little indication that they may be correlated. The Sidestrand assemblage, and others on the Norfolk coast that may be correlated with it, form the basis of an assemblage biozone of *Macoma balthica*, *Cardium edule* and *Mytilus edulis* indicating a boreal or subarctic, intertidal, open coast facies. Facies (*d*) of the Bramerton succession may appear similar to this in regard to palaeoenvironmental conditions, but, in fact, the species making up the assemblages are not similar. There is a much higher percentage of the arctic form *Yoldia* at Sidestrand (10% in SS/K1, 2% at Bramerton Common 580 cm). *Macoma balthica*, absent from Bramerton, contributes 39% of the assemblages in Sidestrand (SS/K1 and SS/K6) and sets the Sidestrand assemblage apart from all others in this paper, except possibly the 'Bure Valley Beds' at Belaugh (mentioned above), for which no counts of molluscs are available. On this basis it may still be held (cf. Norton 1967) that the Sidestrand deposit 'belongs to a later time than the Bramerton ones, or to a geographically distinct theatre of deposition'.

(*d*) *Relation to Ludham and the southern crag*

(i) *Pollen*

The relation of the Bramerton pollen assemblages to those of the Ludham borehole and the southern crag have already been considered in §3 (*d*). It was concluded that the temperate pollen assemblage recorded at Bramerton (*Alnus–Quercus–Carpinus* p.a.b.) was older than the Pastonian but younger than Antian and may be correlated with the Lp 5 biozone at Ludham or with the Chillesford pollen assemblage of Norton & West (1974), as recorded in Suffolk at Chillesford, Aldeburgh, Thorpe Aldringham and Sizewell. If this latter correlation is correct then the crags at these Suffolk sites should be included in the Bramertonian temperate stage (see table 5).

(ii) *Mollusca*

The Mollusca themselves are of very little help for correlation. A number of marine facies, that may be placed in sequence by reference to pollen, have already been recognized in the successions at Ludham, Easton Bavents and Aldeby as follows:

Ludham (Norton 1967)	Aldeby (Norton & Beck 1972)	Easton Bavents (Norton & Beck 1972)
Early Baventian: inner sublittoral, perhaps deeper water than Antian: zone Lm 6		Early Baventian: inner sublittoral, perhaps deeper water than Antian: shell beds 1 and 2
Antian: inner sublittoral with estuarine littoral: zone Lm 5	?Antian: inner sublittoral with diversity of habitats represented	Antian: inner sublittoral with impoverished mollusc assemblages, shell beds 3 and 4. Early Antian littoral open coast facies: shell bed 5

A comparison with Ludham has already been attempted by Norton (1967) and between Easton Bavents, Aldeby and Ludham, by Norton & Beck (1972). Correlation between the sites on the basis of the Mollusca could not be established. A comparison can be made between the Bramerton sequence and the Easton Bavents sequence, shell beds 3, 4 and 5. At Easton Bavents a *Littorina rudis–L. littorea–Cerastoderma edule–Mytilus edulis–Corbula gibba* assemblage gives way to a *Macoma obliqua–M. calcarea–Corbula gibba–Arctica islandica–Spisula subtruncata–Littorina littorea* assemblage, showing a change from open-coast littoral to inner sublittoral. This may be compared with the change at Bramerton Common which was interpreted as one from open-coast littoral conditions at 580 cm to (apparently) rather deeper-water ones at 500 cm (see Norton 1967). However, it will be noted that the species in the assemblages are not similar. Also, the 500 cm assemblage at Bramerton is very impoverished, as are all Bramerton assemblages, as compared with the other sites. It is therefore not possible to suggest firm relations between Bramerton and Easton Bavents.

The range of facies found in the 'Southern Basin' and listed by West & Norton (1974) and Norton (1977) is similar to that at the Bramerton sites, namely:

(A) Sublittoral (or infralittoral) facies, shells abraded and not deposited *in situ*. Sizewell 'A' (pump house pit of the nuclear power station (pollen provisionally correlated with Ludham Lp 4c occurred at this level)), Chillesford '*Scrobicularia* Crag', possibly Aldeburgh '*Scrobicularia* Crag'.

(B) Sheltered estuarine or wadden area facies, reflecting brackish conditions, with *Hydrobia ulvae*: Wangford B6 and B4, Sizewell 'B' (nuclear power station roadway trench), 1 and 4 (with Chillesford pollen assemblage, then provisionally correlated as Pastonian) and Thorpe Aldringham (with Chillesford pollen assemblage).

(C) Open coast facies, succeeding the sheltered tidal-flat facies: *Littorina littorea*, *Cerastoderma edule*, *Hydrobia ulvae*, some *Spisula subtruncata* and *Corbula gibba*. Wangford B1 and C, Sizewell 'B'9, possibly 'B'7. A sample with the Chillesford pollen assemblage occurred elsewhere in the Sizewell 'B' section at about 0.5 m below 'B'9.

(D) High boreal or subarctic silty deposit facies with *Yoldia myalis*, *Mya truncata* (*in situ*): Chillesford Churchyard pit and Aldeburgh Brickyard. A Chillesford pollen assemblage occurred in the underlying Crag about 0.75 m below the base of the silts at a different part of the Chillesford pit, and within the silts at Aldeburgh.

This list of facies contains three (A, B and C) which may be compared with (*a*) or (*b*), (*c*) and Wroxham respectively, but the species in the assemblages differ. The Norwich district assemblages have much lower frequencies of *Donax vittatus*, *Corbula gibba* and *Spisula* spp.

This uncertainty as to how the Norwich district crag may be correlated cannot be resolved at present on the basis of the Mollusca alone so far as they are presented in this account.

(iii) *Foraminifera*

The foraminifers from the lower (Bramertonian) part of the Bramerton sections (e.g. Blake's Pit E 1.70–1.80 m, and Bramerton Common B15) clearly contain an element, here interpreted as re-worked, of Ludham or Red Crag material. Leaving this material on one side, the assemblages are characteristic of a temperate, post-Ludham Crag, early Pleistocene episode and could apparently belong to either of the later temperate episodes recorded by pollen and, in part, by foraminifers (Lp 3 ≡ Lf 5, or Lp 5) in the Ludham borehole.

The most likely correlatives of the Bramertonian foraminifers therefore seem to be either

Lf 5 (≡ Lp 3 = Antian), as originally proposed by Funnell (1961 *a*, *b*), or possibly an as yet unrecognized 'intra-Baventian' temperate stage between Lf 6 and Lf 7 (≡ Lp 4b and Lp 4c = 'Baventian'), or a later temperate stage (≡ Lp 5) for which only fragmentary foraminifers are preserved in the Ludham borehole. It may be significant that the distinctive *Elphidium haagense*, which occurs consistently in the Ludham borehole up to and including the level of Lf 5 (≡ Lp 3 = Antian) in temperate episodes, is absent at Bramerton (and in the crag of N Suffolk). This would eliminate the possibility of the correlation of the Bramertonian foraminifers with Lf 5 (Lp 3 = Antian) and leave the possibility of correlation either with an interval between Lf 6 and Lf 7 (i.e. 'intra-Baventian') or with a period later than Lf 7 (Lp 4c) and post-Baventian. The Bramertonian foraminifers were previously correlated by Funnell (1961 *a*, *b*) with the outcropping crag of N Suffolk at Chillesford, Sizewell (Rifle Range) and Thorpe Aldringham. At that time those crags were thought to pre-date the Baventian. Now they are thought to post-date the Baventian. Therefore, the continuing correlation of the Bramerton foraminifers with these N Suffolk crags remains consistent with their revised correlation with a post-Lf 6 (Lp 4b = Baventian) level in the Ludham borehole.

The foraminifers from the upper (Pre-Pastonian *a*) part of the Bramerton sections (e.g. Blake's Pit W 0.75–0.90 m, and Bramerton Common B84, B78) indicate conditions approaching, but by no means equalling, the cold of the 'Baventian' as recorded by pollen and foraminifers (Lp 4b ≡ Lf 6, and Lp 4c ≡ Lf 7) in the Ludham borehole, and at Easton Bavents, Sidestrand and Covehithe. The coldest conditions at Bramerton Common are recorded by poorly preserved foraminifers from sample B19, above the level of preserved molluscs and pollen.

Whereas the foraminifers of the Pre-Pastonian *a* of Sidestrand and of Lf 7 (≡ Lp 4c) of Ludham are colder in aspect than those of the Pre-Pastonian *a* deposits in which pollen has been found at Bramerton (Funnell 1961 *a*, *b*; Funnell & West 1977), the succeeding foraminifers of the B19 level at Bramerton Common may well be as cold as both the Sidestrand and Lf 7 foraminifers. Unfortunately, however, they are not well preserved, and, in general, there does not so far seem to be any way of distinguishing between the successive cold foraminiferal populations of the Baventian and Pre-Pastonian *a* pollen stages.

(*e*) *A synthesis*

In post-Baventian times a strong transgression occurred in eastern East Anglia and was recorded in marine sediments with temperate foraminifer and mollusc faunas and pollen flora. The Norwich Crag at Bramerton, the Suffolk crag at Chillesford, Aldeburgh, Thorpe Aldringham and Sizewell, and the Westleton Beds were deposited during this transgression. The temperate stage in which it occurred is here named the Bramertonian. The uppermost faunas and pollen flora at Bramerton were sedimented during subsequent deterioration of the climate. This cold event is included in a cold stage, which is thought to be equivalent to the Pre-Pastonian *a* substage of the Norfolk coast. The marine sediments of this substage contain faunas with *Macoma balthica*, which species thus first appears in the Pleistocene of East Anglia during this cold stage. The introduction of quartz–quartzite–flint gravels to the Norwich area must occur later than the Bramertonian temperate stage, and later than the beds we are equating with the Pre-Pastonian *a* at Bramerton. This type of gravel was certainly present by early Pastonian times (Hey 1976), but the exact time of its first appearance remains uncertain.

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Appendix I. Systematic notes on the Foraminifera

By B. M. Funnell

Ammonia beccarii (Linnaeus), 1758

1758 *Nautilus beccarii* Linnaeus (*Systema Naturae*, 10th edn, vol. 1, p. 710. Holmiae, Sweden.)

Distribution

(*a*) *Stratigraphical*

Coralline, Red and Southwold, Thorpe and Chillesford Crags (Jones *et al.* 1866; Burrows & Holland 1897); all Crags except Lf 7 assemblage biozone of Ludham and Sidestrand Crag (Funnell 1961 *a*, *b*; Funnell & West 1977).

Hoxnian of the Nar Valley and Clacton-on-Sea (Brady, in Jones 1865, p. 307; van Voorthuysen, in Baden-Powell 1955, p. 302).

Eemian of Amersfoort (van Voorthuysen 1958 *b*).

Upper Post-Glacial of Nord-Bohuslans (Hessland 1946; Brotzen 1951), Lower and Upper Post-Glacial of Surte, Sweden (Brotzen 1951), Post-Glacial *Ostrea*- and *Isocardia*-clay of the Oslofjord area (Feyling-Hanssen 1954 *a*, *b*).

Holocene of Lancashire and Cheshire (Nyi Nyi 1956), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

Skye, southern North Sea, English Channel, Celtic Sea, Bay of Biscay (Murray 1971), north of Scotland and North Sea (Harris 1958), and as far north as the Faroe Islands (Hofker, *fide* Macfadyen 1932). According to Murray it is a southern species nearing its northern limit of distribution around the British Isles.

Buccella frigida (Cushman), 1922

1922 *Pulvinulina frigida* Cushman (*Contr. Can. Biol. Fish.* **9**, p. 12).

1952 *Buccella frigida* (Cushman). Andersen (*J. Wash. Acad. Sci.* **42** (5), p. 144, text-figs 4*a*–*c*, 5, 6*a*–*c*).

Distribution

(*a*) *Stratigraphical*

Coralline and Southwold Crag (Jones 1897; Burrows & Holland 1897), Easton Bavents Crag, Sidestrand Crag, Lf 5–Lf 7 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

Eemian of Amersfoort (van Voorthuysen 1958 *b*), Lower Late-Glacial to upper Post-Glacial of Surte, Sweden (Brotzen 1951), Lower Post-Glacial *Mytilus* clay of the Oslofjord area (Feyling-Hanssen 1954 *a*), Holocene of Lancashire and Cheshire (Nyi Nyi 1956), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

Barents Sea, northern North Sea, and English Channel (Murray 1971), Arctic (Cushman 1948; Loeblich & Tappan 1953). According to Murray a northern species whose southerly limit is the English Channel.

Buccella inusitata Andersen, 1952

1952 *Buccella inusitata* Andersen (*J. Wash. Acad. Sci.* **42** (5), p. 148, text-figs 10*a*–11*c*).

Distribution

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Thorpe (Aldringham) Crag, Lf 1–Lf 2 and Lf 1–Lf 7 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

This species appears to be more widely distributed in the crags than *Buccella frigida*. Although it is clearly tolerant of cold periods (and Arctic waters) like *B. frigida*, it also appears, unlike that species, to occur in temperate periods in the North Sea Basin.

(*b*) *Geographical*

Off the north of Scotland (Harris 1958), and Arctic (Cushman 1948; Loeblich & Tappan 1953).

Cibicides lobatulus (Walker & Jacob), 1798

1798 *Nautilus lobatulus* Walker & Jacob (in Kanmacher, '*Adam's essays on the microscope*', 2nd edn, p. 642, pl. 14, fig. 36).

1931 *Cibicides lobatula* (Walker & Jacob) (Cushman 1931, *Bull. U.S. natn. Mus.* **104**, pt. 8, pp. 118–120).

Distribution

(*a*) *Stratigraphical*

Coralline, Red and Southwold, Thorpe and Chillesford Crags (Burrows & Holland 1897), Weybourn Crag (Macfadyen 1932), all crags except the uppermost Sidestrand Crag (Funnell 1961 *a*, *b*; Funnell & West 1977).

Eemian of Amersfoort (van Voorthuysen 1958 *b*).

Upper Late-Glacial to upper Post-Glacial of Nord-Bohuslans, Sweden (Hessland 1946; Brotzen 1951), lower Late-Glacial to upper Post-Glacial of Surte, Sweden (Brotzen 1951), lower Late-Glacial to upper Post-Glacial, *Yoldia*-, *Arca*-, *Mytilus*-, *Ostrea*-, and *Isocardia*-clays of the Oslofjord area (Feyling-Hanssen 1954 *a*).

Holocene of Lancashire and Cheshire (Nyi Nyi 1956), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

Barents Sea, North Sea, English Channel and Bay of Biscay (Murray 1971). Arctic (Cushman 1948).

Cibicides lobatulus (Walker & Jacob) var. *grossa* ten Dam & Reinhold, 1941

1941 *Cibicides lobatulus* (Walker & Jacob) var. *grossa* ten Dam & Reinhold (ten Dam & Reinhold 1941, *Meded. geol. Sticht* (C–V) **1**, p. 62, pl. V, fig. 5 *a–c*, pl. VI, fig. 1 *a–c*, tabelle I).

Distribution

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Lf 1–Lf 2, Lf 6 assemblage biozones of Ludham, Chillesford Crag.

(*b*) *Geographical*

Not known, but stratigraphical occurrence suggests within the warmer part of the range of *Cibicides lobatulus*.

Cibicides pseudoungerianus (Cushman) 1922

1922 *Truncatulina pseudoungeriana* Cushman (*Prof. Pap. U.S. geol. Surv.* **129**-E, p. 97, pt. 20, fig. 9).

1931 *Cibicides pseudoungeriana* (Cushman). (Cushman 1931, *Bull. U.S. natn. Mus.* **104**, pt. 8, pp. 123–124, pl. 22, figs 3–7).

Distribution

(*a*) *Stratigraphical*

Coralline Crag (Burrows & Holland 1897), Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Lf 1–Lf 3 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

Eemian of Amersfoort (van Voorthuysen 1958 *b*).

Upper Post-Glacial of Nord-Bohuslans (Hessland 1946; Brotzen 1951), Post-Glacial *Isocardia*-clay of the Oslofjord area (Feyling-Hanssen 1954*a*, *b*).

Holocene of Lancashire and Cheshire (Nyi Nyi 1956). It appears to be restricted to temperate periods in the North Sea basin.

(*b*) *Geographical*

Barents Sea, Belgium coast, Celtic Sea, Bay of Biscay (Murray 1971). Western Atlantic, off S.W. Ireland (Cushman 1931), widespread off north of Scotland, but rare in North Sea (Harris 1958).

Cibicides subhaidingerii Parr, 1950

1950 *Cibicides subhaidingerii* Parr (*Rep. B.A.N.Z. antarct. Res. Exped.* 1929–1931 B **5** (6), p. 364, pl. 15, fig. 7).

Distribution

(*a*) *Stratigraphical*

Coralline Crag (Burrows & Holland 1897), Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Lf 1–Lf 2 assemblage biozones of Ludham (Funnell 1961*a*, *b*; Funnell & West 1977). This species now appears to be restricted to the Pacific, but was earlier present in temperate periods in the North Sea Basin.

(*b*) *Geographical*

Pacific, including localities off the coast of Japan (Cushman 1915).

Elphidiella hannai (Cushman & Grant), 1927

1927 *Elphidium hannai* Cushman & Grant (*Trans. S. Diego Soc. nat. Hist.* **5** (6), pp. 77–78, 82, pl. 8, figs 1*a*–*b*, 2*a*–*b*).

1939 *Elphidiella hannai* (Cushman & Grant). (Cushman 1939, *Prof. Pap. U.S. geol. Surv.* **191**, p. 66, pl. 19, figs 1–2).

Distribution

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Ludham, Norwich and Weybourne Crags at all localities. This is a dominant species in all early Pleistocene intertidal or inner sublittoral deposits in the North Sea Basin (Funnell 1961*a*, *b*; Funnell & West 1962, 1977).

(*b*) *Geographical*

Restricted at the present day to the west coast of North America essentially northwards from Point Conception (at *ca.* 35° N), although there may be a few occurrences further south (Lankford 1962), to the Aleutian Islands (Loeblich & Tappan 1953).

Elphidium crispum (Linnaeus), 1758

1758 *Nautilus crispus* Linnaeus. (*Systema Naturae*, 10th edn, vol. 1, p. 709. Holmiae, Sweden.)

1929 *Elphidium crispum* (Linné) (Cushman & Leavitt *Contr. Cushman Lab.* **5**, pp. 20, 22, pl. 4, figs 3–4).

Distribution

(*a*) *Stratigraphical*

Polystomella crispa (Linné) is recorded by Burrows & Holland (1897) from the Coralline Crag, Red Crag, Chillesford, Southwold, Thorpe and Bramerton Crags, but at the last four localities are likely to refer to *Elphidium pseudolessonii* (*q.v.*). Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Thorpe (Aldringham) Crag, Lf 1–Lf 2 and Lf 4 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

(*b*) *Geographical*

Mediterranean (Cushman 1939), and off Scotland (Harris 1958). Shetland–Orkney, North Kent, Belgian and English Channel coasts, Arcachon and Galicia (Murray 1971). According to Murray a stenohaline, inner shelf, southern species close to its northern limit around the British Isles.

Elphidium excavatum (Terquem) var. *clavatum* Cushman

1875 *Polystomella excavata* Terquem (*Essai Animaux Dunkerque*, pt. 1, p. 25, pl. 2, fig. 2*a–f*).

1930 *Elphidium incertum* (Williamson) var. *clavatum* Cushman (1930, *Bull. U.S. natn. Mus.* **104**, pt 7, p. 20, pl. 7, fig. 10*a–b*).

Distribution (N.B. frequently referred to as *Elphidium incertum* var. *clavatum* or *E. clavatum.*)

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crag, *Scrobicularia* Crag, Chillesford Crag, Thorpe (Aldringham), Easton Bavents and Sidestrand Crags, Lf 1–Lf 2, Lf 5–Lf 6 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West, 1962, 1977).

Hoxnian of Clacton-on-Sea (van Voorthuysen, in Baden-Powell 1955), Upper Late-Glacial to upper Post-Glacial of Nord-Bohuslans (Hessland 1946; Brotzen 1951), and lower Late-Glacial to upper Post-Glacial of Surte, Sweden (Brotzen 1951), Late-Glacial to Post-Glacial of the Oslofjord area (Feyling-Hanssen 1954 *a*, *b*), Holocene of Lancashire and Cheshire (Nyi Nyi 1956), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

Western Atlantic and northern Europe (Cushman 1939), Arctic (Cushman 1948; Loeblich & Tappan 1953). Widespread off the north of Scotland (Harris 1958). Apparently associated with slightly coarser sediment than *E. excavatum* var. *selseyense*, it also seems to be rather more typical of colder waters than that variety. However, they commonly occur together.

Elphidium excavatum (Terquem) var. *selseyense* (Heron-Allen & Earland)

1875 *Polystomella excavata* Terquem (*Essai Animaux Dunkerque*, pt. 1, p. 25, pl. 2, fig. 2*a–f*).

1909 *Polystomella striatopunctata* (Fichtel & Moll) var. *selseyensis* Heron-Allen & Earland (*Jl R. Microsc. Soc.*, p. 695, pl. 21, fig. 2*a–c*).

1939 *Elphidium selseyense* (Heron-Allen & Earland) (Cushman 1939, *Prof. Pap. U.S. geol. Surv.* **191**, pp. 59–60, pl. 16, figs 26–28).

Distribution (N.B. frequently referred to as *Elphidium incertum* or *Elphidium selseyense*.)

(*a*) *Stratigraphical*

Newbourn Crag, Sizewell (Rifle Range), Easton Bavents and Sidestrand Crags, Lf 1–Lf 5 assemblage biozones of Ludham (Funnell 1961 *a, b*; Funnell & West 1962, 1977).

Eemian of Amersfoort (van Voorthuysen 1958), Upper Late-Glacial to upper Post-Glacial of Nord Bohuslans (Hessland 1946; Brotzen 1951), and lower Late-Glacial to upper Post-Glacial or Surte, Sweden (Brotzen 1951), lower Late-Glacial to upper Post-Glacial *Isocardia*-clay of the Oslofjord area (Feyling-Hanssen 1954 *a, b*), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

Widespread in the North Atlantic (Cushman 1939). In bays off the North and Baltic Seas, and the English Channel; also the west coast of Ireland (Murray 1971). According to Murray an inner shelf, probably southern species.

Elphidium frigidum Cushman, 1933

1933 *Elphidium frigidum* Cushman (*Smithson. misc. Coll.* **89** (4), p. 5, pl. 1, figs 8*a–b*).

Distribution (N.B. includes *Elphidium subarcticum*.)

(*a*) *Stratigraphical*

Newbourn and Butley Crag, *Scrobicularia* Crag, Chillesford Crag, Thorpe (Aldringham), Sizewell (Rifle Range), Easton Bavents and Sidestrand Crags, Lf 1–Lf 6 assemblage biozones of Ludham (Funnell 1961 *a, b*; Funnell & West 1977).

(*b*) *Geographical*

Arctic (Cushman 1933; Loeblich & Tappan 1953), the Moray Firth (Harris 1958). East coast of North America to south of Cape Cod (Murray 1973); west coast of North America, essentially from Point Conception northwards.

Elphidium macellum (Fichtel & Moll), 1798 var. *granulosum* (Sidebottom) 1909

1909 *Polystomella macella* (Fichtel & Moll) var. *granulosa* Sidebottom (*Mem. Proc. Manchr lit. phil. Soc.* **53** (21), p. 16, pl. 5, fig. 5).

1939 *Elphidium macellum* (Fichtel & Moll) var. *granulosum* (Sidebottom). (Cushman, *Prof. Pap. U.S. geol. Surv.* **191**, p. 52, pl. 14, fig. 4).

Distribution (N.B. often recorded as *Elphidium* cf. *alvarezianum*)

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, crags of Thorpe (Aldringham) and Sizewell (Rifle Range), Lf 1–Lf 5 assemblage biozones of Ludham.

(*b*) *Geographical*

Probably con-specific with specimens recorded as *Elphidium macellum* from the north coast of Kent (Hedley & Underwood 1957).

Elphidium orbiculare (H. B. Brady), 1881

1881 *Nonionina orbicularis* H. B. Brady (*Ann. Mag. nat. Hist.* (5) **8**, p. 415, pl. 21, fig. 5*a*–*b*).
1946 *Elphidium orbiculare* (Brady). (Hessland, *Bull. geol. Instn Univ. Uppsala*, **31** (1), pp. 262 etc.)

Distribution

(*a*) *Stratigraphical*

Butley Crag, *Scrobicularia* Crag, crag of Sidestrand, Lf 6–Lf 7 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1961, 1977).

Upper Late-Glacial to lower Post-Glacial of Nord-Bohuslans (Hessland 1946; Brotzen 1951) and upper Late Glacial of Surte, Sweden (Brotzen 1951), Lower Post-Glacial *Mytilus*- and *Ostrea*-clay of the Oslofjord area (Feyling-Hanssen 1954*a*).

(*b*) *Geographical*

Arctic (Cushman 1948; Loeblich & Tappan 1953), sporadic off the north of Scotland; most common on the Scottish shelf (Harris 1958).

Elphidium pseudolessonii ten Dam & Reinhold, 1941

1941 *Elphidium pseudolessonii* ten Dam & Reinhold (*Meded. geol. Sticht.* (C–V) **1**, p. 53, tabelle 1, pl. III, fig. 10*a*–*b*).

Distribution

(*a*) *Stratigraphical*

Walton, Newbourn and Butley Crag, *Scrobicularia* Crag, Chillesford Crag, crag of Thorpe (Aldringham), Sizewell (Rifle Range), Easton Bavents, Sidestrand. Lf 1–Lf 5 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

Elphidium williamsoni Haynes 1973

1858 *Polystomella umbilicatula* Williamson (p. 42, pl. 3, figs 81, 82).
1973 *Elphidium williamsoni* Haynes (p. 207, pl. 24, fig. 7, pl. 25, figs 6, 9, pl. 27, figs 1–3).

Distribution (N.B. this species has frequently been recorded as *Elphidium excavatum* and more recently, since 1971, as *Elphidium articulatum*.)

(*a*) *Stratigraphical*

Scrobicularia Crag, Thorpe (Aldringham), Sizewell (Rifle Range), and Sidestrand crags, Lf 2–Lf 5 assemblage biozones of Ludham (Funnell 1961 *a*, *b*; Funnell & West 1977).

Hoxnian of Clacton-on-Sea (van Voorthuysen 1949), Eemian of Amersfoort (van Voorthuysen 1955), Upper Late-Glacial to upper Post-Glacial of Nord-Bohuslans (Hessland 1946; Brotzen 1951), and lower Late-Glacial to upper Post-Glacial of Surte, Sweden (Brotzen 1951), Post-Glacial *Mytilus*-, *Cyprina*- and *Isocardia*-clays of the Oslofjord area (Feyling-Hanssen 1954*a*).

Holocene of Lancashire and Cheshire (Nyi Nyi 1956), Holocene of central Broadland (Coles 1977).

(*b*) *Geographical*

In hyposaline lagoons and estuaries, Baltic and southern North Sea, English Channel, North Wales and Arcachon (Murray 1971). Occurs on tidal flats in Breydon Water (Coles 1977).

Eponides repandus (Fichtel & Moll) 1803

1803 *Nautilus repandus* Fichtel & Moll (*Test. Micr.*, p. 35, pl. 3, figs *a–d*).
1931 *Eponides repanda* (Fichtel & Moll). (Cushman, *Bull. U.S. natn. Mus.* **104**, pt 8, pp. 49–51, pl. 10, fig. 7*a–c*).

Distribution

(*a*) *Stratigraphical*

Coralline Crag (Burrows & Holland 1897), Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Thorpe (Aldringham) Crag, Lf 1–Lf 2 assemblage biozones of Ludham (Funnell 1961*a*, *b*; Funnell & West 1977).

(*b*) *Geographical*

Common in the West Indies, but also extending into cooler waters (Cushman 1931), Barents Sea, southern North Sea, English Channel, Arcachon, Bay of Biscay (Murray 1971).

Quinqueloculina seminulum (Linnaeus), 1758

1758 *Serpula seminulum* Linnaeus. (*Systema Naturae*, 10th edn, vol. 1, p. 786. Holmiae, Sweden.)
1826 *Quinqueloculina seminulum* (Linnaeus) (d'Orbigny *Annls Sci. nat.* (1) **7**, p. 303).

Distribution

(*a*) *Stratigraphical*

Coralline and Red Crags (Burrows & Holland 1897); Lf 1–Lf 2, Lf 5–Lf 6 assemblage biozones of Ludham (Funnell 1961*a*, *b*; Funnell & West 1977).

Upper Late-Glacial to Upper Post-Glacial of Nord-Bohuslans, Sweden (Hessland 1946; Brotzen 1951); Late-Glacial and Post-Glacial of the Oslofjord area (Feyling-Hanssen 1954*a*, *b*). Appears to be commonest during temperate periods in the North Sea Basin, but apparently also tolerant of colder conditions.

(*b*) *Geographical*

Shetland and Orkney Islands, Norway, Fehmarn Belt at entrance to Baltic, southern North Sea, English Channel, Bay of Biscay, Arcachon, Galicia (Murray 1971). Characterized by Murray as a seemingly southern species close to its northern limit around the British Isles, but recorded from the Arctic by Cushman (1948).

Textularia sagittula Defrance, 1824

1824 *Textularia sagittula*. (Defrance, in Blainville, *Mollusques, Vers, et Zoophytes, Dictionnaire des Sciences Naturelles* **32**, p. 177, pl. 13, figs 5, 5*a* (in atlas). Paris, France.)

Distribution

(*a*) *Stratigraphical*

Coralline and Red Crags (Jones *et al.* 1866; Burrows & Holland 1897); Walton, Newbourn and Butley Crags, *Scrobicularia* Crag, Lf 1–Lf 2 and Lf 5 assemblage biozones of Ludham (Funnell 1961*a*; Funnell & West, 1977).

Post-Glacial *Isocardia*-clay of the Oslofjord area (Feyling-Hanssen 1954*a*). The most persistent of the late Cenozoic species of *Textularia* in the North Sea Basin, but probably confined to temperate periods.

(*b*) *Geographical*

Scottish and Faeroes shelves (Harris 1958), Oslofjord, Skagerak, Gullmar Fjord, Kattegat, English Channel, Bristol Channel, Celtic Sea, Arcachon and Galicia (Murray 1971). Characterized by Murray as a southern species with respect to the British Isles area.

APPENDIX II. MOLLUSCA AT WROXHAM HALL

BY P. E. P. NORTON

(*a*) *Stratigraphy*

Woodward (1881, p. 63) described the section at Wroxham Hall Pit (TG 272160) as showing three beds in the upper crag above Chalk. It was opened in 1964 by Hey, West and Norton who observed two adjacent sections as follows:

metres	
0–0.75	brown stony loam
0.75–1.00	reddish hoggin (stony sand and silt)
1.00–1.30	shelly sand with pebbly sand, maybe not *in situ*
1.30–1.50	shelly yellow sand and gravel
1.50–1.57	sandy clay with lumps of clay
1.57–1.70	grey-brown laminated clay (base of upper section)
0.15–0.17	soil and sand (= 1.70 m upper section), grey clay (extending laterally)
0.17–0.27	yellow sand
0.27–0.29	shell grit
0.29–0.34	grey clay
0.34–0.38	pale sand
0.38–0.61	shelly coarse sand with large rounded flints
0.61–0.71	coarse yellow sand
	Chalk

(*b*) *Mollusca*

(i) 0.38–0.61 m sample, lower section, 1.91–2.14 m below top of upper section. Very few shells (30 individuals) were present: *Mytilus edulis* 6.5, *Mya arenaria* 3.5, Bivalves (worn and unidentifiable) 7, *Macoma* sp. 4, *Hiatella arctica* 2.5, *Yoldia* sp. 2. More than half the sample could not be identified properly: in the remainder, littoral shells predominate. These indicate the presence of sandy estuarine conditions (*Mya arenaria*), with *Mytilus edulis* in clumps or on stones. The sublittoral is interpreted as having included muddy, silty and coarse material, with algae or stones supporting *Hiatella arctica*. The assemblage does not appear similar to any so far mentioned.

(ii) 1.30–1.50 m sample, upper section. *Cerastoderma edule* 30 %, *Macoma* sp. 19 %, *Corbula gibba* 7 %, *Donax vittatus* 5 %, *Macoma obliqua* 5 %, *Mya arenaria* 5 %. Forty-seven per cent of the assemblage reflects littoral conditions, 8.5 %, inner sublittoral conditions and 40 % could not be identified properly. The littoral appears to have included rocks (with *Littorina rudis* and *Mytilus edulis*) and sand with slight estuarine influence (*Mya*, *Donax*, *Cerastoderma*). A non-marine species, *Trichia hispida*, was carried in. The sublittoral was silty with coarse material. The general conditions interpreted recall, somewhat, the 'open coast marine' of Bramerton Common 580 cm sample, but the presence of *Donax vittatus* and *Corbula gibba* in 7 and 5 % frequency sets the sample apart from the others studied.

Appendix III. The vertebrate fauna of Bramerton

By D. F. Mayhew

Department of Zoology, University of Cambridge

(*a*) *Introduction*

Substantiated records of vertebrate species from the Bramerton Norwich Crag, and new identifications arising during recent studies are summarized in table 1. With the exception of vole remains, the mammal material is both scanty and fragmentary.

Full horizon and locality details are available only for the more recently collected material; specimens collected in the last century generally have no indication of which pit yielded them. The vertebrate fossils are nearly all recorded as coming from shell beds, or else from a stone bed at the base of the Norwich Crag, immediately overlying the Chalk. Prominent concentrations of shells occur in the sections at both Bramerton Common and Blake's Pit.

Recently, the lower shell bed at Blake's Pit has yielded remains of three species of *Mimomys* (Rodentia, Microtinae) now in the collection of Mr P. G. Cambridge. These specimens help to relate the Bramerton deposits to British and continental European stratigraphic schemes, and will be described in more detail in a separate publication.

(*b*) *Notes on selected species*

(i) *Mimomys pliocaenicus* Major 1902

This species is represented by isolated molar and incisor teeth and a fragmentary mandible. The three available upper third molars have three roots. The enamel islet of the lower first molar persists after the formation of roots, but dies out in the top half of the crown, being absent in the specimen figured (with islet) by Hinton (1926, fig. 100/14). The P. G. Cambridge collection from the lower shell bed at Blake's Pit includes upper second molars of *M. pliocaenicus* with three roots, and lower crowns than molars from the upper shell bed at this locality.

(ii) *Mimomys* (*Kislangia*) *rex* Kormos 1934

This species is represented by a mandible with first and second molars (NCM 728,524), figured by Newton (1882, pl. XIII, fig. 12), Major (1902, fig. 14) and Hinton (1926, fig. 100/12), and previously referred to *M. pliocaenicus*. The large size (M_1 length 4.1 mm), abundant crown cement, thin enamel and acute, backwardly directed, third outer salient angle confirm the identification of this specimen as *M. rex*, described by Kormos (1934*b*) from the Lower Pleistocene (Villanyian) of Hungary (type locality Villany-3). The lower first molar from Bramerton lacks an enamel islet (through wear) but has a clear prism fold. This last feature was not noted in teeth of *M. rex* from the type locality, but is present in teeth referred to this species by Chaline & Michaux (1974). *M. rex* has not previously been recorded from Great Britain.

(iii) *Mimomys* (*Borsodia*) *newtoni* Major 1902 (= *M. hungaricus* Kormos)

The type specimen of *M. newtoni*, from the East Runton Forest Bed, lacks crown cement and has enamel thicker on the concave sides of the triangles, as in the genus *Microtus*. *M. newtoni*

Table 1. Bramerton vertebrate fauna

species	site	horizon	collection	references
MAMMALIA				
Carnivora				
Aonyx reevei (Newton)	?	LSB	NCM	Newton 1890, 1891
Phoca sp.	?	?	BMNH, NCM	
Rodentia				
Mimomys pliocaenicus Major	?	LSB, USB	NCM, BMNH	Newton 1882, 1891, Major 1902 Hinton 1926
	BP	LSB	PGC	
M. rex Kormos	?	USB	NCM	
M. newtoni Major	?	?	BMNH	Hinton 1926
	BP	LSB	PGC	
M. reidi Hinton	?	?	BMNH	
Lagomorpha				
Hypolagus brachygnathus Kormos	BP	USB	NCM	Newton 1891, Mayhew 1975
Artiodactyla				
Euctenoceros cf. *sedgwicki* (Falconer)	?	BB	NCM	Woodward 1893
Proboscidea				
Anancus arvernensis Croiz. et Job.	?	?	IGS (cast)	Alexander 1838
proboscidean indet. (tusk fragments)	?	LSB	NCM	
PISCES				
Chrysophrys Cuvier	?	?	?	Newton 1891
Gadus morrhua L.	?	LSB	NCM	Newton 1891
G. pseudaeglefinus Newton	?	?	?	Newton 1891
G. pollachius L.	?	USB	NCM	Newton 1891
Acipenser L.	?	?	?	Newton 1891

BMNH, British Museum (Natural History); NCM, Norwich Castle Museum; IGS, Institute of Geological Sciences; PGC, P. G. Cambridge collection; LSB, lower shell bed; BB, basal stone bed; USB, upper shell bed; BP, Blake's Pit (= *Scrobicularia* Pit); ?, no information.

is a senior synonym of *M. hungaricus* Kormos 1938, which was allocated to the new subgenus *Borsodia* by Janossy and van der Meulen (1975). Practically all of the British material referred to *M. newtoni* by Hinton (1926) belongs instead to other species of *Mimomys* (Mayhew & Stuart, in preparation).

Mimomys newtoni (= *M. hungaricus*) is known from Bramerton by a lower first molar (BMNH M35155) and an upper second molar (BMNH M35154) with no precise locality data, as well as by a lower first molar and a lower third molar which were collected from the lower shell bed, Blake's Pit, by Mr P. G. Cambridge.

(iv) *Mimomys reidi* Hinton 1910

Mimomys reidi was described by Hinton (1910) on the basis of a single lower first molar from the Weybourne Crag at Trimingham. The material available from Bramerton comprises two lower first molars, a lower second molar, a lower third molar, two upper first molars and an upper second molar from the lower shell bed, Blake's Pit, together with an upper first molar (BMNH M35159) with no locality details. These teeth have enamel thicker on the convex sides of the triangles (*Mimomys* differentiation), little crown cement, and confluencies between the triangles, characters which are typical of *M. reidi*. *M. pusillus* (Mehely 1914) has abundant crown cement and is higher crowned than *M. reidi*.

(v) *Hypolagus brachygnathus* Kormos 1934

This species is represented by a single lower third premolar from the upper shell bed, Blake's Pit (Mayhew 1975). The tooth was figured as 'rodent; genus undetermined' by Newton (1891, pl. V, fig. 19). It is indistinguishable in size and morphology from material of *H. brachygnathus* from Poland (Kamyk, Kadzielnia) and Germany (Schernfeld).

(*c*) *Stratigraphic remarks*

The Bramerton deposits have yielded a spectrum of mammalian species typical of the Lower and lower Middle Pleistocene, and indicating that the deposits are earlier than those of the Cromer Forest-bed Formation (Stuart 1974). The vole remains from Bramerton are similar to those from other Norwich Crag sites, such as Thorpe by Norwich, and represent the most primitive Microtine assemblages at present known from the British Isles.

The small mammals from Bramerton support a correlation with the late Villanyian stage of European biostratigraphy and with the Tiglian C of the Dutch Pleistocene sequence (Kretzoi 1956; van der Meulen 1975; van der Meulen & Zagwijn 1974; Freudenthal *et al.* 1976; Janossy & van der Meulen 1975). The equivalence in age of the Norwich Crag and the later part of the Tiglian (which yielded the Tegelen mammal fauna) has already been suggested by Zagwijn (1974) and van der Meulen (1975).

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