BRITISH GEOLOGICAL SURVEY

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TECHNICAL REPORT WA/97/24

Geological notes and local details for 1:10 000 sheet TG 21 NE (Belaugh)

Part of 1:50 000 sheets 147 (Aylsham) and 148 (North Walsham)

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GEOLOGICAL NOTES AND LOCAL DETAILS FOR GEOLOGICAL SHEET TG 21 NE (BELAUGH)

INTRODUCTION

The following report is designed to be used in conjunction with 1 : 10 000 Geological Sheet TG 21 NE. Uncoloured copies of the map may be purchased from the Survey's offices at Keyworth. The district covered by the map is included in 1 : 50 000 Geological Sheets 147 (Aylsham) and 148 (North Walsham). It formed part of Old Series One-Inch sheet 66 NE, which was surveyed at a scale of 1 : 63 360 by H B Woodward in 1875-1880. An accompanying memoir was published (Woodward, 1881). The district was resurveyed at 1 : 10 000 scale by the present author in 1995-6, with Dr I R Basham as regional geologist.

The area lies to the north-east of Norwich (Figure 1). The town of Wroxham lies on the eastern margin of the area, with Coltishall and Horstead along the northern margin, and Spixworth in the south-west. Smaller settlements within the district include Belaugh and Crostwick, while the bulk of the district is rural. The river Bure flows across the district from north to east, but has no signicant tributaries. It flows eastwards into the area known as the Norfolk Broads and ultimately drains to the sea at Great Yarmouth. The land takes the form of a heavily dissected plateau, rising locally to a maximum of 26m OD [2880 1529], with the River Bure below 5m. Generally, the Breydon Formation peats form flat marshlands at or just below river level. The area underlain by Upper Chalk at rockhead slopes gently up to around 7m OD, the Crag outcrop has significantly steeper slopes, and the Corton Formation forms the almost flat plateau surface.

The plateau of the Corton Formation, which is locally covered by up to rather more than a metre of cover silt, produces excellent agricultural land, neither too heavy nor too light. Large crops of wheat, barley, sugar beet and potatoes are grown, and owing to the water-retentive properties of the cover silt, little artificial irrigation is required despite the low rainfall in this part of the country. However, the land underlain by the Crag and Upper Chalk are very well drained and form relatively poor arable land, requiring much artificial irrigation. Much of this land is wooded and used for commercial shooting. The floodplain of the Bure is given over to permanent pasture, which is largely grazed by cattle. This floodplain lies at an artificially low level as a result of shrinkage of the ground owing to drainage: the peats within the Breydon Formation are particularly prone to shrinkage and oxidation on drying.

National Grid References in this report are given in square brackets; these all fall within 100-kilometre square TG. All depths and thicknesses in the report are given in metres. The non-confidential water wells and boreholes in the district are shown on Figure 2; identification numbers quoted are those of the BGS records collection, in which they are prefixed TG 21 NE. Complete logs of the non-confidential wells and boreholes can be obtained from BGS Information Services (Geological Records) at Keyworth.

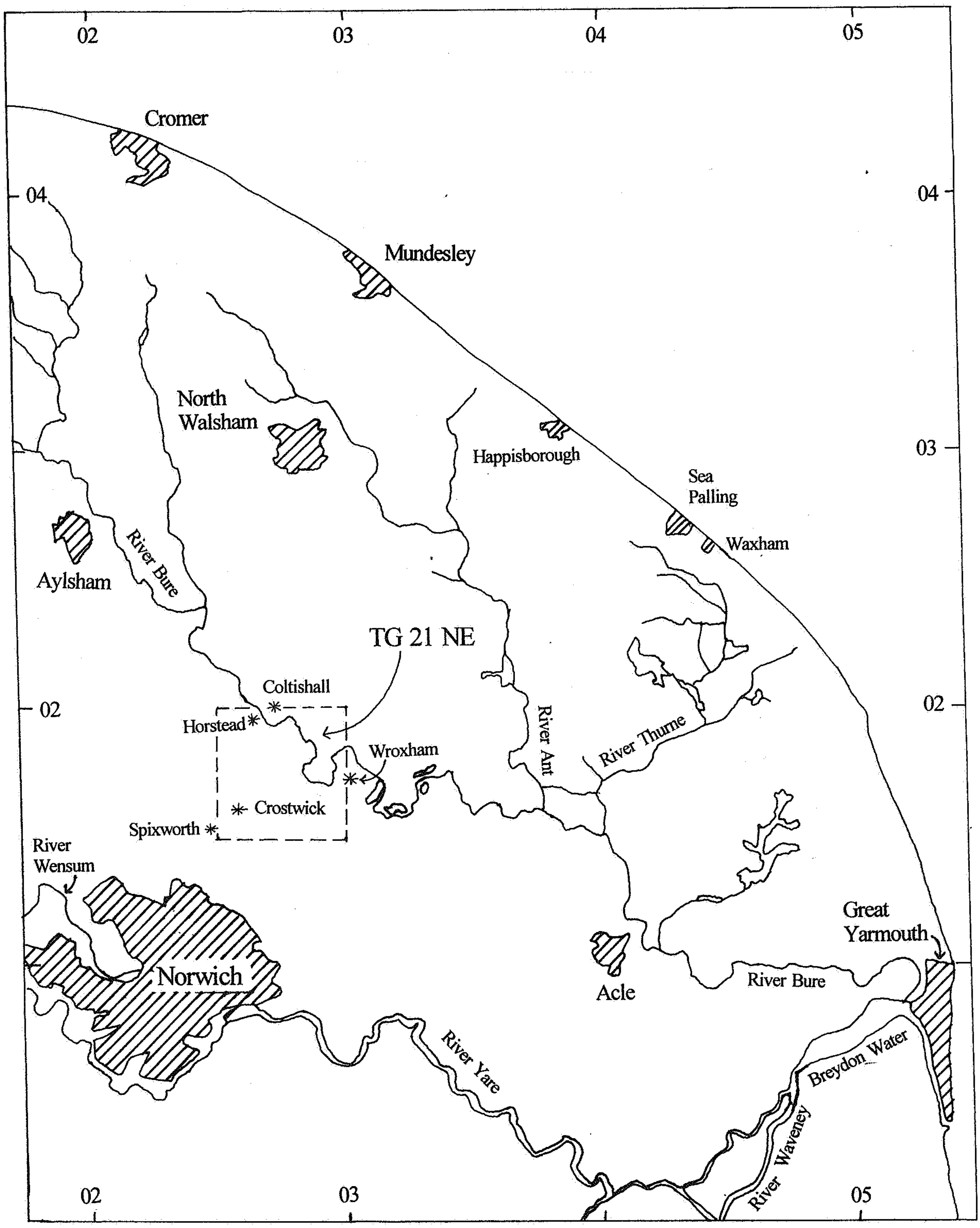
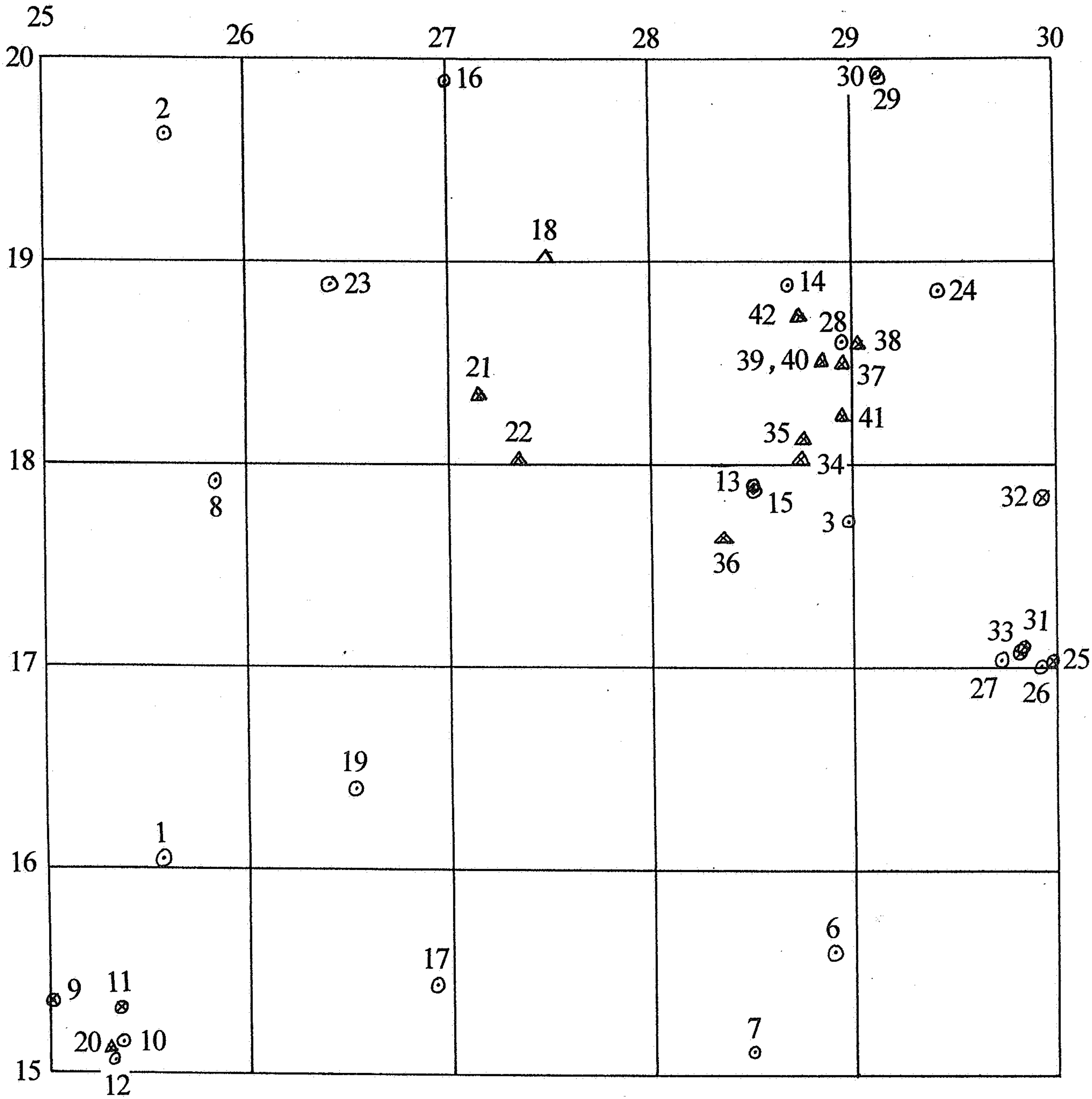


Figure 1 : Location diagram.



⊙ Water well or bore
⊗ Water well or bore, no geological log known
△ Water well or bore, site uncertain
⚠ Water well or bore, site uncertain, no geological log known

Figure 2 : Water wells and bores on Sheet TG 21 NE, taken from BGS records. The number of each site is prefixed TG 21 NE.

GEOLOGICAL SEQUENCE

Strata proved on sheet TG 21 NE are listed below. BGS practice in East Anglia is to classify all deposits overlying the Crag Group as Drift, and the Crag Group as the youngest deposits of the solid succession.

Holocene to Recent	**Made ground**	**Up to c 2.0**
	Breydon Formation	**Up to c 5.0**
	Alluvium	**Up to c 2.0**
Pleistocene to Recent	**Head and Hillwash**	**Up to c 2.0**
	Gravelly Head	**Up to c 5.0**
	River terrace deposits	**Up to c 2.0**
Pleistocene	**Cover silt**	**Up to c 1.5**
	gravel and sand	**Up to c 2.0**
	Yare Valley Formation	**Up to c 7.0**
	Corton Formation	**Up to c 10.0**
	Crag Group	**Up to c 20.0**
unconformity		
Upper Cretaceous	**Upper Chalk**	**98.5+**

SOLID FORMATIONS

CRETACEOUS AND EARLIER FORMATIONS

No strata older than the Upper Chalk have been proved by boreholes within the district, but deep boreholes in the surrounding area (Figure 3) have penetrated strata as old as Silurian. Details can be obtained from the BGS Records Collection, and are summarised in Arthurton *et al.* (1994). All three subdivisions of the Chalk Group, the Lower, Middle and Upper Chalk, are present beneath the whole of the district, although only the Upper Chalk is present at rockhead or has been proved in boreholes. The biostratigraphy, lithology and structure of the Chalk of Norfolk have been reviewed by Peake and Hancock (1961, revised and re-published 1970). The lithostratigraphy, biostratigraphy and history of research of the Chalk of Norwich were updated by Wood (1988), which is summarised in the memoir for the district (Cox *et al.*, 1989).

A map of sub-divisions of the Chalk at rockhead (Peake and Hancock, 1970) indicates that the district is largely underlain by Paramoudra Chalk, with Maastrichtian Chalk coming in around Wroxham in the east, and Beeston Chalk appearing at rockhead in the west (Figure 3). Levels of the base of the Group are also given on Figure 3. These imply a level of around -390m OD beneath the western edge of the present district. Since the base of the Crag here lies at around +10m OD, this implies that the thickness of the Chalk Group is about 400m. The thickness of Upper Chalk actually penetrated by boreholes on sheet TG 21 NE is shown on Figure 4. The base of the group is believed to dip regionally to the north-east at 0.25° to 0.5° (Arthurton *et al.*, 1994).

The principal lithology of the Chalk Group is soft, white, micritic, coccolith limestone, generally rather porous and poorly cemented. The Lower Chalk is less pure than the Middle and Upper Chalk and is grey in colour and flintless, with some indurated layers or 'hardgrounds', and bands of dark grey shell-detrital chalk. The Middle Chalk is flintless except for two horizons, and includes seams of marl throughout its thickness and beds of shell-detrital chalk in its lower part. The bulk of the Chalk Group however comprises the Upper Chalk, which is notably white, and rich in flint in the form of nodules or in tabular form. It contains a number of hardgrounds.

The Trunch Borehole (Gallois and Morter, 1976) (Figure 3) was sunk to provide a standard sequence for the Upper Cretaceous of East Anglia. The full log is held in the BGS Records Collection, while the biostratigraphical zones recognised are summarised in Table 2 (after Arthurton *et al.*, 1994). Comparing this with the subdivisions used by Peake and Hancock (1970) (Figure 3), the *B. lanceolata* zone corresponds with the Maastrichtian, while the Paramoudra Chalk, Beeston Chalk, Weybourne Chalk, Eaton Chalk and Basal *mucronata* Chalk are all *B. mucronata* zone, and the *O. pilula* zone is included in Peake and Hancock's map along with the *G. quadrata* zone.

The lithologies of the main subdivisions of the Upper Chalk in the Trunch Borehole may be summarised as follows:

	Thickness
Maastrichtian Chalk: soft marly chalk with large flints; low core recovery	c 21.3
Paramoudra Chalk: massive white chalk with large tabular thalassinoid flints, generally few fossils	c 54.5
Beeston Chalk: yellow, white and grey, fossiliferous chalks with large thalassinoid flints; hardgrounds at the top and base of the unit, the latter equivalent to the Catton Sponge Bed of Norwich	c 31.1
Weybourne Chalk and Eaton Chalk: grey-white marly and hard yellowish chalks with large thalassinoid-nodular flints; very fossiliferous	c 39.4
Basal *mucronata* Chalk: grey-white chalk with more marly bands and large and small nodular flints; tough hardground marking base of zone	c 17.0
Gonioteuthis quadrata Zone: grey-white marly chalk with large nodular flints; creamy white chalk with small nodular and lensoid flints	c 63.47
Offaster pilula Zone: massive white chalk with a few tabular flints	34.25
Marsupites testudinarius and *Uintacrinus socialis* zones: white massive chalk with oyster beds; largely flintless except for occasional thin tabulars	28.84
Micraster coranguinum Zone: hard grey-white marly burrowed chalk, with small scattered nodular flints; bands of medium-sized nodular flints and *Inoceramus* shells below	84.7
Micraster cortestudinarium Zone: hard grey-white and yellowish white chalk, with stylolitic surfaces, thin marl seams, hardgrounds and medium-sized nodular and tabular flints; fossiliferous, several sponge beds	11.77
Sternotaxis planus Zone: hard white massive chalk with several major hardgrounds, marly concentrations and sponge beds stained yellow or grey; flints small and nodular or thin and tabular; conspicuous marl seam at base of Upper Chalk	30.71

The upper surface of the Upper Chalk is commonly weathered to a soft, weak material sometimes known in borehole logs as 'putty chalk'. The term marl is also common in borehole logs and is also taken to imply soft chalk. In the Trunch Borehole, Gallois and Morter (1976) recorded poor core recovery in the highest 34m of the Upper Chalk, although here it was possibly glacially disturbed. In percussion-drilled water wells the top of the Chalk may not always be accurately recorded because of this softening; sand from higher strata may fall down the hole, mixing with the soft chalk and staining it brown. 'Sandy clay' 0.9m thick, which overlies 'chalk and flints' in borehole TG 21 NE/14 [2870 1890], may be softened Chalk or head. In the extreme case, 7.9m of 'light clay and sand' from +3 to -5m OD in borehole TG 21 NE/3 [2899 1773] has to be interpreted as Chalk, since Chalk is recorded above sea level at an adjacent pit (Woodward, 1881, p.60). 'Soft marly chalk' 7.6m thick was recorded beneath the 'light clay and sand', while 'soft chalk' is also recorded in boreholes TG 21 NE/1, 6, 7, 8, and 10, and 'marl' in TG 21 NE/6, 7, 8, 12, 17, 18, 19, 23, and 29. 'Dirty chalk and flint', 6.1m thick, is recorded in Borehole TG 21 NE/15 [2852 1789], 4.6m of 'sand and marl' in TG 21 NE/27 [2974 1705], and 12.2m of 'sand and chalk' in TG 21 NE/28 [2896

1862], all being interpreted as softened chalk contaminated during drilling.

Local details

Within the present district the Upper Chalk is widespread at rockhead, but there are no natural exposures since it is everywhere covered by gravelly head or valley-fill deposits. The Upper Chalk underlies at shallow depth the gentle slopes above the outcrop of the Breydon Formation peat, and below the steeper slopes of the Crag, and it has become buried beneath the gravelly head derived from the Crag uphill. Thus all the areas shown as Upper Chalk outcrops on the map are quarries, but since all are disused and variously overgrown, there is little Upper Chalk to be seen without excavation. During the current survey, 0.3m of weathered chalk was exposed beneath Crag in a new gravel pit [2657 1675] north of Old Hall Farm, and a similar thickness beneath Crag in a temporary excavation [2874 1664] at Home Farm. The Chalk is also regularly exposed in slip faces in the steeper quarry faces, or ploughed up from beneath the gravelly head in arable fields.

Lyell (1865, p.320) eloquently described the paramoudras exposed by quarrying: "I visited, in the year 1825, an extensive range of quarries then open on the river Bure, near Horstead... which afforded a continuous section, a quarter a mile {0.4 km} in length, of white chalk, exposed to the depth of 26 feet {7.9m}, and covered by a thick bed of gravel. The pot-stones {paramoudras}, many of them pear-shaped, were usually about 3 feet {0.9m} in height and 1 foot {0.3m} in their transverse diameter, placed in vertical rows, like pillars at irregular distances from each other, but usually from 20 to 30 feet {6.1 to 9.1m} apart, though sometimes nearer together... These rows did not terminate downwards in any instance which I could examine, nor upwards, except at the point where they were cut off abruptly by the bed of gravel. On breaking open the pot-stones, I found an internal cylindrical nucleus of pure chalk, much harder than the ordinary surrounding chalk, and not crumbling to pieces like it, when exposed to the winter's frost". Woodward (1881) described the pit as "the one north of Wroxham Old Hall": there were three farms named 'Old Hall' on the Wroxham estate, but the only extensive chalk pit north of any of them is the Little Switzerland/Paradise complex, and the canal [2733 1710 to 2803 1758] cut through Paradise would certainly have revealed a chalk exposure a quarter of a mile in length. Woodward visited this pit 50 years after Lyell, and found only scattered paramoudras; the pit closed in 1878.

Woodward (1881) also records "at St. James's Pit ... I saw a line of three if not four paramoudras, which appeared in the layers of flints that were four or five feet {1.2 or 1.5m} apart. One paramoudra was nearly 7 feet {2.1m} long, and extended through two layers of flints." This pit is presumably the large one beside White Lion Road [280 200], which straddles the boundary of the present district and sheet TG 22 SE. Apart from this, Woodward only records Upper Chalk in his descriptions of Crag sections, although these would most likely all have been in old Chalk quarries. In 'a pit immediately west of Belaugh Old Hall', he records (p.60) beneath the Crag: 'Chalk with flints, and with tolerably even surface'. Belaugh Old Hall must be the 'Old Hall' [290 177] south of Belaugh, although the disused pits are on the north side of the buildings. At the lime-kiln, north of Rackheath Church (Limekiln Hole [269 154]), the Crag rested upon a surface of Upper Chalk 'marked by broad undulations'. Woodward (1881) also records chalk beneath the Crag at the following sites:

p.61: 'by the Wood, S.E. of the Old Hall', which presumably refers to one of the pits [291 175, 291 174] south-east of Old Hall;
p.58: 'a pit by the valley south of Burnt Lane Plantation': (?[272 172]);
p.61: east of the White Horse public house [265 164].
p.63: two pits south of the large pit west of Wroxham Hall; presumably [272 162] and [272 158](Dobbs' Plantation);
p.61: half a mile west of Crostwick Church [251 157].
p.62: 'a pit near Wroxham Park, situated to the east of the hall, near the farm buildings' [286 166].

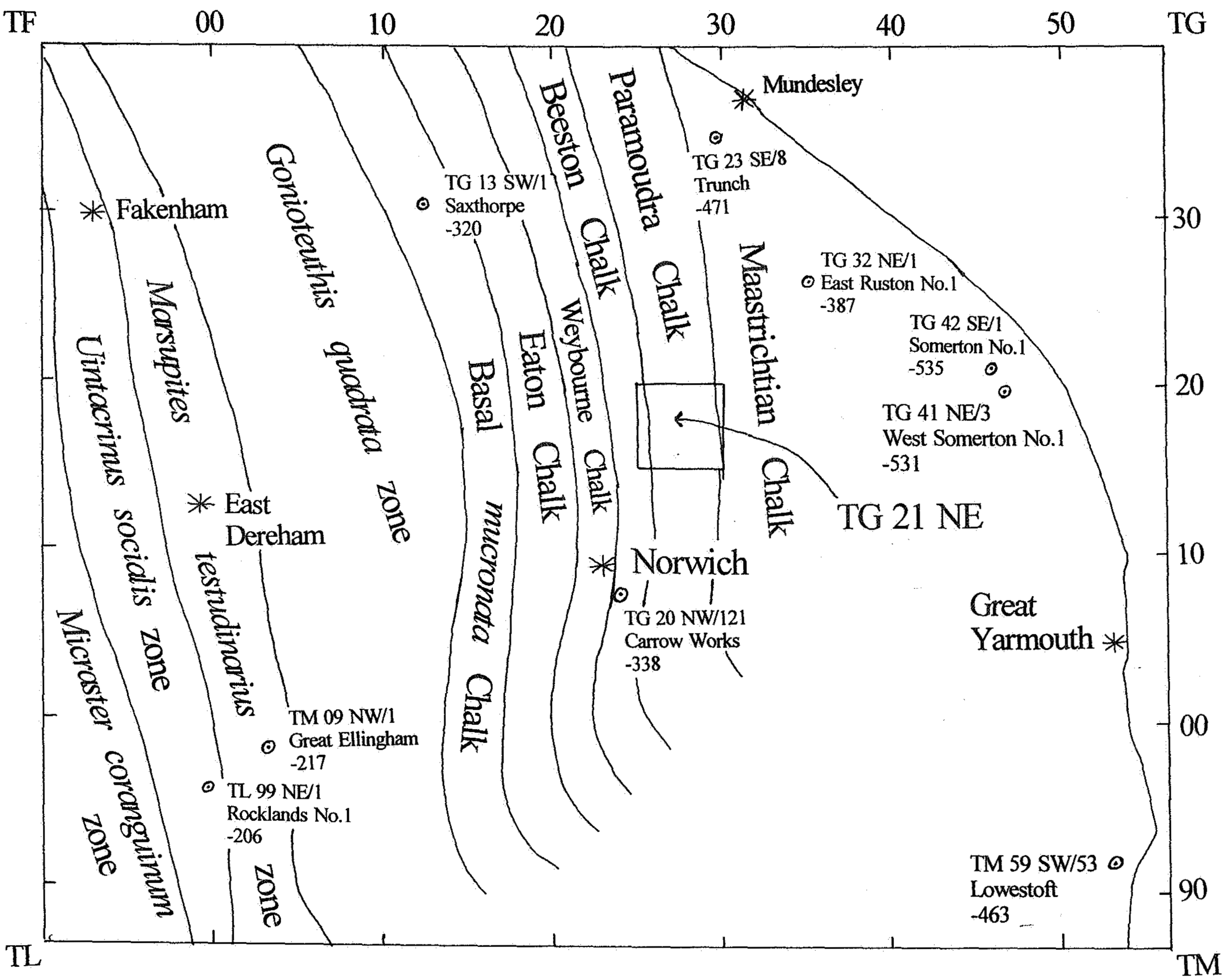


Figure 3 : Map of north-east Norfolk, showing deep boreholes. Along side each is shown its registration number in the BGS borehole records collection, its name, and the OD level of the base of the Chalk Group. The sub-divisions of the Upper Chalk at rockhead are shown, after Peake and Hancock (1970).

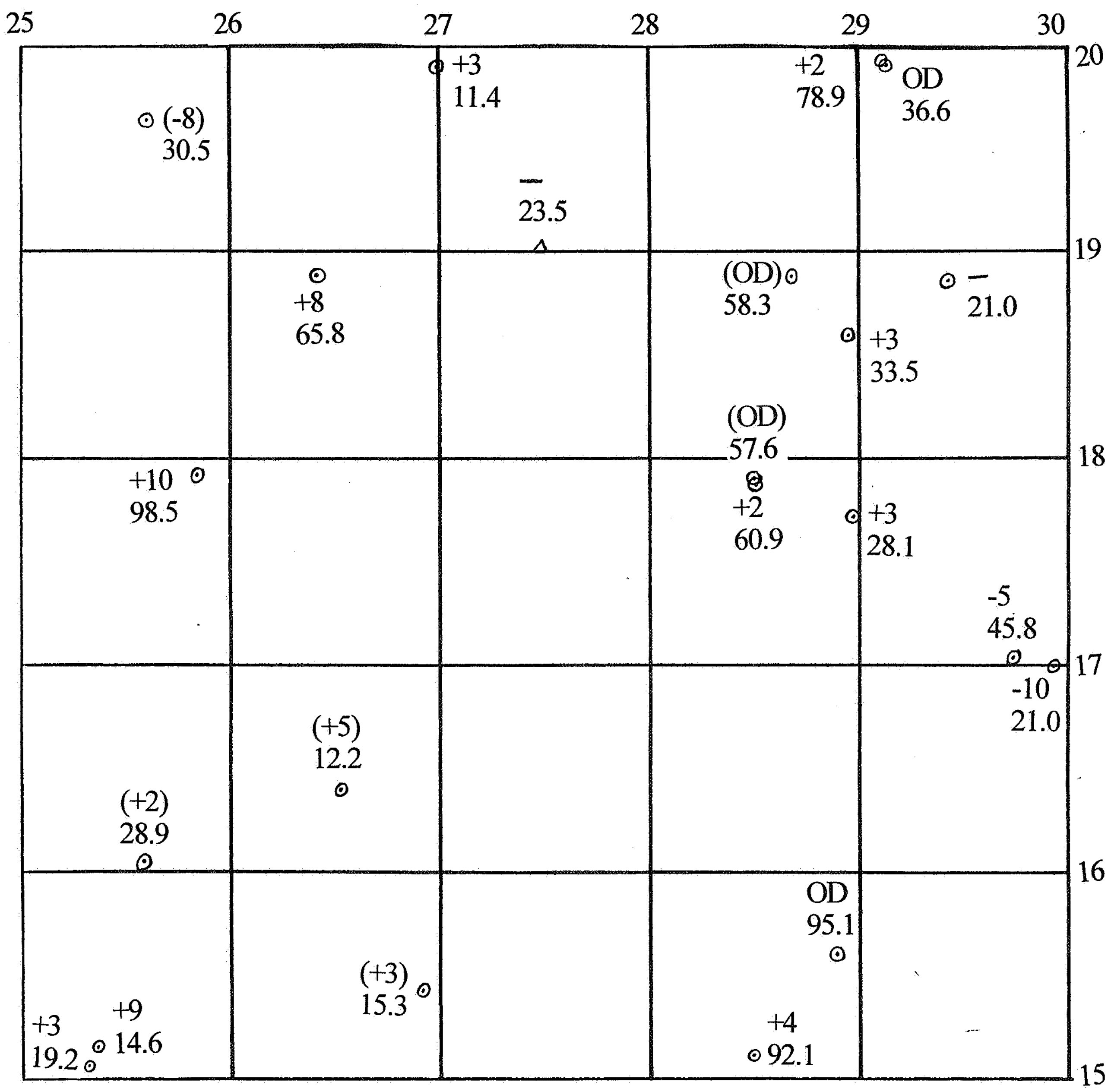


Figure 4 : Water wells proving Upper Chalk. The lower figure indicates the thickness of Upper Chalk penetrated. The upper figure indicates the OD level of the top of the Upper Chalk; where it is in brackets, the Upper Chalk is *not* overlain by Crag.

UPPER CHALK	*Belemnella lanceolata* s.l.	c.61m
	Belemnitella mucronata s.l.	209.07m
	Gonioteuthis quadrata	272.50m
	Offaster pilula	306.72m
	Marsupites testudinarius	?
	Uintacrinus socialis	335.26m
	Micraster coranguinum	411.50m
	Micraster cortestudinarium	432.03m
	Sternotaxis plana	469.32m
MIDDLE CHALK	*Terebratulina lata*	493.97m
	'*Mytiloides labiatus* s.l.'*	500.51m
LOWER CHALK	*Metoicoceras geslinianum*	501.10m
	Calycoceras guerangeri	c.502m
	Acanthoceras jukesbrownei	502.32m?
	Acanthoceras rhotomagense	506.30m?
	Mantelliceras dixoni	509.80m
	Mantelliceras mantelli	512.22m

*includes an unnamed zone, the *Mytiloides* spp. Zone and the *Neocardioceras juddii* Zone

Table 2 : Biostratigraphical zones recognised in the Trunch Borehole, with depths of occurrence of zonal boundaries, after Arthurton *et al.* (1994).

QUATERNARY - CRAG GROUP

The Crag Group represents the relatively coarse-grained marginal facies of a well-developed marine clastic sequence present in the southern North Sea (Cameron *et al.*, 1992). The Crag of the present district has commonly been referred to as the 'Bure Valley Beds' and comprises sands and shelly sands, flint gravels and seams of clay. It has been shown on the 1:10 000 scale map as Norwich Crag Formation, but at the time of writing it is proposed to raise the term Wroxham Crag Formation to include the Bure Valley Beds, and this will be shown on the forthcoming 1:50 000 sheet. Throughout its outcrop in the district, the Crag gives rise to gravelly soils, and hand-augering is rarely effective at penetrating this. However the fourteen boreholes in the district which prove the Crag (Figure 5) indicate that a high proportion of the group is in fact made up of sands and clays. The gravels tend to occur high in the sequence, and being readily eroded, wash downhill, obscuring the sands and clays. Bright orange sands are however commonly found excavated by rabbits and badgers.

The Crag accounts for a greater area of outcrop than any other formation in the district, and occupies the steepest slopes, between the plateau of the Corton Formation above and the less steeply sloping outcrop of the gravelly head which rests upon the Upper Chalk below. Figure 5 shows the sites of the fourteen water wells and boreholes which proved Crag, with the inferred levels of the base and top. However these figures should not be accepted without question. It has already been explained that the top of the Chalk is difficult to fix in borehole logs, because the highest Chalk is very soft and sand can fall down into it and stain it brown during drilling. The top of the Crag is also difficult to distinguish, since the overlying Corton Formation may be formed of similar gravel.

The unconformable base of the Crag appears to be a gently undulating surface, affected by solution and piping of the Upper Chalk. It rises generally westwards from a minimum record of -10m OD in Wroxham in the east to a maximum of +10m OD in the west. Mapping confirms the gently undulatory nature of the unconformity and its westward rise, although in the absence of exposures or quarries indicating its exact position, mapping of the base is not very precise. The unconformity gives rise to a change of slope since the Crag is more readily eroded than the Uppper Chalk, and hence occupies steeper slopes, but the unconformity itself is covered by gravelly head and the change of slope is not clear-cut as there is no spring-line, the Crag and Chalk being in hydraulic continuity.

Where it is overlain by the Corton Formation, boreholes indicate that the top of the Crag rises from around +12m OD in the north-east, to +18m OD in the south-west, while mapping of the outcrop of the base of the Corton Formation indicates a level of around +13m to +17m OD over most of the district. However this mapping is also rather imprecise, since both the highest Crag and lowest Corton are very gravelly. The junction is indicated by an upward increase in the amount of fresh, shattered flint in the gravel brash, by a rather gentle change of slope, and commonly by disused gravel pits at the top of the Crag. The greatest thickness of Crag proved is 18.6m, in borehole TG 21 NE/26 [2995 1701], and a figure of 20m has been adopted on the map, although it is possible, in view of the variable solution of the upper surface of the Chalk, that the Crag may locally exceed this thickness.

The sands of the Crag are fine- to medium-grained, well-sorted and micaceous. In an unweathered state they are glauconitic and dark green or dark grey in colour, but near the surface they normally become oxidised to shades of yellow and red, with layers of iron pan developing from the decomposition of glauconite. Out of 14 boreholes which penetrated the Crag, 12 mention sand, but only two of these indicate the colour of the sand: both TG 21 NE/23 [2643 1890] and /30 [2914 1994] indicate red sand at the base of the sequence, while /30 also records yellow sand higher up. Since the Crag is relatively thin and deeply dissected in this district, it is possible that no unweathered glauconitic strata are preserved. Fossils are not common, particularly in the upper part of the sequence, possibly as a result of decalcification, but shelly sands are common lower in the sequence. The only reference to fossils in a borehole record is 9.1m of 'sand and sea shells' in TG 21 NE/15 [2852 1789].

Gravels are an important constituent of the local Crag: only one borehole (TG 21 NE/7 [2850 1513]) records a complete sequence with no mention of gravel at all, either as 'gravel', 'shingle' or 'stone'. However its importance is hard to assess objectively from field mapping, since the gravel washes down over the sands and gives the impression that it is totally dominant. Boreholes TG 21 NE/16 and /8 [2700 1990, 2586 1793] record the whole Crag sequence, and also the thin overlying Corton Formation, as gravel, respectively 12.2m and 6.4m thick. Boreholes TG 21 NE/3, /12, /25 and /27 record the whole sequence as gravel and sand, not subdivided, and thickest (18.6m) at /25. The other five borehole logs subdivide the sequences, with gravel low in the Crag in TG 21 NE/28 [2896 1862] and high in the Crag at TG 21 NE/10, /15, /23, and /30. The gravel is dominated by flint clasts, and these may be up to 20cm long. The flints are generally of high sphericity, well rounded and chatter marked, particularly the smaller ones, but a distinction was noted between pits in which massive beds of very high sphericity flints indicated beachface aggradation [2662 1680, 2872 1724], and a pit [2696 1700] where less massive, more sandy beds of gravel, with flints of lower sphericity, indicated offshore, possibly sub-littoral sedimentation. Quartz and quartzite are also important constituents of the gravels.

In Suffolk the Crag commonly has a basal bed of pebbles and cobbles of glauconite-coated flint, up to 2m thick, representing a transgressive beach deposit (Hamblin, in Moorlock *et al.*, in press). A similar basal conglomerate in Norfolk is generally referred to as the Stone Bed. It is certainly present at the only pit [2657 1675] at which the unconformity was observed during the present survey. The flints there are up to 20 cm long, with black cortices and white patinas, with their horns broken off by abrasion, in a matrix of orange-brown coarse-grained sand. However, only one of the boreholes specifically mentioned a basal bed: TG 21 NE/10 recorded 0.6m of 'hard pan', which could either mean gravel of iron pan. Six boreholes quote thick sand sequences resting directly on the Chalk, whilst the other seven record generally gravelly sequences in this situation.

Clays, generally grey or buff in colour, are common in the Crag, interbedded with the sands and gravels. They are recorded in four of the boreholes, TG 21 NE/7, /28, /29 and /30, up to 4.3m thick. In eastern Suffolk a similar aggradation of sands, gravels and clays is recorded (Hamblin, in Moorlock *et al.*, in press), and interpreted as a coastal complex, with gravel bodies (the 'Westleton Beds') interpreted as shoreface deposits, and the Easton Bavents and Covehithe clays interpreted as estuarine and lagoonal. The same interpretation may apply in the present district.

The Crag in this district is wholly of Quaternary age. The nearest boreholes at which thick sequences have been dated are at Ludham on sheet TG 31 NE, where the Red, Norwich and Wroxham Crag formations are about 50m thick, and Ormesby on TG 51 SW, where they are 56m thick (Arthurton *et al.*, 1994). Pollen and foraminiferal studies of the Ludham boreholes (West, 1961; Funnell, 1961) led to the raising of five climatic stages (West, 1961). From the base up, these are the Ludhamian (temperate), Thurnian (glacial), Antian (temperate), and Baventian (glacial). Further stages have since been proposed: the Pre-Ludhamian (cold; Beck *et al.*, 1972) beneath the Ludhamian, and the Bramertonian (warm; Funnell *et al.*, 1979), Pre-Pastonian (cold; West, 1980) and Pastonian (warm; West, 1980) above the Baventian. However, it has since been suggested that the Bramertonian underlies rather than overlies the Baventian, so that the Antian and Bramertonian represent a single warm stage, and the Baventian and Pre-Pastonian a single cold stage (Gibbard *et al.*, 1991).

The presence of large local breaks in deposition can pose problems with correlation of the Crag. For instance, whilst all stages from Ludhamian to Baventian are represented in the Ludham Borehole, in the Ormesby Borehole the lower strata are referred to the Pre-Ludhamian and Ludhamian stages, and the upper strata to the Pre-Pastonian and Pastonian stages (Harland *et al.*, 1991). This break is believed to represent a regional unconformity between the Thurnian regression and the Antian/Bramertonian transgression, and is taken by Hamblin *et al.* (1997) as the base of the Norwich Crag. These authors propose that a further transgression occurred after the Baventian regression, and they suggest that this occurred during the Pastonian. This transgression is taken as the base of the Wroxham Formation. The Crag sequence in Suffolk is shown in Figure 6, taken from Hamblin *et al.* (1997).

The name Bure Valley Beds was introduced by Wood and Harmer (1868; see also Harmer, 1869, 1877, 1894; Wood, 1870). They realised from their fossil content that the beds were marine, but because of the presence of the cold-water mollusc *Macoma balthica* they classed them as the lowest horizon of the Glacial Series and not with the Crag. However, Prestwich (1871) classed most of the fossiliferous beds, with or without *Macoma balthica*, as Norwich Crag, and equated the gravels of the Bure Valley Beds with the Westleton Beds of Suffolk. These latter have recently been demonstrated to be of Baventian age (Hamblin *et al.* 1997). Woodward (1879, 1881) similarly included the Bure Valley Beds in the Crag, and noted (1881) that *M. balthica* occurs only in the upper part of the Bure Valley Beds. This was confirmed by excavation of the section at Dobbs' Plantation [272 158] in 1977 (Cambridge, 1978a, b). Funnell (1979) studied the foraminifers from Dobbs' Plantation and found an intertidal or shallow sub-tidal, temperate, open coast assemblage at the base, and a boreal, increasingly cold intertidal or shallow sub-tidal assemblage from 0.4 to 1.25m above the Chalk.

The gravels of the Bure Valley Beds closely resemble the Westleton Beds in their sedimentology, as appreciated by Prestwich, and indeed the whole assemblage of gravels, clays and sands closely resembles the Baventian coastal complex of Suffolk, of which the Westleton Beds comprise the gravel component. Also the Baventian strata of Suffolk and the Bure Valley Beds both formed in a cold climate. However, the Bure Valley Beds are unlikely to be Baventian in age, since they contain a significant proportion of quartz and quartzite pebbles, species which were not available in any quantity during the Baventian. It thus follows that the strata with *Macoma balthica* formed either during a later part of the cold period of which the Baventian formed an early part, or else during the next cold period. However, whilst the upper part of the Bure Valley Beds clearly formed in a cold period, this is not the case with the lower strata, which lack *M. balthica*. Also, since the gravels of the Bure Valley Beds resemble the Westleton Beds, which are known to be a regressive sequence formed at a time of low sea level, it is difficult to relate them to the transgression required at the base of the Bure Valley Beds. Thus it is likely that the lower part of the Bure Valley Beds represent a transgression during a warm period, whilst the upper part, with *M. balthica*, represent a regression during a cold period. Since no disconformity is known within the Bure Valley Beds, it is likely that both of these periods are post-Baventian, and it is suggested that the transgression is equated with the Pastonian transgression proposed in Suffolk by Hamblin *et al.* (1997).

Since the above comments are based on excavations in the western part of the district, the possibility remains that in the eastern part of the district, where the Crag is thicker, strata earlier than the Bure Valley Beds, ie Norwich Crag earlier than the Pastonian transgression, may also be present.

Local details

Six outcrops of Crag occur within the district, separated by valleys in which the Upper Chalk is present at rockhead.

Buxton Road

The Crag is about 11m thick, with the arable fields revealing gravel brash of rounded flints, quartz and quartzite at all levels. Orange sand and gravel were noted at burrows in an old marl pit [2505 1977] and scrapes of orange sand in the bank nearby [2507 1981, 2529 1980]. The large marl pit with canal communication [259 199] was deserted and overgrown by the time Woodward (1881) recorded a few shells collected from it.

Coltishall

Borehole TG 21 NE/16 [2700 1990] records 12.2m of 'gravel' overlying the Upper Chalk; this is believed to include the whole of the Crag plus around a metre of Corton Formation. No exposures and very little brash were recorded in this largely built-up area.

Horstead to Stanninghall

Gravel brash of rounded flints, quartz and quartzite occurs at all levels in the arable fields west of Frettenham Road, including a specimen of *Cerastoderma edule* [252 195]. In the west of the district, orange sand was augered [2501 1896, 2511 1913], and a seam of brown clay was noted within the Crag outcrop [2510 1949]. One disused pit [259 195] was worked for marl from the Upper Chalk, but two others [251 193, 260 193] appear to have been worked for gravel or clay from the Crag. Crag was previously exposed in marl pits north of Green Lane [264 194 to 267 192]; Burnet (1728, vol.2, p.46) noted "a bed of these Cockle-shells at Horstead in Norfolk, in a Gravel Pit, in a Rising Ground, near the River, by the Mill", while Woodward (1881, p.58) recorded 12 species of shells in the road cutting [2681 1922]. South of Green Lane is a further disused gravel pit [267 190], and bright orange sand had been dug from a pipe trench [2661 1920]. Borehole TG 21 NE/23 [2643 1890] records clay (Corton Formation?) to 1.8m, sand and stone (?all Crag) to 7.6m and red sand to 10.4m, resting upon Upper Chalk. The Crag is thus about 8.6m thick.

East of Horstead Lodge [264 188] is an extensive outcrop of Crag, with disused marl pits around the edge and small infilled pits within the outcrop [2777 1849, 2775 1843, 272 186]. The arable fields here are characterised by soils with orange coarse-grained sand, and are mostly less gravelly than to the north-west, although very gravelly areas were noted [268 185, 274 188, 272 185, 276 187]. Another small old pit occurs [265 185] south of Horstead Hall. In the ploughed fields west of Heggatt Hall [271 183] the brash suggests that the higher part of the Crag is more gravelly than the lower, although borehole TG 21 NE/8 [2586 1793] records 6.4m of gravel which will account for the whole of the formation, probably including some Corton Formation above. South-east of Heggatt Hall most of the fields are grassed, but ploughed fields revealed very gravelly [271 175] and less gravelly [277 180] soils. There is a small disused pit adjacent to the hall [272 181].

Whitehead (1881) records the following section in the Crag, resting directly on the Upper Chalk, at 'a pit by the valley south of Burnt Lane Plantation', which may be that [272 172] south of Granny Bard's Lane:

Pebbly gravel and sand	1.52
Laminated clay	0.08
Sand	0.15
Gravel	0.15
Laminated clay and sand	0.31
False-bedded sand and gravel with large flints	1.07

West of here the soil is very gravelly, and three small, active gravel pits confirm that most of the Crag sequence here is gravel:

Section TG 21 NE/HA1 [2696 1700]:

Gravel, clast-supported; largely flint, well rounded and chatter-marked, clasts to 7cm long, little shattering; small amounts of quartz and quartzite; well sorted; deep orange-brown to deep orange; cross-bedding dipping north; stringers of orange coarse-grained sand up to 10 cm thick, very lenticular, with channel structures and cross-bedding dipping to N110 and N290; much iron pan in both gravels and sands... c.3.0+

Section TG 21 NE/HA3 [2662 1680]:

Gravel, clast-supported; pale grey to deep reddish brown; mostly flints around 4cm long, a few up to 40cm; small flints are of high sphericity and not shattered, large ones are less worn and more shattered; some iron pan; matrix of coarse-grained sand, grey, yellow and brown; stringers of sand and sandy gravel showing cross-bedding due north & south; overall dips due north & south imply cambering... c.3.0m

Section TG 21 NE/HA2 [2657 1675]:

Gravel, clast-supported; deep orange-brown, poorly sorted, structureless except for some apparently horizontal stringers of yellow-orange coarse-grained sands; flints of all sizes up to 20cm long, the smaller ones well rounded, chatter-marked and not shattered, the larger ones less rounded and more shattered	2.0+
Clay and silt, pale grey stained brown; horizontal, well bedded	0.5
Gravel; large fresh flints, with black cortex and white patina, up to 20cm+ long; mostly rather worn, with horns broken off; matrix of orange-brown sand	0.4
Upper Chalk; white chalk, weathered and softened	0.3+

Hills and Holes Farm is possibly named after a series of disused gravel pits in the upper part of the Crag [261 172, 262 172, 263 172], although there are also pits lower in the sequence [263 170, 261 167]. The soil in the ploughed field [262 168] east of Stanninghall Wood was very gravelly, with very rounded, chatter-marked flints, quartz and quartzite clasts up to 8cm long. West of North Walsham Road the soil continues to be very gravelly and there are further disused pits, presumably worked for gravel, in the upper and middle part of the Crag sequence [260 171, 259 171, 255 173, 255 171, 252 174, 253 173, 253 170, 252 168]. Orange sands were seen in burrows in two of these pits [255 173, 255 171], and red clay was ploughed up [253 175] west of Stanninghall Farm. The pit [252 168] north of Hillside is 4m deep and burrows revealed gravel of rounded flints, quartz and quartzite.

Crostwick

The common at Crostwick is very gravelly, with several small disused pits [257 156, 257 157, 257 158] presumably dug for gravel, while depressions [259 161, 259 162] in the field to the north-east probably represent disused pits now ploughed over. The pits on the common were overgrown by 1880 (Woodward, 1881), but Pitt (1840) recorded the following section:

Accumulation of several patches of Crag, some of which are highly coloured with oxide of iron	4.57
Coarse gravel, "valves of *Cyprina Islandica* and *Nucula Cobboldiæ* in great profusion and in better preservation than in any other deposit", bed cemented into hard conglomerate	1.22
Stratum of shells embedded in fine yellow sand	0.30
Chalk...	

At the marl pit [251 157] west of North Walsham Road, Woodward (1881, p.61) noted 3.05m of false-bedded sand and pebble gravel, resting on 0.3m of flints and clay (the Stone Bed), then Chalk; he recorded six species of bivalves. Brown clay was noted in the brash adjacent to the road [2550 1550].

East of Crostwick the soil in the fields is moderately to very gravelly, with bright orange sand in badger setts [259 156, 265 159]. Fine-grained yellow sand was augered [2619 1558], overlying grey, green and orange silty clay. The pit [266 162] south of Old Hall Farm lies very low in the sequence and may have been dug for marl from the Upper Chalk. At the much larger marl pit [265 163] opposite the farm, Whitehead (1881) recorded 3.7m of pebbly sand, with fragments of shells, resting on the Chalk: 3m of orange sand, heavily bioturbated by modern burrowing, is currently visible. Borehole TG 21 NE/12 [2533 1503] recorded 'sand and shingle mixed' resting on Chalk at 15.5m depth: this must include the whole of the Crag, and also a couple of metres of Corton Formation at the the surface. Borehole TG 21 NE/10 [2537 1516] recorded brickearth (Corton Formation) to 1.5m, 'pea shingle' (Crag and ?Corton Formation) to 2.1m, sand to 9.1m then 'hard pan' to 9.8m resting on Chalk.

Belaugh

Two boreholes at Grange Farm [291 199] recorded Crag to depths of 12.5m and 14.6m, beneath thin Corton Formation: TG 21 NE/30 [2914 1994] recorded gravel to 1.8m, yellow sand to 6.1m, clay to 10.1m, then red sand to 12.5m, on Chalk, while TG 21 NE/29 [2915 1992] started in an old well at a depth of 8.5m but then confirmed the clay and sand beds at the base of TG 21 NE/30, to depths of 12.8m and 14.6m respectively. Brash in the fields to the south of the Corton Formation outcrop confirmed the gravelly nature of the upper part of the Crag. There are two disused gravel pits high in the Crag [296 198, 296 196] near Belaugh Green, and rabbit burrows in an old irrigation reservoir [291 196] high in the sequence yielded bright orange sand and gravel dominated by rounded, chatter-marked flints, whilst badger setts [2933 1959, 2934 1946] revealed further bright orange sand.

There are many disused marl pits along the base of the Crag from Coltishall to Belaugh, all now overgrown or ploughed over. Woodward (1881, p.60) records nine species of Crag fossils from the large pits in Anchor Wood [281 195], with very abundant *Macoma balthica*, but concluded that the portion of the pit then being worked (presumably for gravel) was in spoil resulting from earlier marl working. At the old pit at Grange Farm, Belaugh [288 188], Woodward (1881, p.60) described a section excavated in 1877:

Pebbly sand	3.05-3.66
Brown pebbly sand with shells	0.91-1.22
Sand	1.37-1.52
Laminated clay and sand	0.15
Stiff brown and blue clay	3.05
Sands and clays	1.07
Large flints, ?Stone Bed (at base of Crag)...	

Harmer (1869) stated that the main shell bed with abundant *Macoma balthica* was 3.1-4.6m above the Chalk, with another, less rich in *M. balthica*, below. Woodward (1881, p.41) gives a complete list of species collected.

There does not appear to be any Corton Formation on the peninsular south-west of the sewage works [292 183], and the fields of the plateau top are all very gravelly, indicating that at least the upper part of the Crag is formed of gravel, but borehole TG 21 NE/28 [2896 1862], situated only just below the plateau top, recorded sand to 1.5m depth and then gravel and 'Crag' to 12.2m. Borehole TG 21 NE/15 [2852 1789] recorded loamy sand and gravel to 1.5m then sand and 'sea shells' to 10.7m, confirming the gravelly nature of the upper part of the Crag. At a pit 'immediately west of Belaugh Old Hall', presumably one of the two [289 178, 290 178] immediately north of the hall, Woodward (1881) recorded:

Pebbly sands	2.4-3.0
Laminated clay	1.2-1.5
Chalk with flints, and with tolerably even surface...	

Presumably the section seen was below the gravels present high in the Crag hereabouts. South-east of the Old Hall, presumably at the old pit [291 185], Woodward (1881) records about 6.1m of sand and gravel, with traces of laminated clay at the base, resting on the Upper Chalk.

Farther south, gravels occur low in the Crag sequence. The large pit [286 173] south of Juby's Farm appears to be a disused gravel pit wholly within the Crag outcrop, although it is possible that it is a partially backfilled marl pit. Adjacent to it is a recently opened gravel pit, TG 21 NE/HA4 [2872 1724]:

Gravel, clast-supported, pale yellow-grey to deep orange-brown; mostly flint clasts, many of them chatter-marked, with significant amounts of quartz and quartzite; clasts mostly around 4cm long, but some flint, quartz and quartzite pebbles up to 12-15cm long; not many clasts shattered except for the largest sizes; matrix of orange to grey coarse-grained sand; much gravel is structureless, with some cross-bedding dipping at up to 28 degrees to N24, picked out by bands of deep orange to deep yellow coarse-grained sand	c.3.0+

The base of this pit is only a metre or so above the Upper Chalk.

Wroxham to Rackheath

In the field north of Wroxham Church [2965 1754], ploughing revealed bright orange fine-grained micaceous sands and well-sorted rounded-flint gravels, with much iron pan. The fields farther north are generally very gravelly, with a disused pit probably once worked for gravel [296 178], but augering yielded pale brown silty fine-grained sand [2991 1786], and pale brown to orange, micaceous clayey silt [2987 1782]. Pits farther south [2962 1732, 2962 1726, 2965 1724] appear to have been worked for clays, since this area is labelled 'brick field' on the old 1 : 63 360 scale map. Borehole TG 21 NE/27 [2974 1705] recorded 15.2m of gravel and sand, resting upon 'sand and marl' interpreted as Upper Chalk. Borehole TG 21 NE/26 [2995 1701] records 18.6m of sand and gravel resting upon Chalk at about -10m OD, which if correct is the deepest Crag known in the district.

An apparently thick seam of clay mapped on sheet TG 22 NW could be traced onto TG 21 NE to a clay pit [299 163] east of Salhouse Road, but could not be traced across the road, where gravel was augered on higher ground. Pits relatively low in the Crag [292 167, 294 168] to the south-west of Wroxham were probably worked for clay. Woodward (1881, p.63) records the following section at 'a pit by the wood between Wroxham Hall and the brickfield', which may be the more westerly of these:

Pebbly sand	1.2 to 1.5
Laminated clays and sands	1.2 to 1.5

Several large pits high in the succession [294 166, 295 162, 296 162, 292 160, 294 160] could have been worked for gravel or clay; the surrounding soils included clays [2949 1661, 2950 1630], bright orange sand and rounded-flint gravel.

Orange sand and rounded-flint gravel could be followed up the valley to a disused gravel pit [287 157] at the top of the Crag. Borehole TG 21 NE/6 [2890 1562] within the Crag outcrop, records 11.6m of sand resting upon marl (Upper Chalk), while TG 21 NE/7 [2850 1513], within the Corton Formation outcrop, records clay to 3.0, sand to 3.7, clay to 7.3, then sand to 14.6 resting upon marl (Upper Chalk) at OD +4: the lower sand is undoubtedly Crag, and possibly also the lower clay.

West of Wroxham Road, gravelly soils are found on both the Crag and Corton Formation outcrops and it is not easy to map the boundary, but a vague change of slope could be followed and the ground is most gravelly just below this, at the top of the Crag. There are marl pits along the Crag:Chalk boundary, but little evidence of gravel or clay working within the Crag. Woodward (1881, p 62) records the following section at a pit [c. 286 166] east of Wroxham Hall, near the buildings of Home Farm:

4. Sand and pebbly gravel	2.4 to 3.0
3. Shell-bed (impersistent), sand and gravel	(thickness included in Bed 4)
2. Laminated clay and sand	0.3
1. Sand and shell-bed	0.5
A. Chalk with flints	

He lists 12 fossil species, and recorded *M. balthica* abundantly in Bed 3 but not Bed 1. The succession is thus similar to that recorded in Dobbs' Plantation (Cambridge, 1978a, b). Prestwich (1871, p.468) regarded Bed 2 as probably the Chillesford Clay, but Woodward realised that the clay beds in the Crag are not persistent over such distances.

Further old marl pits line the Crag:Chalk boundary north of Wroxham Hall, but there are no pits within the Crag outcrop. Woodward (1881, p.63) records, at one of these pits north of Wroxham Hall [282 165], 3.7m of 'rather coarse ferruginous flint gravel, similar to beds opened up by the wood south of Belaugh Broad' [293 172], but he records shells as only 'formerly found' at the very large 'picturesque old pit with a branching canal' west of Wroxham Hall.

The Crag outcrop east of Dobbs' Beck is lined with disused marl pits, but there is only one small disused pit wholly within the Crag outcrop [2713 1534], where gravelly clay had been ploughed up. Very gravelly to moderately gravelly orange sand was found in the fields. Despite searching diligently, Woodward (1881, p.63) failed to find any fossils in the Crag sand and gravel at one of these marl pits (?[272 162]), but recorded 13 species at the next pit south, Dobbs' Plantation [272 158]:

3. Pebbly gravel with shells up to the surface	1.8
2. Laminated clay	0.15
1. Shell bed, sand and gravel	0.6
Chalk with flints...	

He recorded *M. balthica* in Bed 3 but not in Bed 1. On the basis of Woodward's description, this site was chosen for excavation by the Geological Society of Norfolk and the Ipswich Geological Group, in September 1977 (Cambridge, 1978a, b). Their excavation revealed, beneath 1.5m of sandy loam hillwash, a total of 1.35m of Crag resting upon Upper Chalk:

Sands, pale coloured, many worn shells including *Macoma balthica*	0.18
Sands, red, shelly; also gravel, better rounded than that below	0.57
Intermittent ferruginous layer of flattened concretions	0.10
Gravel, badly sorted, sandy; shelly; ovoid, well rounded chatter-marked flints; fresh looking angular flaked flints up to 30 cm across, and detached flakes; Chalk fragments; quartz and quartzite pebbles not uncommon	0.36 - 0.37
Sands, gravelly and shelly, pale coloured, with numerous well-preserved shells especially *Macoma*, rich in vertebrate remains	0.13 - 0.14

There were no sharp divisions between the various gravels, and no 'Stone Bed' at the base. A large fauna was collected (Cambridge, 1978b), confirming previous accounts that *M. balthica* was only present in the highest beds. Funnell (1979) examined the foraminifers collected, and also re-assessed the molluscs.

Trimmer (1845) recorded a bed of Crag shells exposed by contemporary quarrying at Limekiln Hole [269 154]. The bed was about 0.9m long and 0.6m thick. Less fossils were seen by Woodward (1881, p.61), after the quarry had been abandoned, although he noted casts of Crag shells in ironstone:

Pebbly gravel	1.8
Black ironstone and indurated sand with ironstone nodules, and casts of '*Cardium edule*' and '*Litorina litorea*'	0.15
Yellow sand and gravel	2.7
Laminated sandy clay, disturbed at top	0.3 to 0.45

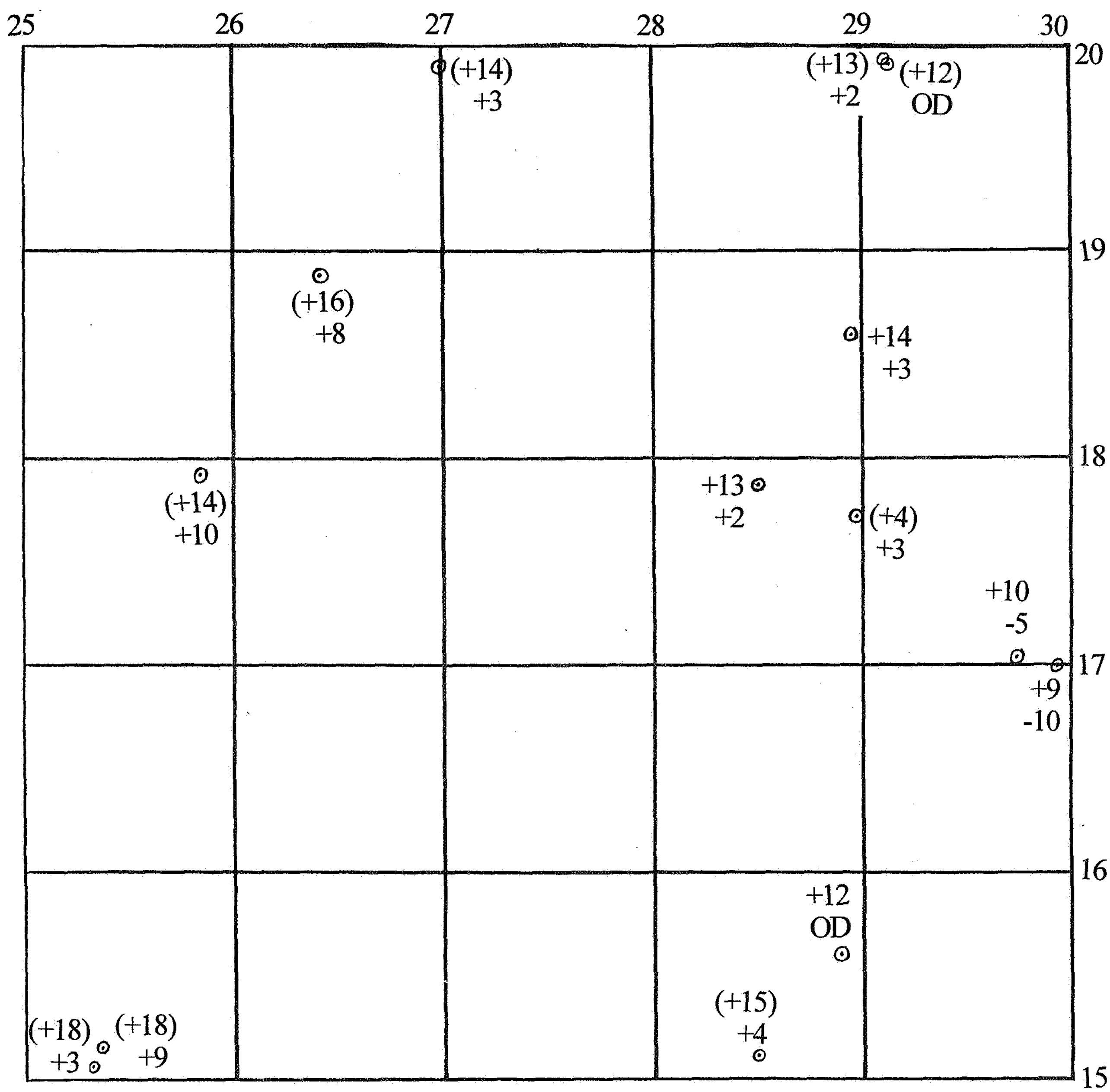


Figure 5 : Water wells and boreholes penetrating the Crag. The lower figure is the level of the base of the Crag resting upon Upper Chalk. The upper figure is the level of the top of the Crag: where this is in brackets, the Crag is overlain by drift, and the level is an estimate; where the number is not in brackets, the Crag is at outcrop but the full thickness is not preserved.

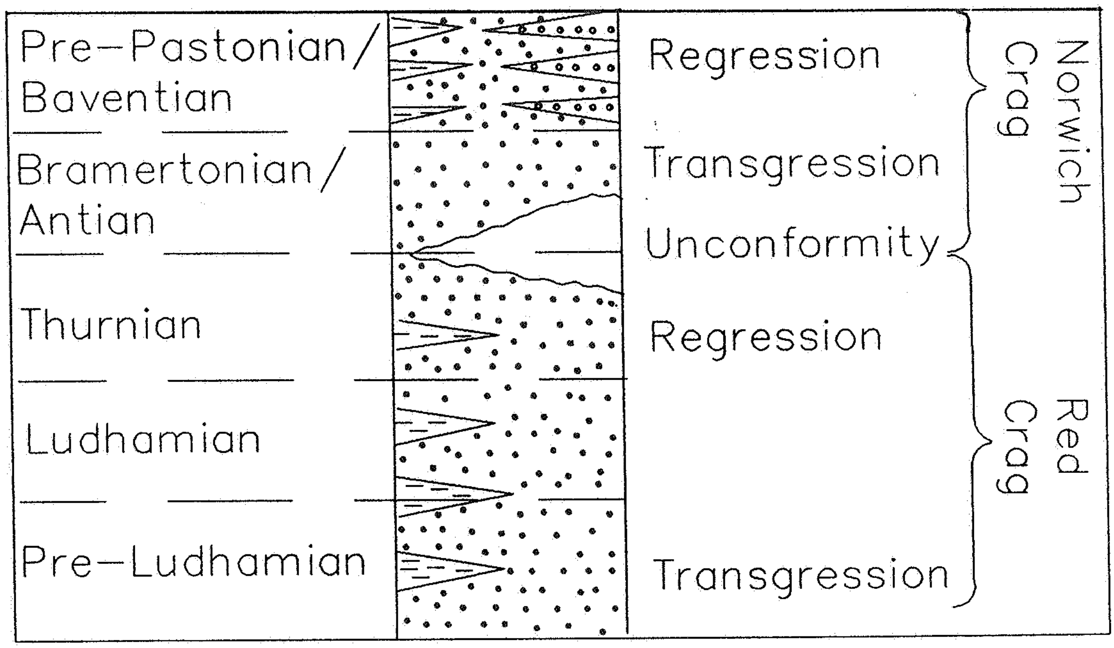


Figure 6 : Generalised stratigraphy of the Red and Norwich Crags, after Hamblin *et al.* (1997). The sedimentology indicated is that found in eastern Suffolk, and recognises sands (dotted), 'Westleton Beds' gravels (small circles), and clays (dashed).

DRIFT DEPOSITS

It is the practice of the British Geological Survey to portray the largely marine Early Quaternary deposits of the Crag Group as solid, and all succeeding deposits as 'drift'. In the present district the earliest drift deposits known to be exposed at surface are the Corton Formation, a glacigenic formation of Anglian age. However, it is possible that earlier, pre-Anglian drift deposits are represented at depth, or even that they appear at outcrop and have not been distinguished from the overlying Corton Formation.

DRIFT DEPOSITS UNDERLYING THE CORTON FORMATION

Within the Lowestoft-Saxmundham district to the south, three pre-Anglian drift formations are known (Hamblin and Moorlock, 1995). These are the Kesgrave Sands and Gravels, a terraced sequence of fluvial sands and gravels corresponding to the pre-Glacial River Thames; the Bytham Sands and Gravels, a similarly terraced fluvial sequence deposited by a river flowing from the West Midlands to the Lowestoft area, and the Cromer Forest-Bed Formation, a coastal complex of interbedded fluvial, estuarine and marine strata which form the downstream correlative of the Bytham Sands and Gravels. In the memoir for the Great Yarmouth district (Arthurton *et al.*, 1994) these are combined as the Kesgrave Group, but that practice has not been adopted elsewhere.

The **Cromer Forest-Bed Formation** is known along the Norfolk coast north of the present district, but in the Happisburgh Borehole [3834 3112] (West, 1980), Corton Formation rested on Pastonian strata which have been included in the Crag in the present survey, so no strata accredited to the Cromer Forest-Bed Formation are present. The Formation is also known from coastal areas north and south of Lowestoft, but it is possible that these and the North Norfolk coastal outcrops represent separate estuaries. Thus it is unlikely to be present the Belaugh district.

The earliest members of the **Kesgrave Sands and Gravels** have commonly been portrayed as extending northwards through eastern Suffolk and Norfolk (Rose, 1994; Arthurton *et al.*, 1994). However, mapping of the Lowestoft and Saxmundham 1:50 000 geological sheets has revealed no evidence of these deposits north of Aldeburgh (Hamblin and Moorlock, 1995), and it appears unlikely that the Thames ever crossed north-eastern Suffolk or Norfolk, although it may well have flowed northward beneath what is now the North Sea east of the present district. It is thus unlikely that the Kesgrave Sands and Gravels are present in the Belaugh district.

The **Bytham Sands and Gravels** are known to follow the line of the River Waveney in the area around Bungay, and are believed to continue north-eastward to pass into the Cromer Forest-Bed Formation between Lowestoft and Yarmouth (Hopson and Bridge, 1987). Sands and gravels with a pebble content resembling the Bytham Sands and Gravels are known at Flordon, south of Norwich (Rose, Allen *et al.* 1996), but there is no evidence that they occur within the present district. However a third river is believed to have existed, farther north than the Kesgrave or Bytham rivers and flowing eastward from the Pennines to pass into the Cromer Forest-Bed Formation in north Norfolk. A pebble suite implying input from this

'Northern River' is recorded in the Norwich Crag Formation south of the present district at How Hill on sheet TG 31 NE (Rose, Gulamali *et al.*, 1996).

Although it is considered unlikely by the present author that the Kesgrave Sands and Gravels *sensu stricto* occur in Norfolk (Hamblin and Moorlock, 1995, 1996, Hamblin *et al.*, 1996), sands and gravels with a pebble content implying derivation from the proto-Thames are common in the area (Green and McGregor, 1996). Most of these deposits are marine and hence form a part of the Crag Group; the Crag at How Hill contains proto-Thames as well as Pennine material. Where fluvial deposits with a proto-Thames pebble signature occur, for instance at Caistor St. Edmund south of Norwich (Postma and Hodgson, 1987) and at Mayton Wood Pit on sheet TG 22 SW ('Coltishall' in Rose, Allen *et al.*, 1996), they overlie Crag with a similar pebble content, and could have been derived by re-working of the Crag.

It is thus likely that after the completion of the infilling of the marine Crag basin, the mouth of the 'Northern River' moved eastward and fluvial deposits were formed in the present district. These would be expected to contain clasts derived from the Pennines via the 'Northern River', and also proto-Thames material derived from reworking of the youngest Crag. It is thus possible that gravelly sands interpreted as Corton Formation or as Crag during the current survey might belong to such a fluvial formation. Since they are fluvial rather than marine they would be expected to have less well rounded flints than in the Crag, so in field mapping they could be mistaken on the ground for Corton Formation. However, the thickness of such a formation is not likely to be more than a few metres.

ANGLIAN GLACIAL DEPOSITS

The Anglian glacial deposits of Norfolk are included within two formally defined formations (Arthurton *et al.* 1994), the Corton Formation below and the Lowestoft Till Formation above, although only the former is present in the Belaugh district. The formations derive from two separate ice-sheets, the North Sea Drift or 'Scandinavian Ice Sheet' which entered the area from the north or east of north, and the 'British Eastern Ice Sheet' which entered from the west. In general it can be said that the deposits of the Corton Formation are derived from the former ice sheet, since they are characterised by a suite of Scandinavian igneous and metamorphic erratics, while the deposits of the Lowestoft Till Formation are derived from the latter ice sheet and contain erratics derived from Mesozoic outcrops to the north-west, principally the Chalk and Kimmeridge Clay. However, there is evidence to suggest that the deposits of the Corton Formation also include detritus from the British Eastern Ice Sheet.

Where the two formations are found in contact, the Lowestoft Till Formation always overlies the Corton Formation, and it has been suggested (eg Hopson and Bridge, 1987) that the Scandinavian Ice Sheet withdrew from East Anglia before the British Eastern Ice Sheet reached the area. However, many more authors (eg Hart and Peglar, 1990; Hart and Boulton, 1991) consider that the two ice sheets co-existed, although the Scandinavian Ice Sheet must have retreated from the area before the British Eastern Ice Sheet reached its eastern limit. A possible explanation is that the Anglian in reality represents two glaciations, as suggested by Sumbler (1995) on the basis of work in the South Midlands. The main Anglian glaciation is generally ascribed to Oxygen Isotope Stage 12 (Bowen *et al.*, 1986), principally because deep-sea data show this to be one of the coldest stages of the Mid-Pleistocene, and on this basis it is accepted that the Corton Formation dates from Stage 12. However, the type site of the Hoxnian, at Hoxne, has been shown by amino acid geochronology to date from (warm) Stage 9 (Bowen *et al.*, 1989), hence it is likely that, at least in western Suffolk, the Lowestoft Till Formation dates from (cold) Stage 10. If the Lowestoft Till Formation represents a single till sheet then the same age must apply in Norfolk, but this has not been proved, and in particular no (warm) Stage 11 deposits have ever been found underlying the Lowestoft Till Formation, even where it overlies the Corton Formation. The possibility thus arises that the British Eastern Ice Sheet advanced into east Anglia during both stages 12 and 10, with the Scandinavian Ice Sheet only reaching the area in Stage 12.

Corton Formation

The Corton Formation is present throughout the district as a series of plateau remnants overlying the Crag. Its base rises from about +12m OD in the north-east to about +18m OD in the south-west. It is thickest, around 11m, in the south-east, where its base lies at an estimated +15m OD in borehole TG 21 NE/7 [2850 1513], and it reaches an altitude of over +25m OD [293 150]. The formation comprises tills (diamicts), sands and sandy gravels, and subsidiary lacustrine clays, and it is believed to comprise both waterlain and terrestrial sediments (Lunkka, 1988; 1994). Eyles *et al.* (1989) noted that the close association of tills and sands indicates allied depositional environments, and considered that the tills were the products of 'rain-out' of fine-grained suspension and coarse debris from floating ice. They concluded that the water-lain deposits are marine, but Lunkka (1994) considered that they formed in a large lake. It is now widely believed that the Dover Strait was cut by the overflow of a pro-glacial lake during the Anglian (Gibbard, 1988; Hamblin *et al.* 1992), and it is suggested that a part of the Corton Formation was formed within this lake, held up between the Chalk ridge of the Dover Strait to the south and the 'Scandinavian Ice Sheet' to the north.

The stratotype of the formation is at Corton in the Great Yarmouth district (Arthurton *et al.*, 1994). Here a basal till, the Corton Till, is overlain by fine-grained chalky sands, the Corton Sands. The Corton Till comprises very silty sandy clay or clayey sand, commonly laminated, with a scatter of pebbles. It is brownish grey to yellowish brown in colour and firm to stiff when fresh, but in surface outcrops it is commonly decalcified and weathers rapidly to a soft and friable condition because of its high sand content. At least a part of the till is believed to be water-lain, formed by the 'rain-out' of material from a floating ice-sheet (Eyles *et al.*, 1989). However, the basal part of a till exposed at the base of the Corton Formation in a temporary section at How Hill [377 199], assumed to be laterally equivalent to the Corton Till, lacked laminations and appeared to have been formed sub-aerially (Rose, Gulamali *et al.*, 1996).

Mechanical analysis of till from an area around Lowestoft (Bridge and Hopson, 1985; Hopson, 1991) showed the <2mm fraction to be extremely uniform and to comprise 22.0% clay, 23.6% silt and 54.4% fine- and medium-grained sand, while pebbles and coarse sand (>4mm) accounted for only 4.7% by weight and included a high percentage of coarse sand-grade chalk. Pebbles were mostly flints, with subordinate vein quartz, quartzite, chalk and shell fragments (from the Crag), and a sparse suite of rhomb porphyries, non-porphyritic lavas, mica schists, gneisses and granitoids believed to be of Scandinavian origin (Boswell, 1916). The 4mm to 8mm size range comprised 54% flint, 24% vein quartz, 8% quartzite, 3% sandstone and 2% each of limestone, ironstone and igneous/metamorphic rocks.

The Corton Sands comprise greyish or yellowish brown well sorted fine- to medium-grained sands, locally clayey, formed from sub-angular to sub-rounded quartz with subsidiary sand-grade flint, quartzite and disseminated chalk grains, calcite prisms and some mica flakes. Thin layers of silt, clay or pebbly diamicton occur, but pebble-grade material accounts for only 0.3% of the deposit (Hopson and Bridge, 1987), occuring as stringers of fine-grained gravel with angular and rounded flint, vein quartz, quartzite, chalk and traces of Scandinavian porphyry, granitoids and metamorphics. Sedimentary structures recorded in coast sections demonstrate that the sands are waterlain, and it is suggested that they were deposited in the ice-dammed lake, ahead of the ice-sheet from which the till was deposited. After the till was formed, the ice-sheet retreated northward to leave open water within which the sand was deposited. Further, the high degree of sorting and roundness of the sand grains, which gives them a smoother 'feel' than the Crag sands, implies that at least a proportion of the material has an aeolian history, presumably being blown into the body of water in which the strata were forming.

Hopson and Bridge (1987), working in the Waveney Valley (Lowestoft District), identified a clastic unit of the Corton Formation below the Corton Till, which they termed the Leet Hill Sands and Gravels. At Scratby they also identified a second Corton Formation till above the Corton Sand, overlain by further sands and then a third till, although it is possible that this third till may be part of the Lowestoft Till Formation. In the area around Potter Heigham (Hamblin, 1997), the Corton Formation comprised a discontinuous basal sand and gravel unit (which would equate with the Leet Hill Sands and Gravels), overlain by the Corton Till, the Corton Sands, and a further till. The gravels within the basal unit of the formation are dominated by sub-angular to angular black-hearted white-patinated flints in a matrix of fine- to coarse-grained sand. Other pebbles include quartz and quartzite, sandstones and igneous rocks.

In the present district there is only one till known, and although it is thin and discontinuous it appears most likely that this is the local representative of the Corton Till. It is overlain by sands, but augering implies that these contain a significant proportion of coarse sand and gravel as well as the typical fine-grained sand of the Corton Sands. The till is also widely underlain by further Corton Formation comprising coarse sands and gravels. Where the till is absent, a thick sequence of sand and gravel overlies the Crag. As has been explained above, the base of the Corton Formation is not clear in the field, but it can generally be mapped by a vague change of slope and an upward increase in the proportion of fresh, angular, shattered flints.

Corton Formation - Details

Gravel brash with rounded flint, quartz and quartzite pebbles was mapped on the plateau top at Buxton Road [255 199] and in Coltishall [270 199], while borehole TG 21 NE/16 [2700 1990] records 12.2m of 'gravel ' from surface: presumably this will include thin Corton Formation resting on Crag.

South-west of Horstead, brown medium- to coarse-grained sands and gravelly sands low in the Corton Formation were augered in fields either side Frettenham Road. To the south-west, these are overlain by till around Clamp Wood [251 182]; cover silt is absent here and till clays are ploughed up in the fields. Further till may be present to the north, where standing water was noted in a ditch [2502 1872]. However, between Frettenham Road and Norwich Road is a hill [262 188] where the till is apparently absent and Corton Formation sands and gravels extend up to about +23 OD. Burrows in the slopes indicate orange to brown medium- to coarse-grained sands with gravel, the gravel content apparently increasing uphill and including rounded and angular flints, quartz and quartzite. Two-metre deep pits on the flank of the hill [260 188, 260 187] are characterised by very sandy soil, but were presumably worked either for gravel or for local 'pods' of clay. To the east of the hill, only gravelly coarse-grained sands were augered, but borehole TG 21 NE/23 [2643 1890] recorded topsoil to 0.9m, clay to 1.8m, then sand and stone to 7.6m. The latter may be wholly Crag or may include basal Corton Formation, but from its OD level the 'clay' must be Corton Formation till.

West of Stanninghall Farm, further coarse sands and gravels were augered, overlain by till [250 175]. A further large outlier of till occurs at Stanninghall Road [255 181 to 262 177], overlain by a small patch of sand and gravel [257 180]. There are several small clay pits [258 177, 260 179, 262 176, 262 177, 263 177], and borehole TG 21 NE/8 [2586 1793] records topsoil and brickearth to 1.5m, grey clay to 1.8m, then gravel to 8.2m. The latter will be mainly Crag but may include basal Corton Formation, while the topsoil and brickearth may include some cover silt. This till dies out eastward, and east of Norwich Road orange, yellow and brown medium- to coarse-grained sands were augered up to over +20 OD. These included two small 'pods' of till [267 176, 267 173], which have been extensively worked.

In the south-west corner of the district, gravelly medium- to coarse-grained sands are overlain by two patches of till [252 152 to 258 154, 257 150], with clay ploughed in the fields both sides of Norwich Road. Borehole TG 21 NE/10 [2537 1516] records topsoil and brickearth to 1.5m, pea shingle to 2.1m then sand to 9.1m: the base of the Corton Formation is believed to lie within the 'pea shingle'. Borehole TG 21 NE/12 [2533 1503] simply records 'sand and shingle mixed' from surface to 15.5m, which will include both the Crag and the Corton Formation.

In the north-east of the district, the plateau has been heavily dissected, leaving only thin Corton Formation gravel outliers straddling Belaugh Road [286 192, 294 188]; a burrow [2953 1866] revealed pale brown gravelly sand with pebbles of rounded and angular flint, quartz and sandstone. However the outcrops of sand and gravel which extend along the edge of the district [283 200 to 300 187] form the edge of a large outcrop extending to the north and east. Borehole TG 21 NE/30 [2914 1994] recorded gravel to 1.8m then yellow sand to 6.1m; the base of the Corton Formation is believed to lie within the 'gravel'.

The Corton Formation is thickest in the south-east of the district. A broad plateau extending from Wroxham Road [291 159] to [270 150] beyond Dobbs' Lane is characterised by loose sandy soils, variously gravelly, low in the Corton Formation. These are overlain by till [276 151 to 286 150, 289 150] which is overlain by further sands [282 151]. Borehole TG 21 NE/7 [2850 1513] records clay (till) to 3.0m, sand to 3.7m, clay to7.3m and sand to 14.6m: the lower sand is undoubtedly Crag and the lower clay probably so, while the upper sand may be wholly Corton Formation of include more Crag. Eastwards the till dies out and to the south of Wroxham Road [287 153], orange to dark brown gravelly medium- to coarse-grained sands of the Corton Formation extend up a steep slope from +16m to about +24m OD. To the south of the outcrop of Gravel and Sand of Uncertain Age and Origin the Corton Formation sands and gravels reach their highest elevation of over +25m OD, while farther east their outcrop is characterised by gravelly soil with rounded and angular flints, with brown and orange sands dug from burrows.

GRAVEL AND SAND OF UNCERTAIN AGE AND ORIGIN

This deposit is characterised by sandy gravels dominated by angular shattered flints up to about 20 cm long, with minor rounded flint, quartz, quartzite and sandstone, in a matrix of coarse-grained sand. It occurs on hilltops, invariably overlying sands and gravels high in the Corton Formation. The largest outcrop lies at around +25m OD at Stonehouse Road [287 152 to 294 152], with further outcrops at around 24m [261 187] near Horstead Lodge, around 22m at Dobbs' Lane [281 150], and several around 20m [257 180, 262 176, 263 176, 266 175].

Since the deposit occurs only at high levels, unrelated to the post-glacial drainage, it is unlikely that it represents deposition later than Anglian, but it is not clear whether it belongs to the Corton Formation or the Lowestoft Till Formation. The high content of relatively large, shattered flints would suggest the latter, since high concentrations of large flints are uncommon high in the Corton Formation, but this cannot be satisfactorily demonstrated since no undoubted Lowestoft Till Formation is known in the immediate vicinity. Alternatively the deposit may have been formed by winnowing of the Corton Formation, with concentration of the larger flints by removal of the finer constituents.

WOLSTONIAN AND DEVENSIAN DRIFT DEPOSITS

During the Wolstonian/Saalian and Devensian/Weichselian glacial episodes, southern England was subject to periglacial conditions, and sea levels in the North Sea dropped sharply as up to 5% of the global water budget was locked up in the form of ice. During these periods remarkably little erosion occurred in the present district: the bulk of the erosion of the Corton Formation must have occurred during the waning of the Scandinavian ice sheet in the Anglian stage, since in adjacent districts the Lowestoft Till Formation occurs at low levels in river valleys. Hence later erosion must be very largely restricted to overdeepening of the river valleys.

Four deposits were formed during these periods: the Yare Valley Formation, cover silt, gravelly head, and head. The **Yare Valley Formation** (Arthurton *et al.*, 1994) occurs beneath the Breydon Formation in the valleys of the River Bure and at least some of its tributaries.

It comprises fine- to coarse-grained gravels, mostly of flint, with variable amounts of fine- to coarse-grained sand, some silt, shell fragments and chalk cobbles. It is up to 11m thick near Great Yarmouth, and is generally considered to be of late Devensian and/or early Holocene age. Similar gravels are likely to have formed late in the Anglian, as the North Sea Ice Sheet waned and the post-glacial drainage system was initiated, but these would most probably have been eroded and reworked during Wolstonian and Devensian periods of low sea level, so the surviving deposits are assumed to be Devensian.

Boreholes in Horstead revealed angular flint gravel, fine- to coarse-grained sands and silts, underlying the Breydon Formation at around +2m OD and resting on the Upper Chalk at around -8.5m OD. Borehole TG 21 NE/2 [2562 1964] revealed loam to 0.6m then brown sand and stones to 12.2m depth, resting upon Upper Chalk at -8m OD. The latter deposit will include gravelly head overlying Yare Valley Formation.

Cover silt is the term given to a drape of silt and sand which locally masks the outcrop of the Corton Formation. Silt is the main component, with subordinate fine- to medium-grained sand, giving a bimodal distribution (Catt *et al.*, 1971; Perrin *et al.*, 1974). These authors consider the deposit to be aeolian in origin, possibly modified by frost-heaving and biological mixing. It is considered to be Devensian in age, formed during the last ten thousand years which preceded the Flandrian marine transgression, and derived by aeolian transport from Devensian outwash sediments in northern England. In the present district the cover silt is not shown on the map. It may be up to around a metre thick, but most commonly 0.4-0.7m, and tends to be thickest where it collects within concave slopes.

At the base of the cover silt, where it rests upon till or gravelly sands of the Corton Formation, there is a layer a few centimetres thick of hard-packed gravel. This is commonly impenetrable by hand auger, and makes mapping the underlying Corton Formation difficult. It is believed to be a deflationary product of the underlying units, the fines having been winnowed out by the wind to leave hard-packed gravel. There is commonly no such gravel where the cover silt rests upon gravel-free sands of the Corton Formation.

Gravelly head comprises sandy gravels and gravelly sands, the gravel component being dominated by angular, shattered flint, with subordinate rounded flint, quartz and quartzite. It overlies the Upper Chalk on the gentle slopes below the Norwich Crag outcrop, but only extends a short distance upslope of the Chalk:Crag unconformity. It is believed to have been formed during periglacial periods, by sheetflood and streamflood processes, rather than solifluction. Such mass movement would have been initiated late in the Anglian, but the deposits would have been reworked during later Wolstonian and Devensian cold periods, so as in the case of the fluvial sands and gravels the surviving deposits are likely to be Devensian.

Gravelly head occurs in all the deep valleys in which the Chalk appears at rockhead, with outcrops up to 300m wide and up to about 5m thick. Borehole TG 21 NE/13 [2852 1791] records sand and gravel to 3.4m, and TG 21 NE/1 [2558 1605], sand to 4.6m, both resting on Upper Chalk. Borehole TG 21 NE/14 [2870 1890] records topsoil and sandy clay to 0.9m, gravel to 2.7m, then sandy clay to 3.7m, on Chalk. The upper sandy clay will be head and the gravel will be gravelly head, but the lower sandy clay may be weathered chalk. Borehole TG 21 NE/2 [2562 1964] revealed loam to 0.6m then brown sand and stones to 12.2m depth, resting upon Upper Chalk at -8m OD. The loam is most likely head, and the sand and stones will include gravelly head overlying Yarmouth Roads Formation.

Head comprises poorly sorted and poorly stratified clayey sands and sandy clays derived from earlier Quaternary deposits by mass movement on sloping ground. The processes involved include hillwash and soil creep as well as solifluction. The head is assumed to be largely late Devensian in age in view of the periglacial conditions then prevailing, but some may survive from the Wolstonian or even late Anglian, and some hillwash and soil creep may date from the Holocene.

Remarkably little head is seen in East Anglia considering the intensity of the periglacial climate to which the area has been subjected during the last three glaciations, and in the present district head is restricted to small strips and patches up to about 2.0m thick in the valleys of the River Bure and its tributaries. Only one [284 185] is sufficiently large and clearly defined to show on the map, but smaller, poorly defined patches are common. For instance, borehole TG 21 NE/2 [2562 1964] records 'loam' to 0.6m depth, and TG 21 NE/14, topsoil and sandy clay to 0.9m, in both cases resting on gravelly head.

BREYDON FORMATION

Breydon Formation (Arthurton *et al.*, 1994) is the name given to the Holocene estuarine sequence which forms the marshland occupying the floodplains of the various rivers which make up the Waveney/Yare/Bure catchment. The Formation as defined by Arthurton *et al.* is a 'fossil' formation formed under estuarine to marine conditions, and is not intended to include any fluvial deposits formed so far inland as to be out of estuarine influence, or deposits formed in recent times after the sea had been artificially excluded from the area and the marshland drained. The components of the Breydon Formation in the Great Yarmouth district comprise an impersistent basal peat, the Lower Clay, the persistent Middle Peat, the Upper Clay and the marginal Upper Peat.

In the lower reaches of the Bure catchment, the Upper Clay and Upper Peat are both exposed at the surface. The former takes the form of a broad band either side of the rivers, while the latter occurs discontinuously along the shoreward margins of the marshland and in tributary valleys. This is because the centre of the floodplain was more prone to marine inundation than the margins, allowing vegetation to grow in the less saline marginal areas and tributaries and leading to peat growth. The exposed Upper Peat and Upper Clay are thus of approximately the same age. However, the Upper Clay does not extend upstream at surface as far as the present district, where the Upper Peat covers the whole of the floors of the valleys of the River Bure and its tributaries.

In the present district, which is remote from the sea, the formation is believed to be only around a maximum of 5m thick and it is doubtful whether all the elements of the formation are present, or even whether the standard stratigraphy applies. Boreholes at Horstead show the peats interbedded with organic clayey silts, sands and even gravels, but it is impossible to correlate this with the succession in the Great Yarmouth district.

RIVER TERRACE DEPOSITS AND ALLUVIUM

River terrace deposits have been mapped in small areas of tributary valleys of the Bure [267 166, 268 156]. They are planar sheets of sandy gravel, estimated to be up to 2m thick, formed by the fluvial reworking of the gravelly head. They are believed to be late Devensian or Holocene in age.

Alluvium has been recorded in one tributary of the River Bure [270 157 to 268 150]. It comprises soft laminated silty clays and clayey silts, deposited by the stream during the Holocene.

MADE GROUND, WORKED GROUND AND LANDSCAPED GROUND

There is very little made ground in the district, and it is largely restricted to railway and road embankments. A sewage works [293 184] is shown as landscaped ground.

The Upper Chalk was in the past widely worked for agricultural lime ('marl'), lime mortar and flints, since, along with the outcrop in the Yare Valley at Norwich, the Upper Chalk in this district is the most easterly Chalk available in Norfolk. Chalk working and lime burning were a major industry in Horstead and Coltishall, as well as on the Wroxham estate, well into the 19th century, although all the pits appear to have been abandoned and become overgrown before the end of the century (Woodward, 1881). The materials were exported by barge to Great Yarmouth for onward shipment, and several of the larger quarries have canals extending into them from the River Bure [260 199, 27 17, 276 165], the marl being loaded onto barges straight from the quarry face. The resulting quarries tend to be long and narrow and extend some distance into the hillside.

The chalk pits tend to be relatively high in the Upper Chalk outcrop, possibly to maintain workings above the water table or else because the highest Chalk was the most weathered and hence easiest to work. Thus the workings extend well into the Crag outcrop. There is not known to have been any mineral extraction from the Crag in these Chalk pits, and all the Crag sand, clay and gravel was removed as overburden and later dumped back in the pits. Thus, although the pits are shown as worked ground on Upper Chalk, they are all likely to contain a certain amount of made ground in the form of Crag backfill. Pits are shown on the map as infilled ground where they have been backfilled to original ground level, eg that in the Crag outcrop west of Bell Lane [299 161], and there may be further, unknown areas of infilled ground (wholly back-filled worked ground) which are not shown on the map.

Although it is believed that the Crag and Upper Chalk were not worked together, there are a large number of disused pits within the Crag, although generally these are much smaller than the chalk pits. They have variously been worked for gravel, clay and sand. Since most of the pits are very overgrown it is rarely possible to be certain which pit worked which mineral, although many may have worked more than one. The pits at Wroxham [296 172] are marked as 'Brick Field' on the old series geological map, and that [299 163] east of Salhouse Road presumably also worked clay for brick-making. Four small pits within the Wroxham estate are currently worked for gravel for the estate's own needs [2696 1700, 2657 1675, 2662 1680, 2872 1724]. Otherwise it may be suggested that those disused workings which lie low in the Crag sequence more likely worked brick clays, while those higher in the sequence worked gravel. However, in some cases, eg the large pit [286 173] south of Juby's Farm, a pit shown on the map as being low in the Crag outcrop may be in fact an old Chalk pit which has been so infilled with Crag backfill as to raise its floor above the level of the base of the Crag.

The sands and gravels of the Corton Formation have not been widely worked, since better quality gravel would have been readily available from the Crag, and some of the disused pits shown within the outcrop of undifferentiated Corton Formation may have been within small 'pods' of till, eg flow tills. There are a number of disused brick clay pits within the mapped outcrop of the Corton Formation till, along with ponds dug for watering cattle. Within the Breydon Formation, Norton's Broad [290 168] and Belaugh Broad [293 172] were presumably Medieval peat workings, the pond [272 168] West of Wroxham Hall is a wildfowl decoy, and a number of ponds downstream of Belaugh Broad could have been either. Other excavations include an ornamental pond [287 186] and irrigation reservoirs [268 150, 253 161].

ECONOMIC GEOLOGY

Industrial minerals

At present mineral extraction activity within the district is restricted to gravel extraction by farmers for there own use, although in the past, marl and flints have been extracted from the Upper Chalk, clay, sand and gravel from the Crag and Corton Formation, and peat from the Breydon Formation. However, gravels within the upper part of the Crag are of high quality, comprising largely flint, quartz and quartzite. Further gravels occur both in the Corton Formation and in the Yare Valley Formation underlying the Breydon Formation: the former are too sandy and possibly too poorly sorted to be of economic value, while the latter have not been explored but would possibly be too thin and too difficult to extract to be economic.

Water supply

The Crag, the sand and gravel units of the Corton Formation, and any intervening pre-Anglian drift deposits are minor aquifers, with water flow through pores between the sand grains. The Crag is in hydraulic continuity with the basal sand and gravel unit of the Corton Formation, and with any intervening pre-Anglian drift deposits. The tills in the Corton Formation are thin, sandy and discontinuous, and would not be effective aquacludes. The Upper Chalk is a major aquifer, with all flow through fissures rather than intergranular, and the Crag and Upper Chalk are in hydraulic continuity.

Within the district, 40 bores for water are known, TG 21 NE/1 to 3 and 6 to 42, and depths quoted range from 2.0m to 106.7m. Most if not all of these penetrated the Upper Chalk, but detailed logs for many are not known. Where logs are available, the depth of penetration into the Upper Chalk is shown in Figure 4. Wells revealed rest water levels of -7m to +8m O.D. Water consumptions quoted vary widely, and 14-day pumping tests at TG 21 NE/13 and 14 yielded 42,460 gallons (193,022 litres) per hour, with depression of 7m and 13m respectively. A test at TG 21 NE/6 yielded 26,800 gallons (121,832 litres) per hour with a depression of 2.6m. Water from the Upper Chalk is hard, and in some wells ferruginous.

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APPENDIX - ABBRIEVIATED LOGS OF BOREHOLES HELD BY BGS TO AUGUST 1996

Confidential boreholes are omitted, also boreholes for which no geological logs are held. The stratigraphic classification given is the author's interpretation of the drillers' log; the quality of data is such that this must be treated with caution. Copies of the original logs may be obtained from the Survey's offices at Keyworth; the site numbers given here are prefixed TG 21 NE.

	Depth (m)	O.D. Level (m)
1. 2, The Common, Crostwick [2558 1605] SL c +7		
Topsoil	to 0.6	+6
Head		
Sand	to 4.6	+2
Upper Chalk		
Soft chalk	to 4.9	
Chalk	to 33.5	-27
2. White House, Horstead [2562 1964] SL c +4		
Topsoil	to 0.3	+4
Head		
Loam	to 0.6	+3
Gravelly Head, Yarmouth Roads Formation		
Sand and stones; brown sand; sand and stones	to 12.2	-8
Upper Chalk		
Chalk	to 30.5	-27
3. Old Hall Farm, Belaugh [2899 1773] SL +5		
Topsoil	to 0.6	+4
Gravelly Head, Crag Group		
Sand and stone	to 2.4	+3
Weathered Upper Chalk?		
Light clay and sand	to 10.4	-5
Upper Chalk		
Soft marly chalk; hard chalk & flints; soft chalk & flints	to 30.5	-26
6. Manor Farm, Salhouse [2890 1562] SL c +12		
Crag Group		
Sand	to 11.6	OD
Upper Chalk		
Marl; soft chalk; chalk	to 106.7	-95

7. Rackheath [2850 1513] c +19

Corton Formation, Crag Group		
Clay	to 3.0	+16
Sand	to 3.7	+15
Clay	to 7.3	+12
Sand	to 14.6	+4
Upper Chalk		
Marl; soft chalk; medium flinty chalk; soft chalk; chalk	to 106.7	-88

8. Stanninghall Farms [2586 1793] c +18

Topsoil	to 0.6	+17
Corton Formation, Crag Group		
'Brickearth'	to 1.5	
Clay, grey	to 1.8	+16
Gravel	to 8.2	+10
Upper Chalk		
Chalk marl; soft chalk; hard and soft chalk and flints; hard chalk and flints; soft chalk	to 106.7	-89

10. St.Mary's, Crostwick [2537 1516] + 18.9

Topsoil	to 0.6	+18
Corton Formation, Crag Group		
'Brick earth'	to 1.5	+17
Pea shingle	to 2.1	
Sand	to 9.1	
'Hard pan'	to 9.8	+9
Upper Chalk		
Soft chalk; hard open chalk	to 24.4	-6

12. North Walsingham Road, Spixworth [2533 1503] c +19

Corton Formation, Crag Group		
Sand and shingle mixed	to 15.5	+3
Upper Chalk		
Marl; chalk	to 34.7	-16

13. Juby's Farm, Belaugh [2852 1791] + 3

Topsoil	to 0.3	+3
Gravelly Head		
Sand and gravel	to 3.4	OD
Upper Chalk		
Chalk and flints	to 61.0	-58

14. Grange Farm, Belaugh [2870 1890] + 2.3

Topsoil	to 0.3	+2
Head		
Clay, sandy	to 0.9	+1
Gravelly Head		
Gravel	to 2.7	OD
?Weathered Upper Chalk		
Clay, sandy	to 3.7	-1
Upper Chalk		
Chalk and flints	to 61.0	-59

15. Juby's Farm, Belaugh [2852 1789] + 12.6

Topsoil	to 0.3	+12
Crag Group		
Loamy sand and gravel; sand & sea shells	to 10.7	+2
Upper Chalk		
Dirty chalk and flint; white chalk and flint, harder below	to 71.6	-59

16. The Nurseries, Coltishall [2700 1990] + 15

Corton Formation, Crag Group		
Gravel	to 12.2	+3
Upper Chalk		
Chalk	to 23.6	-9

17. Dobbs' Cottage [2694 1545] +7

Made ground or gravelly head		
Gravel soil; red sand and gravel	to 3.6	+3
Upper Chalk		
Marl; chalk	to 18.9	-12

18. Heath Farm [275 190] + 13.7

(well)	to 14.5	
Upper Chalk		
Marl; chalk	to 37.9	-24

19. Hall Farm, Crostwick [2654 1641] + 4.6

Upper Chalk		
Marl; chalk	to 12.2	+8

23. Horstead Lodge Farm [2643 1890] c +18

Topsoil	to 0.9	+17
Corton Formation, Crag Group		
Clay	to 1.8	
Sand and stone; red sand	to 10.4	+8
Upper Chalk		
Marl; chalk; hard chalk & flint; fine chalk; chalk flint; chalk	to 76.2	-58

24. Kama, Belaugh [2942 1887] c +13

(well)	to 9.1	
Upper Chalk		
Chalk	to 30.2	-17

26. Keys Hill House, Wroxham [2995 1701] c +9

Crag Group		
Sand and gravel	to 18.6	-10
Upper Chalk		
Chalk	to 39.6	-30

27. Hillcrest, Wroxham [2974 1705] c +10

Crag Group		
Gravel and sand	to 15.2	-5
Upper Chalk		
Sand & marl; chalk	to 61.0	-51

28. Council Houses, Belaugh [2896 1862] + 14.9

Crag Group		
Sand	to 1.5	
Gravel and Crag	to 12.2	+3
Upper Chalk		
Sand and chalk; chalk and flints	to 45.7	-31

29. Grange Farm, Coltishall [2915 1992] + 15

(well)	to 8.5	+6
Crag Group		
Clay	to 12.8	+2
Sand	to 14.6	OD
Upper Chalk		
Marl; chalk; marl; chalk	to 51.2	-36

30. Grange Farm, Coltishall [2914 1994] + 15

Corton Formation, Crag Group		
Gravel	to 1.8	+13
Yellow sand	to 6.1	
Clay	to 10.1	
Red sand	to 12.5	+2
Upper Chalk		
Flint & medium chalk; good chalk; alluvial chalk	to 91.4	-76