BRITISH GEOLOGICAL SURVEY

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TECHNICAL REPORT WA/97/25

Geological notes and local details for 1:10 000 sheet TG 22 SE (Scottow)

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 22 SE (SCOTTOW)

INTRODUCTION

The following report is designed to be used in conjunction with 1 : 10 000 Geological Sheet TG 22 SE. 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 sheets 66 NE and 68E, and was surveyed at a scale of 1 : 63 360 by H B Woodward in 1875-1880. Accompanying memoirs were published (Reid, 1882; 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 area is predominantly rural, although RAF Coltishall occupies a significant part of the western half of the district. The village of Coltishall straddles the southern margin of the district, and the smaller villages of Tunstead and Sloley straddle the eastern margin. Smaller settlements include Scottow and Sco Ruston in the east and Little Hautbois in the west. The river Bure flows across the south-west corner of the district from north-west to south-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. North-east of the valley of the Bure, the land takes the form of a plateau rising to a maximum of just above 25m OD north of Scottow [280 240], with the River Bure lying below 5m OD. Two almost dry valleys cut the plateau to drain south-westward into the Bure, while along the northern margin of the area the valley of Stakebridge Beck drains south-westwards into the Bure. The smaller valley in the north-east drains eastwards into the River Ant, and thence into the Bure. 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 at rockhead are very well drained and form relatively poor arable land, requiring much artificial irrigation. The floodplain of the Bure is given over to woodland and permanent pasture, which is largely grazed by cattle and sheep. 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 22 SE. Complete logs of the non-confidential wells and boreholes can be obtained from BGS Information Services (Geological Records) at Keyworth.

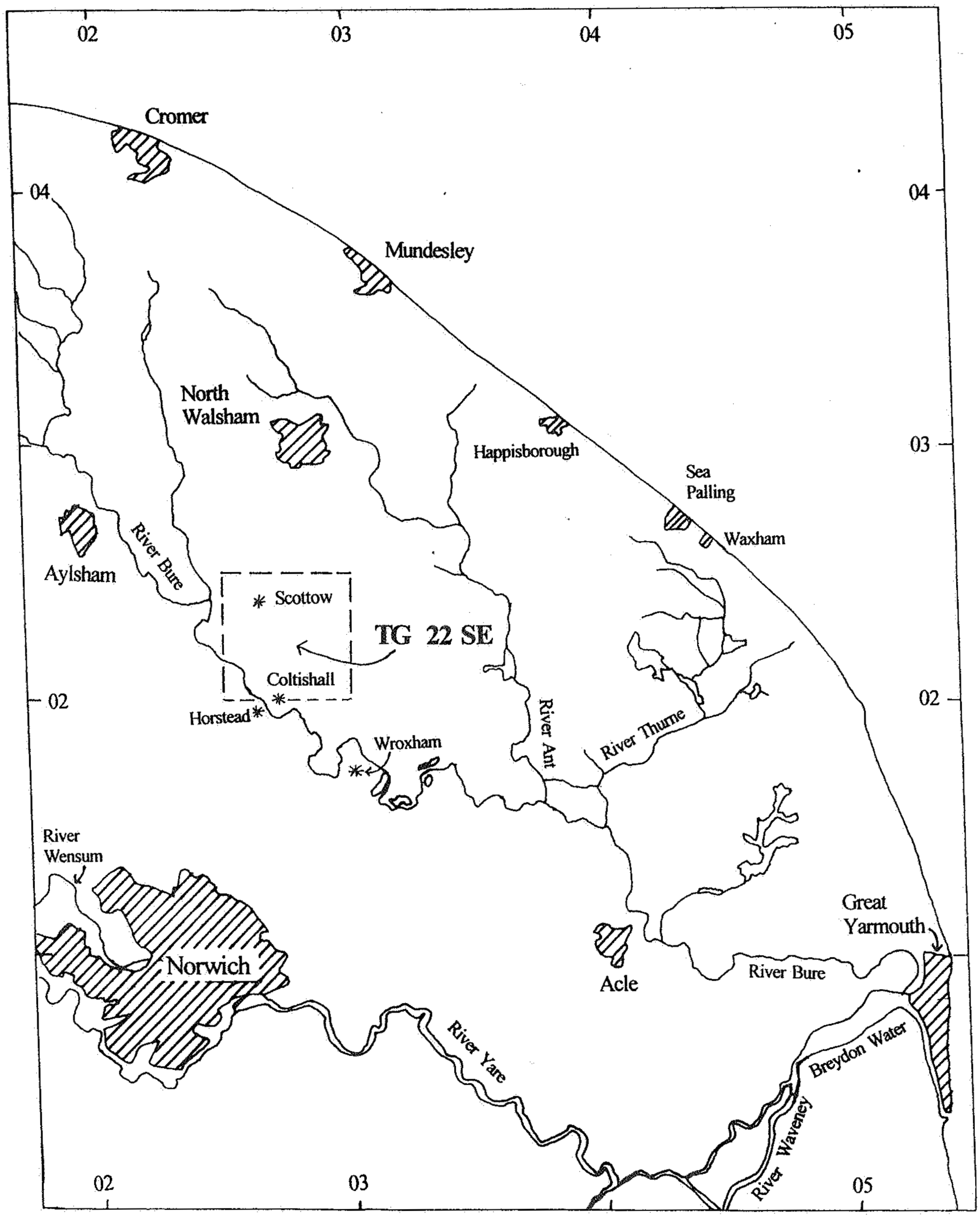

Figure 1 : Location diagram.

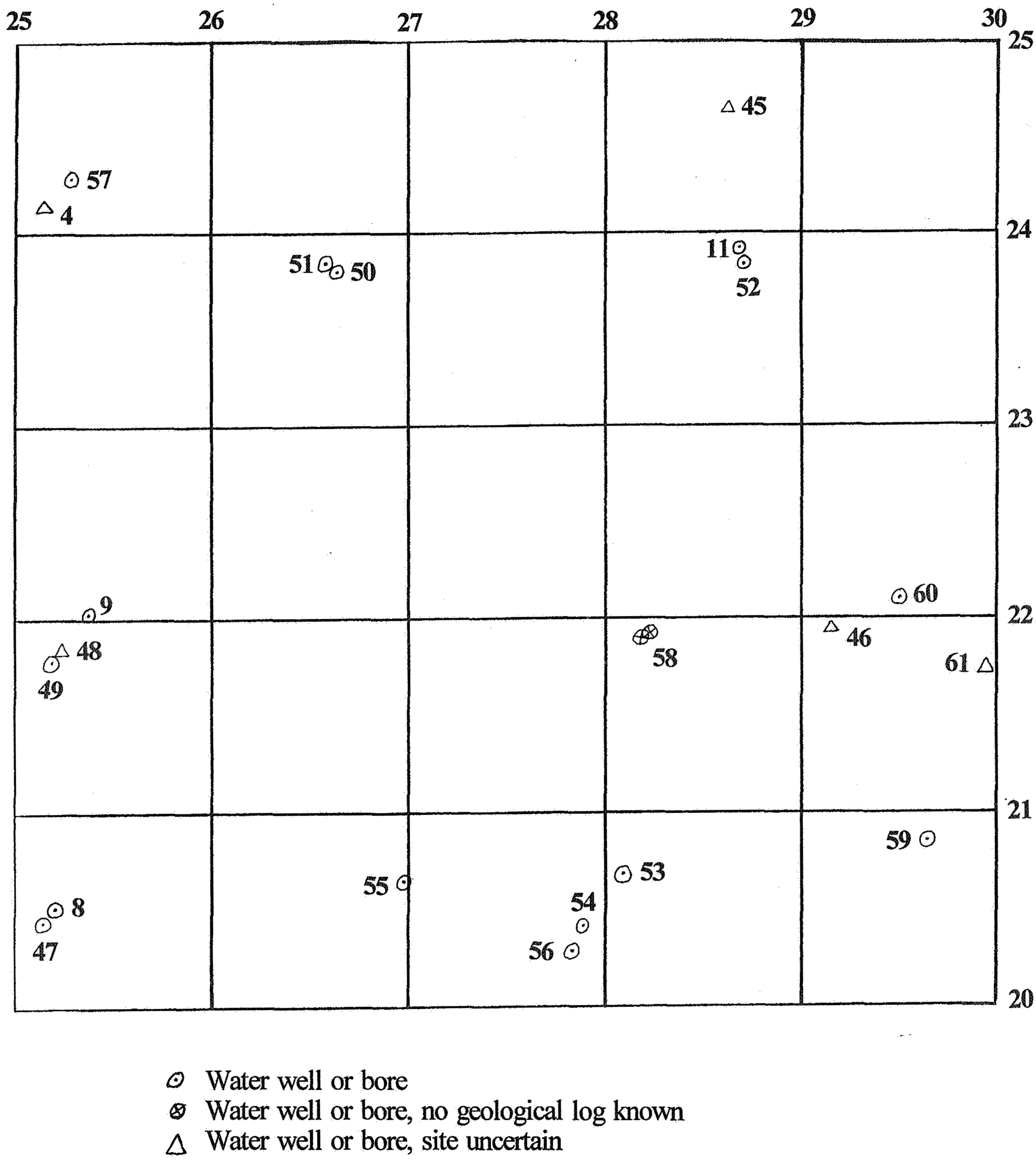

Figure 2 : Water wells and bores on Sheet TG 22 SE, taken from BGS records. The number of each site is prefixed TG 22 SE.

GEOLOGICAL SEQUENCE

Strata proved on sheet TG 22 SE 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 deposit of the solid succession.

Holocene to Recent	**Made ground**	**Up to c 2.0**
	Breydon Formation	**Up to c 3.0**
	Peat	**Up to c 2.0**
	Alluvium	**Up to c 2.0**
Pleistocene to Recent	**Head**	**Up to c 2.0**
	Gravelly Head	**Up to c 5.0**
Pleistocene	**Cover silt**	**Up to c 1.5**
	gravel and sand	**Up to c 3.0**
	Yare Valley Formation	**Up to c 7.0**
	Corton Formation	**Up to c 10.0**
	Crag Group	**Up to c 12.0**
unconformity		
Upper Cretaceous	**Upper Chalk**	**70+**

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 at depth beneath the Crag 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 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

On sheet TG 22 SE the Upper Chalk has been penetrated by 19 non-confidential and 7 confidential boreholes. The thickness penetrated by the non-confidential boreholes is shown on Figure 4; the maximum is 70.1m at borehole TG 22 SE/11 [2870 2393].

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. However, the borehole logs for the present district suggest that there is much less weathering of the Chalk surface here than in the Belaugh district immediately to the south (Hamblin, 1997b).

There are only two references to 'marl' (TG 22 SE/46 [291 219] and /57 [2529 2429]), one to 'soft chalk' (TG 22 SE/56 [2785 2030]) and one to 'cobbly chalk and sand' (TG 22 SE/11 [2870 2393]), although in the last-named case the sand may have fallen down the hole during drilling, and in the case of the 'soft Chalk' this could be recent weathering, since Chalk was proved at a depth of only 3.0m. The references to 'marl' are the only positive indication of weathering beneath the Crag or Corton Formation. There are four references (boreholes TG 22 SE/9, 45, 47 and 49) to 'clay' overlying 'chalk', which in the Belaugh district commonly indicated weathered Upper Chalk, but in this case the levels of the clay in boreholes /45 and /47 suggests that the clay is Crag; in /9 and /49 the Upper Chalk is recorded at unusually low levels, and these are discussed fully below. However, apart from these anomalously deep records in boreholes TG 22 SE/9 and /55, the levels of the base of the Crag in boreholes are consistently a few metres lower than the levels mapped along the sides of the valleys of the Bure and its tributaries, suggesting a consistent error on the part of the well-sinkers, which is most likely a reflection of the weathered state of the top part of the chalk.

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 apart from the railway cutting at Little Hautbois, all the areas shown as Upper Chalk outcrops on the map are quarries, and since all are disused and variously overgrown, there is little Upper Chalk to be seen without excavation. Weathered chalk is however occasionally 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 in the Belaugh district: "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) 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 21 NE. Apart from this, Woodward only records Upper Chalk in his descriptions of Crag sections, although apart from the railway cutting these would most likely all have been in old Chalk quarries. In a pit 'a little to the south-east of the railway station' at Coltishall, he records (p.59) beneath the Crag: 'Chalk, with flints and paramoudras, about 12 feet {3.7m} exposed'. Woodward also records Upper Chalk beneath the Crag at the following sites:

> p.57: 'south of the letters *ut* of Great Hautboys'; this is described on the Old Series map as a 'Crag and Chalk Pit' [266 203].
> p.59: a pit 'a little further west' of a 'large deserted pit with canal communication...west of Horstead Church' [218 201].
> p.59: a pit 'south of Stewpond Car' [2567 2027].

During the current survey, weathered chalk was exposed beneath Crag in the railway cutting [2525 2181], immediately beneath the road bridge; Woodward (1881, p.56) records: "Between {Hautboys} Hall and Mayton Bridge the railway-cutting showed a loamy surface soil, resting on the pebbly sands {Crag}. Three or 4 feet (0.9-1.2m) of Chalk was exposed by the bridge. East of the bridge and above the Chalk (which was extended but for a short distance in the cutting)..."

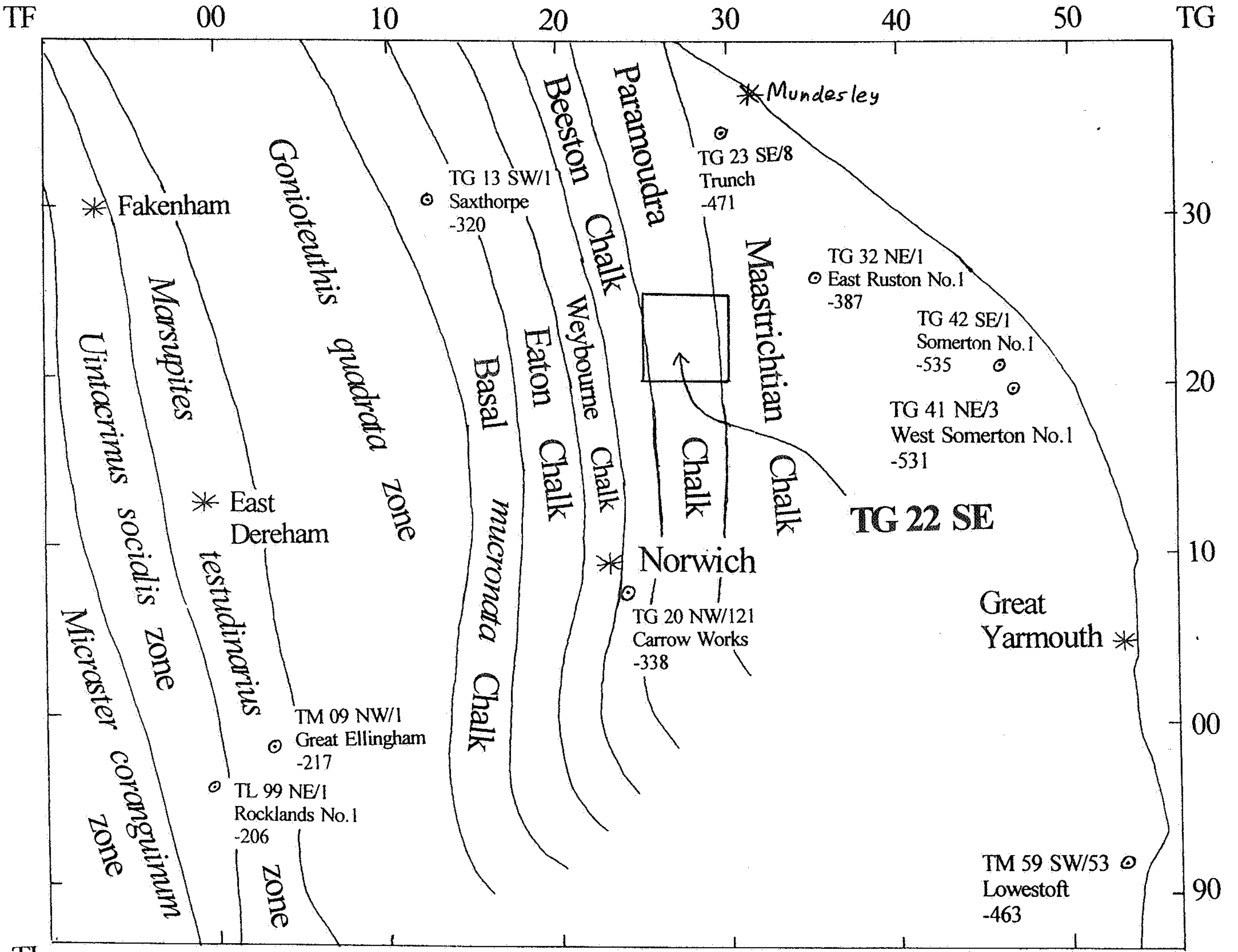

Figure 3 : Map of north-east Norfolk, showing deep boreholes. Along side each is shown its registration number in the BGS borehole records collection, its name, and the OD level of the base of the Chalk Group. The sub-divisions of the Upper Chalk at rockhead are shown, after Peake and Hancock (1970).

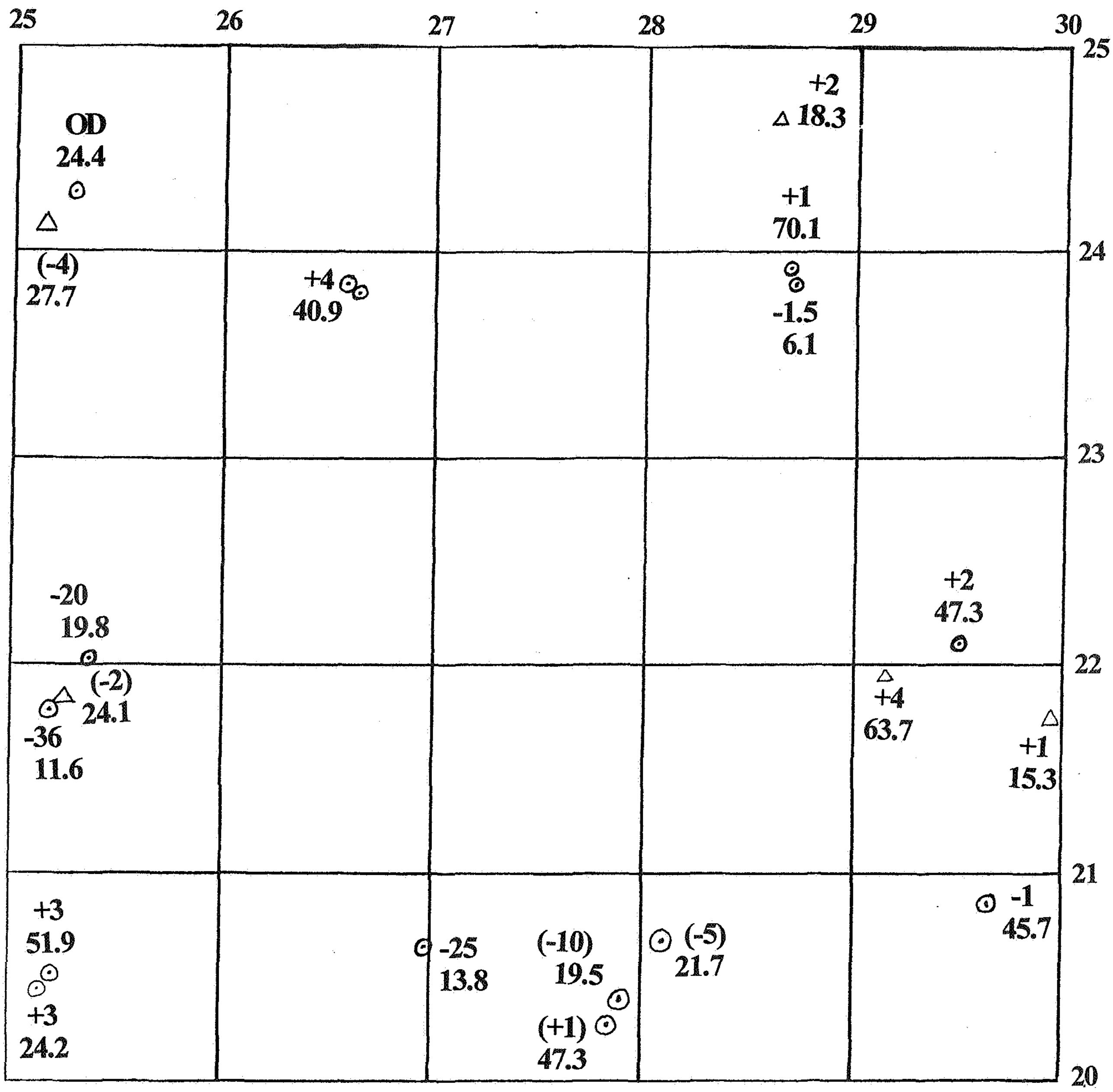

Figure 4 : Water wells proving Upper Chalk. The lower figure indicates the thickness of Upper Chalk penetrated. The upper figure indicates the OD level of the top of the Upper Chalk; where it is in brackets, the Upper Chalk is *not* overlain by Crag.

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).

THE UPPER SURFACE OF THE UPPER CHALK

Figure 4 shows the levels of the surface of the top of the Upper Chalk. Those figures in brackets indicate that the Upper Chalk is overlain by strata younger than the Corton Formation, ie some form of post-glacial valley-fill deposits: five such boreholes show the top of the Upper Chalk at OD -10m to +1m. Eleven boreholes show the Upper Chalk overlain by Crag at between OD -1.5m and +4m, while a further six confidential boreholes extending between TG 22 SE/9 [2538 2203] and /52 [2872 2384] show it overlain by Crag between OD +3 and +7m. This implies that the gross structure of the Upper Chalk surface is a gently undulating planar surface inclined generally towards the east. In practice, mapping in the Bure Valley and its tributaries in the south-east and north-west parts of the district suggest that the base here lies at around OD +5 to +7, with a highest value of around OD +12m [253 203]. This implies that the borehole records are consistently a few metres out, which is probably because of the problem of the weathered uppermost chalk becoming contaminated and unrecogniseable during percussion drilling. It might be relevant here that the confidential boreholes, which were for site investigation, give higher values than the non-confidential borings, which are well sinkings, implying a higher quality of logging in the case of the site-investigation holes, but these do not alter the overall interpretation of a gently undulating, eastward-dipping surface.

However there are three well sinkings which are highly anomalous: TG 22 NE/9 [2538 2203], TG 22 NE/49 [2520 2179] and TG 22 NE/55 [2699 2065] show the top of the Upper Chalk at respectively OD -20m, -36m and -25m, where Crag would be expected to overlie it at around OD to +7m. In the two first-named cases, the Upper Chalk is overlain by clay then sand, whilst no description is given for the equivalent deposits in /55.

These anomalies have not been wholly explained, but five possible explanations can be considered:

1) The well-sinker has been contracted to drill a certain depth into the chalk, and has deliberately falsified the logs to increase the required depth of hole and thus increase his profits. This does not appear to be a common practice, and is thus an unlikely explanation for three closely spaced holes which were sunk at widely different times by two different companies.

2) The driller has mistakenly logged the Upper Chalk as Crag as a result of brown, iron-stained sand washing down the hole and contaminating the chalk. This also does not appear likely: it has been pointed out above that recognising the Crag:Upper Chalk boundary in boreholes is easier in this district than in the Belaugh district to the south, suggesting that the chalk is less weathered and thus less liable to contamination, so as mistakes on this scale are unknown in the Belaugh district they are unlikely here. It is particularly unlikely to happen to three closely-spaced holes sunk at different times by two different companies.

3) The anomalies are sited on buried channels of sub-glacial origin, as suggested by Woodland (1970). He considered the age of the glaciation to be Saale or younger, but

in fact it would need to be Anglian, related to the Corton Formation (see below). However, whilst buried channels beneath the Lowestoft Till Formation are common and well documented, and are clearly tied to post-glacial drainage since they are confined to the bottoms of present-day river valleys (Woodland, 1970), those postulated beneath the Corton Formation in north-east Norfolk are much less common or well documented and their mode of origin and relationship to the Corton Formation must at best be considered unproven. Woodland (1970, p.554) refers to "a scatter of 39 boreholes showing anomalous depths of drift. In general the bores are not located in the bottom of the present valleys and it is not easy to identify the pattern of channels to which they belong".

In the present district, an Anglian buried channel appears unlikely. Such a channel would be a major feature of the local geology, representing lcoally a considerable increase in the thickness of the Corton Formation, and would surely have been detected by the mapping, whilst in practice two of the boreholes lie only just inside the mapped outcrop of the (thin) Corton Formation, and the other completely outside it. Furthermore, the infilling of clay overlain by sand does not accord with a sub-glacial buried channel, which would be cut by water under very high pressure and would be expected to be infilled, at least towards its base, with high-energy, coarse-grained deposits. Also, between boreholes /9 and /49, Crag is exposed in the roadside [2429 2192] at around OD +12, and Upper Chalk is exposed in the railway cutting [2225 2181] at around OD +8m. It would not be possible for these outcrops to be an erratic or erratics within the buried valley, since the erratics would have been broken up by the waters cutting the valley, so they must be *in situ.* Thus boreholes /9 and /49 represent separate features, and two sub-glacial buried valleys so close together, each more than 30m deep, would be unlikely.

4) The anomalies are caused by Crag falling or washing into karstic solution fissures exploiting joints in the chalk. This explanation is supported by the narrowness of the features and the fact that if they are long and linear, then they must be orientated NW-SE, parallel to the adjacent River Bure. However, this explanation is considered unlikely since no such features on this scale have ever been recorded in the Upper Chalk of northeast Norfolk, despite the large number of chalk quarries examined by geologists in the nineteenth century. Many such pits are known in this district, including several that lie on a NW-SE line either side of the boreholes in question.

5) The anomalies are original irregularities in the floor of the Crag sea, caused by tidal scour. This solution reduces the scale of the postulated anomalies, since their depth need only be measured below the normal base of the Crag rather than below that of the overlying Corton Formation, and it would explain their not having been picked up by the surface mapping, since two boreholes lie well within mapped outcrop of the Crag and the other anomaly is buried beneath gravelly head. This explanation would accord with the small number and irregular distribution of the anomalies in northeast Norfolk: tidal scour hollows tend to be localised since they are controlled by tidal currents which are in turn controlled by the nature of the adjacent coastline. The size of the anomalies is well within the recorded range of tidal scour hollows, which may be over 200m deep

(Belderson *et al.*, 1982; Mogi, 1979); tidal scour is currently active at depths of 80+m in the English Channel (Hamblin, 1991a, b). This would thus appear to be the most likely explanation for the anomalies.

A fourth possible anomaly, borehole TG 22 NE/54 [2791 2043] shows Upper Chalk at -10m overlain by 'shingle'. This anomaly may have a similar explanation to the three described above, although it is just outside the mapped limit of the Crag. However it is shallower than the others, and the infill is different. Since it lies within a valley, beneath gravelly head, it is possible that the shingle can be explained as Yare Valley Deposits, although this does seem rather thick for that formation in a minor tributary valley of the Bure so far upstream.

QUATERNARY - CRAG GROUP

The Crag 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 sheets. Throughout its outcrop in the district, the Crag gives rise to gravelly soils, and hand-augering is rarely effective at penetrating this. However the fifteen 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 occupies the steepest slopes in the district, 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 fifteen 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. The basal surface of the Crag has been discussed above, while the top is also difficult to distinguish in boreholes, since the overlying Corton Formation may be formed of similar gravel. Mapping confirms the gently undulatory nature of the basal unconformity, 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 Upper 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.

Mapping indicates that the base of the Corton Formation overlying the Crag lies at around OD +15m in the north and west of the district, rising to around OD +17m in the extreme south-west and north-east but dropping to around OD +12m in the central and south-eastern parts 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. In the few boreholes which reliably record the base of the Corton Formation the base is interpreted at around OD +12 to +13m. A figure of 20m has been adopted for the thickness of the Crag on the map, but if the interpretation of anomalous boreholes as representing tidal scour hollows beneath the Crag sea bed is correct, then locally the thickness would be 40m at TG 22 SE/55 and 32m at /9.

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. Both grey and brown sands are mentioned in borehole logs, which suggests that although the Crag is relatively thin and deeply dissected in this district, unweathered glauconitic strata are preserved at depth. Fossils are not common, especially in the upper part of the sequence, possibly as a result of decalcification, but shelly sands are common lower in the sequence; shells are recorded low in the sequence in boreholes TG 22 NE/11 and /60.

Gravels are an important constituent of the local Crag: only boreholes TG 22 SE/45 and /51 record complete sequences with no mention of gravel at all, either as 'gravel' 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. The thickest gravel bed mentioned in a borehole is 4.2m thick, in borehole TG 22 SE/60 [2951 2211]. 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 in the Belaugh district to the south (Hamblin, 1997b) 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 present at the only pit at which the unconformity was observed during the present survey in the Belaugh district [2657 1675] (Hamblin, 1997b). 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 coarse-grained orange-brown sand. In the present district, boreholes TG 22 NE/11, /46, /57, /59 and /60 specifically mention gravel at the base.

Clays, generally grey or buff in colour, are common in the Crag, interbedded with the sands and gravels. They are recorded at the base of the sequence in two of the boreholes (TG 22 SE/9, /49) in which the Upper Chalk was anomalously deep, respectively 6.1m and 1.5m thick, and also in TG 22 SE/45 and /47, respectively 5.8m and 10.4m thick. These thicknesses are much higher than ever recorded at outcrop, and probably refer to interbedded clays, silts and sands. Clays are recorded higher in the sequence in boreholes TG 22 SE/11, /57 and /60, up to 3.1m 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 total about 50m, and Ormesby on TG 51 SW, where they total 56m (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 Red and Norwich 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. Prestwich (1871), however, 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 in the Belaugh district [273 158] 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 a later 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 adjacent Belaugh district, the possibility remains that strata earlier than the Bure Valley Beds, ie earlier than the Pastonian transgression, may also be present at depth.

Local details

The Crag crops out widely in the valley of Stakebridge Beck in the north-west of the district, with its base at around OD +7m in overgrown chalk pits. Its top rises eastward from OD +15m to +17m east of the North Walsham road. Generally the fields are gravelly, particularly on upstanding knolls [250 237, 254 245], but orange sands were augered west of Workhouse Corner [267 248]. Two pits [268 248] near Workhouse Corner, and two pits [257 246, 266 244] high in the sequence on the south side of the valley, are unlikely to have reached the Upper Chalk and presumably worked gravel and/or clay in the Crag. Clay was augered [2532 2420] by The Grange. Borehole TG 22 SE/57 [2529 2429] within the Crag outcrop recorded brown clay to 1.5m, sand and stone to 10.7m, on Chalk, while /51 [2660 2386], within the Corton Formation outcrop, recorded 'fat sand' to 9.1m, blowing sand to 14.6m and dark grey sand to 20.1m, on Chalk; the base of the Corton Formation is unclear.

Either side of Grove Farm [275 247] the fields were gravelly, but orange sands were augered in the wide outcrop west of the North Walsham Road, and much bright red and orange sand was seen [280 249] where an old wood had recently been replanted. Clays were augered [2783 2493, 2771 2461], and the pond [2829 2482] by Old Hall Farm similarly implies clay. Borehole TG 22 SE/45 [286 246] records beneath the Corton Formation brickearth, 5.5m of sand and 5.8m of clay, upon Chalk. At borehole TG 22 SE/11 [2870 2393] the base of the Corton Formation is postulated at 8.5m depth, OD +13m, and is underlain by 12.8m of yellow and grey clays, sands and gravels, with a basal bed of grey sand and gravel and shell resting upon the Chalk.

Fields in the broad Crag outcrop west of the airfield are very gravelly, particularly on the bank [255 228] by the road, with no exposures in the old chalk pits. The bank beside the valley [257 220] south-west of the airfield was particularly gravelly, with rounded chatter-marked flints, quartz and quartzite, and the following section (TG 22 SE/HA2) was measured in a pit dug to bury dead pigs [2582 2217]:

Corton Formation...	
Crag Group	
Sand, yellow, orange and dark brown; coarse-grained, gravelly, with rounded flint, quartz, quartzite; less gravelly downwards, most clasts up to 5cm long, some up to 10cm long	0.5 - 1.0
Sand, yellow, buff and orange; fine- to medium-grained, non-gravelly	0.5+

The Crag exposures in the railway cutting at Little Hautbois are now overgrown, but orange sands can be seen in burrows, and east of the bridge [2525 2181] Woodward (1881, p.57) recorded the 'stone-bed', capped by sands, seams of laminated clay, and pebbly gravel, to a total thickness of about 3m. The following section (TG 22 SE/HA1) was measured in the roadside [2529 2192] above Little Hautbois :

Clast-supported gravel, up to 7cm clast size, with sand matrix; clasts of rounded flint, quartz, quartzite	0.15
Sand, deep orange-brown, coarse-grained; horizontal, flat-bedded; few pebbles of flint up to 1cm long; seams of pale brown clay to 8mm thick	0.20

Borehole TG 22 SE/9 was situated just inside the mapped outcrop of the Corton Formation, and recorded an anomalous depth to the Upper Chalk, recording brown sand and stones to 4.6m depth, brown sand to 27.4m, and grey clay to 33.5m. Borehole TG 22 SE/49, situated on gravelly head outside the mapped area of the Crag, recorded a similar anomalous depth to the Chalk, with sand logged to 43.3m depth, clay to 44.8m, then Chalk. If the interpretation of the depressions in the Chalk surface as tidal scour hollows formed in the Crag sea is correct then it is likely that the clay and most of the sand in this borehole are Crag, but this site has not been shown on the map as being within the Crag outcrop because of doubts as to the origin of the depressions.

Orange sands were seen in burrows in the railway cutting south-east of Little Hautbois, and a thick bed of clay at or near the base of the sequence south-west of the road [257 214 to 260 211] was detected by augering and feature mapping. There are many small abandoned chalk pits to the south-west and north-east of Hautbois Common [262 208], but no Crag was exposed during the current survey, and none was described by Woodward (1881). There are two abandoned pits wholly within the Crag outcrop at Hautbois Common [261 210, 265 206]: since the latter is adjacent to the railway it might have provided gravel specifically for railway ballast. Several large abandoned pits within the Crag outcrop in the valley north-east of Hautbois Common [269 215, 270 218, 271 216, 273 217] have been ploughed over but are associated with very gravelly soils and may have been worked for gravel and/or brick clays, while patches of very gravelly soil were noted almost to the northern limit of the Crag outcrop in this valley.

The largest pit in the area [266 204] has been regraded as part of a campsite, but Woodward (1881, p.57) recorded:

Red gravel	0.2
Laminated clay and white sand	3.1
Chalk	

In the foundations of the bridge by Coltishall Station [270 204], Woodward (1881, p.60) recorded 3m of pebble gravel overlain by the Corton Formation, whilst he records an elephant or mastodon bone found in pebble gravel near the station goods shed. The railway land on the north side of the tracks [267 206 to 269 205] has obviously been excavated and possibly provided ballast for the railway.

One of the best sections to be seen in the nineteenth century was at the pit [269 202] south-east of the station, where not only was chalk excavated but laminated clay in the Crag was worked for bricks. In 1877 Woodward (1881, p.59) recorded:

False-bedded pebble gravel and sand	2.7 - 3.7
Laminated clay with bed of sand	1.8 - 2.0
False-bedded sand, gravel, and shell-beds, with seams of clay and clay-pebbles	1.5
Chalk, with flints including paramoudras	3.7+

Laterally the clay becomes interbedded with sand, while the gravel rests on an eroded surface of the clay. Woodward recorded *Mytilus edulis* from 0.3-0.6m above the Chalk; at one point the shell bed terminated in a mass of buff unfossiliferous sand. Prestwich (1871, p.459) mentioned a subordinate bed, 0.5m thick, of ferruginous sandstone and ochreous clay, in the pebble gravel. He referred to the gravel as Westleton Beds, and the clay as Chillesford Clay, both terms relevant to the Norwich Crag of Suffolk.

South-west of the River Bure, the Crag crops out north and south of Horstead Hall [251 207]. The fields are very gravelly, particularly [254 206] east of Grange Farm, while bright orange sands are widespread in burrows in the abandoned chalk pit [250 208] north-east of the hall. At a pit (?[254 203]) 'between Stewpond Car and Horstead Hall', Whitehead (1881, p.59) recorded 8 ft (2.5m) of pebble-gravel containing boulders of quartz and large flints. At the pit 'south of Stewpond Car' [256 202] he recorded:

Sand and pebble-gravel	0.9 - 1.2
Laminated clay (irregular)	0.6
Sand and gravel with shells; stone bed and white sand	0.1 - 1.2
Chalk	

The large pit west of Horstead Church, served by a canal [260 200], was abandoned and overgrown by the time of Whitehead's visit, but at another pit 'a little further west' [258 201] he recorded:

Pebble gravel with large flints and shells	1.2 - 1.5
Laminated clay	0.9
Sand and gravel; stone bed, rolled flints and pebbles	0.9
Chalk.	

Whitehead (1881, p.59) considered this to be the pit at which Prestwich (1871, p.459, 468) recorded that "At Horstead the Westleton shingle with crag-shells overlies the Chillesford Clay".

The valley running north-eastward from Coltishall contains many abandoned pits within the Crag outcrop and straddling the Crag:Corton boundary, and these will have been variously worked for gravel and clay. That by Tunstead Road Cottages [280 202] is described as a sand pit on the Old Series map, but was more likely a brick pit, whilst that [287 220] opposite Marter's Farm was also clearly a brick pit, since there is much orange clay in the soil and a pond in the pit. Dry pits higher in the succession are generally associated with gravelly soil and may have been worked for clay and/or gravel, while a pit [280 216] within the outcrop of the Corton Formation, which is very overgrown and has a pond within it, provided bricks for building Sco Ruston Hall [282 220]. The outcrop immediately below the base of the Corton Formation is commonly very gravelly, with rounded flints dominant, for instance [289 222] by Manor Farm and [294 214] south of Granary Lane.

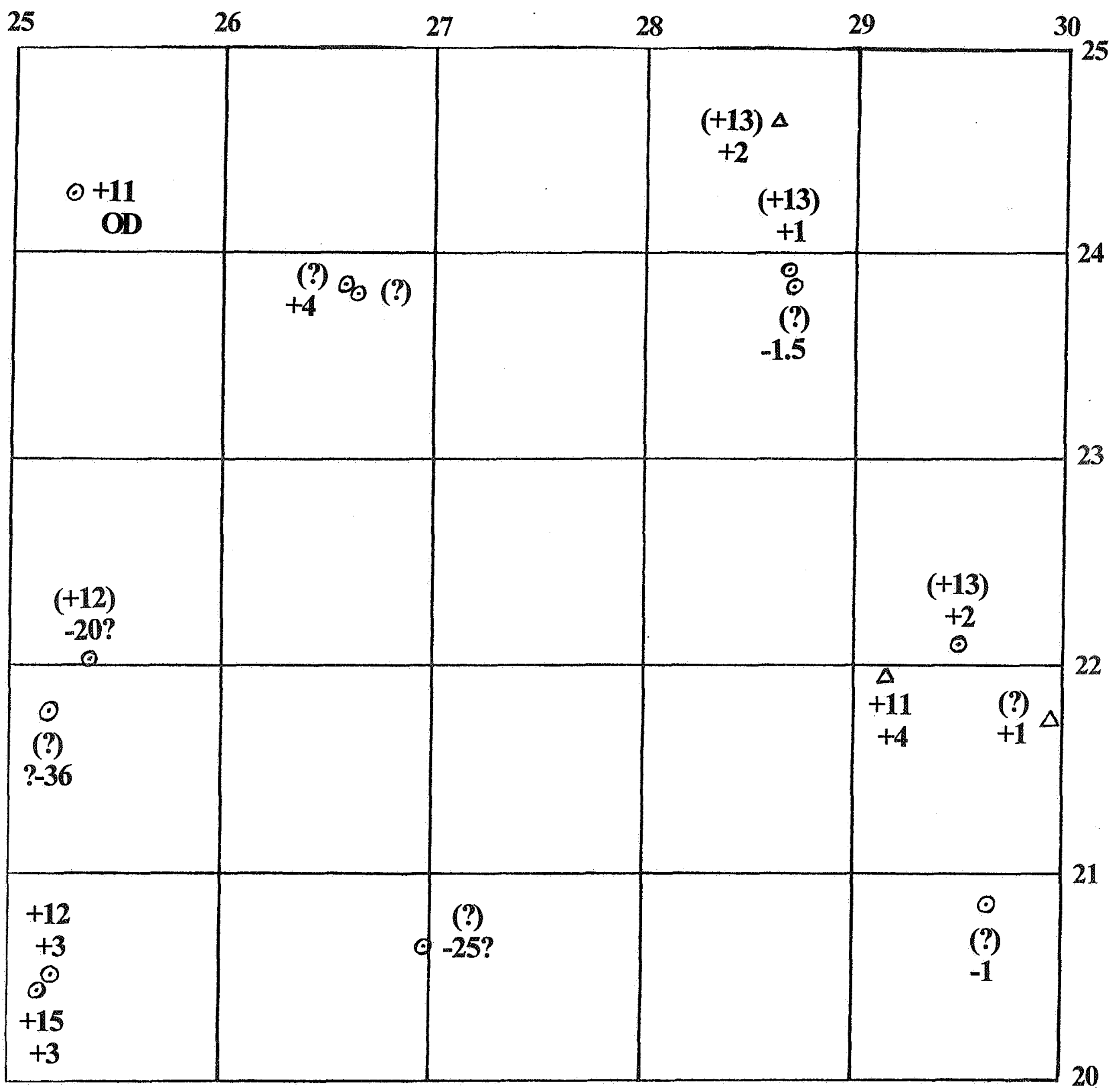

Figure 5 : Water wells and boreholes penetrating the Crag Group. The lower figure is the level of the base of the Crag resting upon Upper Chalk. The upper figure is the level of the top of the Crag: where this is in brackets, the Crag is overlain by drift, and the level is an estimate; where the number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

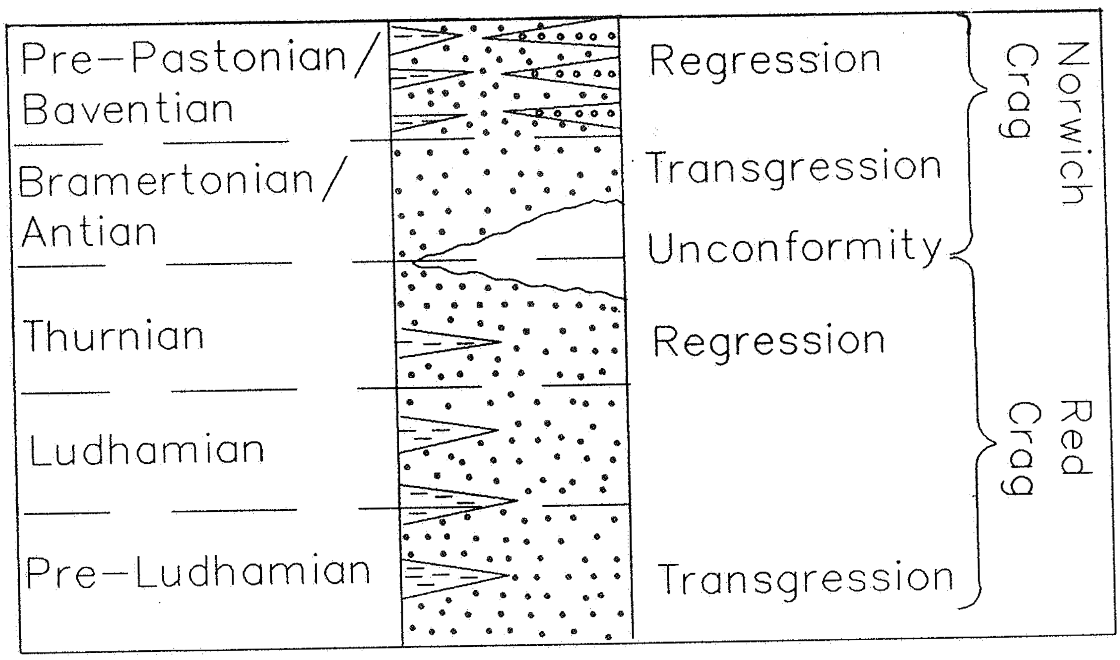

Figure 6 : Generalised stratigraphy of the Red and Norwich Crags, after Hamblin *et al.* (1997). The sedimentology indicated is that found in eastern Suffolk, and recognises sands (dotted), 'Westleton Beds' gravels (small circles), and clays (dashed).

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

In Suffolk, 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. Either way it is unlikely to be present the Scottow 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 Scottow 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 Crag 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). However most of these deposits are marine and hence form a part of the Crag. 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 that.

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 Scottow 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 a large part of the district, overlying the Crag. Mapping indicates that the base of the formation lies at around OD +15m in the north and west of the district, rising to around OD +17m in the extreme south-west and north-east but dropping to around OD +12m in the central and south-eastern parts of the district. However this mapping is rather imprecise, since both the highest Crag and lowest Corton Formation are very gravelly. The junction is indicated by an upward increase in the amount of fresh, angular, 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. In the few boreholes which reliably record the base of the Corton Formation, the base is interpreted at around OD +12 to +13m. It is thickest, around 10m, in the north-east, where it reaches an altitude of over +25m OD [282 241]. 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 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 brown or yellowish 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, 1997a), 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.

Mapping of the Corton Formation is hindered by the overlying cover silt, which often has a basal bed of gravel which is impenetrable to an auger, so while it has proved possible to broadly separate areas of clay deposits (mostly till), and arenaceous deposits (Corton Sands, sands and gravels) it is likely that further pods and patches of till occur within the arenaceous deposits, and vice versa. Over a large part of the centre of the district a till crops out which is assumed to be the local representative of the Corton Till. This is widely underlain by further Corton Formation comprising coarse sands and gravels, and over a large part of the south of the district these are the only surviving remnant of the Corton Formation. The till is overlain by sands to the north, 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. In the north-east of the district two tills are present, separated by typical Corton Sands, but as these are close together (in a vertical sense) they may be two partings of the single till known at Corton. In other areas in the north of the district no till is present and a thick sequence of sand and gravel overlies the Crag.

Corton Formation - Details

East of Workhouse Corner [267 247], a thin outlier of basal Corton Formation gravelly sands forms a low plateau. South of this, the base of the formation drops from OD +15m [254 244] near The Grange to about +13m [270 245], then rises to about +17m [285 248] near The Old Hall. Above this to the south, an east-west ridge rises to OD +25m at the rugby ground [280 240], and to OD +22m [2662 2387] at Scottow Hall, where Borehole TG 22 SE/51 [2660 2386] shows the whole of the Corton Formation and Crag to be sand. Apart from a shelf of till [256 243] above The Grange, at the same level as the till at the airfield, the fields along the north side of the ridge show no shelf feature to indicate a till within the sands, and there is no suggestion that the till which forms the plateau of the airfield, to the south of the Scottow ridge, extends beneath the ridge. There is however a small patch of till at OD +22m at the top of the ridge [266 239], much higher than the level of the airfield. Generally the ridge is blanketed by cover silt, and augering proved gravel at the base of this, so the Corton Formation could rarely be sampled. However, at the western end of the ridge, south of Grange Farm Cottage [2565 2408], several auger holes penetrated sands and gravels of the Corton Formation, while at the eastern end of the ridge, around the rugby ground, several holes proved typical Corton Sand.

In the north-east of the district, two tills are present, but as these are close together (in a vertical sense) they are believed to be leaves of the till which outcrops at the airfield. The higher till crops out around The Old Hall, but at outcrop it could not be traced farther south than the road to the south, being surrounded to the west, south and east by Corton Sand. The lower till to the west, a metre or so below the higher till, appears to rest directly on Crag, but this also cannot be traced far south at outcrop, although borehole TG 22 SE/45 [286 246] records brickearth to 7.0m depth, OD +13m. To the east the lower till crops out at Worstead Common [294 249] but could not traced farther south-west than the pond [2922 2482] at Lacey Farm. Farther south, borehole TG 22 SE/11 [2870 2393] also appears to record two tills very close together: sand to 1.2m, soft sandy clay to 5.5m (OD +17), sand to 5.8, yellow clay and sand and stone to 7.6m (OD +14m), sand to 8.5m (base of Corton Formation postulated at OD +13m). The higher of these tills crops out in the valley to the east, being proved in several auger holes particularly at the northern end of its outcrop, and passing onto sheet TG 32 SW at Frankfort [300 243]. Corton Sands were augered to the south and west of this till outcrop, while farther south, between the outcrops of gravel and sand of uncertain age and origin, both Corton Sands and coarser, more gravelly sands were proved.

A sheet of till forms the flat plateau on which stands Coltishall airfield, although as explained above this does not appear to extend far beneath the sands of the ridge to the north. Till was proved by augering in fields to the west, north-east and south-east of the airfield [260 225, 275 235, 264 217], and in confidential boreholes within the airfield limits. It is, however, likely that patches and pods of sand are present within this till, but the airfield was not augered because of the certainty of the ground having been disturbed and because of the ubiquitous veneer of cover silt with its basal gravel making augering results inconclusive. To the west the till was augered on the shelf west of Hautbois Road [253 233], but it could not be traced north of the cross-roads [253 237]. To the east of the airfield the till outcrop continues to Sco Ruston, where there is a large abandoned brick-clay pit [284 222], thence south-south-west almost to Coltishall [273 208]. From Manor House Farm [285 226] the outcrop extends to Tunstead and thence across sheet TG 32 SW. The continuity of the till outcrop was adequately proved by augering, but because many holes were ended in the gravel bed at the base of the overlying cover silt, it is impossible to say how many patches and pods of sand may occur within the till. A patch of till south-west of Tunstead [293 208] may be an erosional outlier of the main till, or may be a small pod of till within the arenaceous deposits.

To the west, south and east of the airfield, Corton Formation gravelly sands crop out between the till plateau and the Crag. Corton Sand was augered at one point [2570 2228]. The following section (TG 22 SE/HA2) was recorded in a temporary pit [2582 2217]:

Cover Silt: silt, medium purplish brown; scattered angular flints	0.9
Corton Formation	
Coarse angular sand, pale to medium brown, gravelly, with pebbles of rounded and angular flint, quartz and quartzite	0.85
Sandy gravel; sand as above, gravel is mostly rounded flints up to 8cm long with a few up to 15cm long, also quartz and quartzite; very poorly sorted	0.1

The gravelly sands beneath the till have a wider outcrop north of Coltishall village, but augering rarely penetrated the gravelly base of the cover silt. Three 2m-deep abandoned pits [278 217, 278 216, 279 214] south-west of Sco Ruston Hall appear to lie within this outcrop; around the pit adjacent to the road, the soil was very gravelly with large fresh flints. Between here and [286 222] north of Marter's Farm, several auger holes penetrated Corton Formation coarse gravelly sands, and one [2863 2210], Corton Sand. In the south-east corner of the district these basal Corton gravelly sands cover a plateau at about OD +15m over a wide area, but they never reach a great thickness; borehole TG 22 SE/60, just within the outcrop of the overlying till [2951 2211] records 'sandy soil with stones' to a depth of 2.4m, on Crag. Scattered auger holes penetrated the base of the cover silt to prove gravelly sands, and one [2927 2031], Corton Sand.

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 gravelly sands high in the Corton Formation. It is only found in the north-east quarter of the district, where five patches rest at levels of OD +22m to +26m.

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 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 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 been 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.

In the present district, the Yare Valley Formation has not been proved by boreholes in the valley of the River Bure itself, but boreholes beside the Bure in Horstead, at the northern end of sheet TG 21 NE, 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. Three boreholes in the tributary valley at St. James are believed to have penetrated the formation beneath gravelly head: TG 22 SE/53 [2809 2069] recorded 'sand and stones' to 7.6m depth, OD -5m; TG 22 SE/56 [2785 2030] recorded 3.0m of 'top soil' to OD +1m, resting upon Chalk, but TG 22 SE/54 [2791 2043] recorded sand to 11.9m then shingle to 14.0m, OD -10m. This seems rather deep for Yare Valley Formation in a tributary valley so far upstream in the Yare/Bure/Waveney system, and the possibility arises that this is an anomalous depth to the Chalk as discussed above. However, the presence of 2.1m of shingle accords with the identification of Yare Valley Formation, since TG 22 SE/9 and /49, which undoubtedly record anomalous depths to the Chalk, record the Chalk as being overlain by clay.

In the valley of the Stakebridge Beck, borehole TG 22 SE/4 records loam to 1.2m, sand and stones to 3.7m, brown sand to 8.8m, then sand with layers of clay to 11.9m, resting upon Chalk at OD -4m. These deposits are believed to be Yare Valley Formation beneath thin head; the lack of gravel in the Yare Valley Formation would indicate low energy conditions in a relatively quiet tributary of the Bure.

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 1.5m 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 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 Yare Valley Formation, the surviving deposits are likely to be Devensian. Gravelly head occurs in valleys of the River Bure and its tributaries, where the Upper Chalk appears at rockhead, with outcrops up to 300m wide and up to about 5m thick.

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 tributaries of the Bure. The only large and clearly defined area lies around Long Plantation [275 249], but smaller, poorly defined patches are common, and strips of head are shown on the map west of Tunstead [293 223, 293 219, 293 214].

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 3m thick and it is doubtful whether all the elements of the formation are present, or even whether the standard stratigraphy applies at all. Boreholes at Horstead in the Belaugh district (TG 21 NE) 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.

ALLUVIUM AND PEAT

Alluvium has been recorded in the valley of Stakebridge Beck, a tributary of the River Bure [250 242 to 247 250]. It comprises soft laminated silty clays and clayey silts, deposited by the stream during the Holocene.

Peat is widespread in the tributary valley of Stakebridge Beck south of Workhouse Coppice [260 250 to 271 246], up to about 2m thick. Much of it has been formed since the creation of Scottow Pond [263 247]. It is not included in the Breydon Formation since it is unlikely that marine influences persisted this far upstream.

MADE GROUND, WORKED GROUND AND LANDSCAPED GROUND

There is very little made ground in the district. This is largely restricted to railway and road embankments, and an old castle mound [261 202]. A sewage works [251 224] 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 and upstream of Coltishall well into the 19th century, although all the pits were abandoned and became overgrown before the end of the century (Woodward, 1881). The materials were exported by barge to Great Yarmouth for onward shipment, and one quarry has a canal extending into it from the River Bure [260 200], the marl being loaded onto barges straight from the quarry face.

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 those [270 215, 270 213] farthest up the valley above Hautbois Common. There may be further, unknown areas of infilled ground (wholly back-filled worked ground) which are not shown on the map.

It is believed that the Crag and Upper Chalk were not normally worked together, although the pit [266 203] north of Great Hautbois House is marked on the Old Series map as a 'Crag Pit and Chalk Pit'. However there are a large number of disused pits within the Crag. Generally these are smaller than the chalk pits. They will have variously worked 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 pit low in the succession at St James [280 202] is described as a sand pit on the Old Series map, but clay in the soil implied that it was also a brick-clay pit, while the pit [280 216] beside the North Walsham road worked clays for the bricks to build Sco Ruston Hall [282 220]. 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 more likely worked gravel. However, in some cases, 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 arenaceous Corton Formation may have been within small 'pods' of till, eg flow tills. There are surprisingly few disused brick clay pits within the mapped outcrop of the Corton Formation till, suggesting that the Crag was worked for preference. The largest brick clay pit in the Corton Formation [284 222] is shown on the Old Series map as a 'loam pit', while a shallow depression [279 232] south of Scottow is believed to be a back-filled brick pit. Other, smaller holes were probably dug as ponds for watering cattle, although the larger ponds, such as those at Herne's Farm [266 219] and Manor Farm, Scottow [266 233] may have initially been worked for brick clays. There are no peat workings or 'Broads' known in the district, either in the Breydon Formation or the younger peat, but some small ponds within the Breydon Formation were probably dug as wildfowl decoys. Scottow Pond [263 247] has been created artificially by damming the valley.

ECONOMIC GEOLOGY

Industrial minerals

At present mineral extraction activity within the district is restricted to minimal gravel extraction by farmers for there own use, although in the past, marl and flints have been extracted from the Upper Chalk, and brick clay, sand and gravel from the Crag and Corton Formation. Gravels within the Crag are of high quality, comprising largely flint, quartz and quartzite. These have been worked at Mayton Wood to the west, and future workings within the present district are a possibility. 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, 21 bores for water are known, TG 22 SE/4, 8, 9, 11 and 45 to 61, and depths quoted range from 30.5m to 91.4m. All of these penetrated the Upper Chalk, but detailed logs for some 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 -4m to +14m O.D. Water consumptions quoted vary widely: a 4-hour pumping test at TG 22 SE/45 at 1500 gallons (6818 litres) per hour yielded a depression of 13.4m, with recovery in 24 minutes. Water from the Upper Chalk is hard, and some wells reported it to be ferruginous.

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APPENDIX - ABBRIEVIATED LOGS OF SELECTED BOREHOLES HELD BY BGS TO JANUARY 1997

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 22 SE.

	Depth (m)	O.D. Level (m)
4. Stakebridge Farm [251 241] OD c +8		
Head, Gravelly head, Yare Valley Formation		
Topsoil, loam	1.2	+7
Sand and stones	3.7	+4
Brown sand	8.8	-1
Sand with layers of clay	11.9	-4
Upper Chalk		
Chalk	39.6	-32
8. Grange Farm, Horstead [2520 2052] OD c +12		
Crag		
Top soil, loam, sand and stones	4.9	+7
Brown sand	9.1	+3
Upper Chalk		
Chalk	61.0	-49
9. Hautbois [2538 2203] OD c +13		
Corton Formation, Crag, Upper Chalk		
Topsoil, brown sand	1.5	+11
Sand and stones	4.6	+8
Brown sand	27.4	-14
Grey clay	33.5	-20
Chalk	53.3	-40
11. Home Farm, Sloley [2870 2393] OD c +22		
Corton Formation, Crag		
Top soil, sand	1.2	+21
Soft sandy clay	5.5	+17
Sand	5.8	+16
Yellow clay and sand and stone	7.6	+14
Sand	8.5	+13
(postulated base of Corton Formation at +13)		
Yellow clay and sand and stone	9.8	+12
Hard grey clay and sand and stone	10.7	+11

Sand and gravel	13.7	+8
Grey sand and gravel and clay	19.2	+3
Grey sand and gravel and shell	21.3	+1
Upper Chalk		
Cobbly Chalk and sand	22.3	OD
Cobbly chalk and flint	91.4	-69

45. High Kennels, Sloley [286 246] OD c +20

Corton Formation, ?Crag		
Top soil, brickearth	7.0	+13
?Corton Formation, Crag		
Sand	12.5	+8
Crag, ?Upper Chalk		
Clay	18.3	+2
Upper Chalk		
Chalk	36.6	-17

46. Manor Farm, Tunstead [291 219] OD c +12

Gravelly head		
'Topsoil'	0.6	+11
Crag		
Yellow sand	4.3	+8
Grey sand	5.8	+6
Yellow sand	7.3	+5
Stones	7.9	+4
Upper Chalk		
Marl	13.1	-1
Loose chalk, stones	32.9	-21
Chalk, flints	71.6	-60

47. The Grange, Horstead [2515 2045] OD c +15

Crag		
Top soil, brown sand	1.8	+13
Crag, ?Upper Chalk		
Soft grey and yellow clay	12.2	+3
Upper Chalk		
Chalk	36.6	-22

48. Woodside, Little Hautbois [252 218] OD c +9

?Crag or ?infilled ground		
Top soil, sand and shingle	11.0	-2
Upper Chalk		
Chalk	35.1	-26

49. Bridge Farm, Little Hautbois [2520 2179] OD + 8.5

Gravelly Head, Upper Chalk

Sand	43.3	-35
Clay	44.8	-36
Chalk	56.4	-48

50. Scottow Hall [2665 2381] OD + 24.3

Corton Formation, Crag		
Clay		
Sand		
Clay		
Black clay		
Silver sand		
Sand	13.2	+11

51. Scottow Hall [2660 2386] OD + 23.8

Foundations	1.0	+23
Corton Formation, Crag		
Fat sand	9.1	+15
Blowing sand	14.6	+9
Dark grey sand	20.1	+4
Upper Chalk		
Chalk, chalk and flints, chalk	61.0	-37

52. Sloley Farm [2872 2384] OD + 22.6

Corton Formation, Crag		
(undescribed)	24.1	-1.5
Upper Chalk		
Chalk	30.2	-7.6

53. Horngate Cottage [2809 2069] OD + 3

Brick shaft	2.7	OD
?Gravelly head, ?Yare Valley Formation		
Sand and stones	7.6	-5
Upper Chalk		
Chalk	29.3	-26

54. St. James Farm [2791 2043] OD + 4.3

Gravelly head, ?Yare Valley Formation		
soil, sand	11.9	-8
shingle	14.0	-10
Upper Chalk		
Chalk	33.5	-29

55. Council Houses, North Walsham Road [2699 2065] OD + 15.8

Corton Formation, Crag, Upper Chalk		
Depth to Chalk	41.1	-25
Chalk	54.9	-39

56. The Old Hall, Coltishall [2785 2030] OD c +4

Gravelly head, ?Yare Valley Deposits		
'Top soil'	3.0	+1
Upper Chalk		
Soft chalk; flints encountered at 18.3m and 48.8m.	50.3	-46

57. Grange Farm, Scottow [2529 2429] OD c +11

Top soil	0.3	
Crag		
Brown clay	1.5	+9
Sand and stone	10.7	OD
Upper Chalk		
Marl	21.3	-10
Chalk	35.1	-24

59. Laurels Farm, Tunstead [2965 2085] OD c +15

Well	6.7	+8
Crag		
Sand and shingle	16.2	-1
Upper Chalk		
Chalk, with much stone	61.9	-47

60. New housing site, Tunstead [2951 2211] OD +15.8

Soil	0.4	+15
Corton Formation		
Sandy soil with stones	2.4	+13
Crag		
Fine gravel	3.4	+12
Coarse gravel	6.6	+9
Blue loamy clay - water	10.7	+5
Grey sand	12.2	+4
Sand and shells	13.4	+2
Flint bed	13.7	+2
Upper Chalk		
Chalk - water	61.0	-45

61. British Railways' No.7 gatehouse, Tunstead [299 217] OD c +16

Brick shaft	4.6	+11
Crag		
Sand	15.2	+1
Upper Chalk		
Chalk	30.5	-15