BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/88/31

Onshore Geology Series

TECHNICAL REPORT WA/88/31

Geological notes and local details for 1:10 000 Sheet SP20SW (Filkins)

Part of 1:50 000 Sheets 235 (Cirencester), 236 (Witney), 252 (Swindon) and 254 (Henley on Thames)

A Horton

Geographical index
UK, Cotswolds, Oxfordshire, Gloucestershire

Subject index
Geology, Jurassic

Bibliographic reference
Horton, A. 1988. Geological notes and local details for 1:10 000 Sheet SP20SW (Filkins). *British Geological Survey Technical Report* WA/88/31.

 Keyworth, Nottingham British Geological Survey 1988

1 PREFACE

This account describes the geology of the 1:10 000 map SP 20 SW, which includes parts of the 1:50 000 New Series Sheets 235 (Cirencester), 236 (Witney), 252 (Swindon) and 253 (Abingdon). The district was first surveyed on the one-inch scale by E Hull and was published as part of Old Series One-Inch Sheet 34 in 1857; the descriptive memoir by Ramsey, Aveline and Hull was published in 1858. The geology of the district was subsequently described in the Geological Survey Memoirs: 'The Country around Cirencester' (Richardson, 1933) and 'The Geology of the Country around Witney' (Richardson, Arkell and Dines, 1946). The hydrogeology of the district was described in two Geological Survey Water Supply memoirs - Wells and Springs of Gloucestershire (Richardson, 1930) and Water Supply of Oxfordshire (Tiddeman, 1910).

The drift was surveyed and the solid geology partly revised by H G Dines in 1931 and 1935. The primary Six-inch geological survey was commenced in 1967 by P Toghill with the mapping of the area south of Grid line 001. This was further revised by E G Poole in 1969 and included in the New Series Sheets 252 (Swindon) and 253 (Abingdon) published in 1974 and 1971 respectively. This survey was completed by Dr A W Kemp in 1973 and the results published as part of the 1:50 000 Sheet 236 (Witney) in 1982. The area has been entirely resurveyed by A Horton in 1984.

The present survey forms part of a joint project partly funded by the Thames Water Authority to prepare new geological maps of the southern half of Sheet 235 (Cirencester) and adjacent areas.

The geological map SP 20 SW was published in 1985. Dyeline black and white copies can be ordered from Book Sales, British Geological Survey, Keyworth. Borehole records can be consulted at the Keyworth Office.

F Geoffrey Larminie, OBE
Director
British Geological Survey
Keyworth
Nottingham NG12 5GG

GEOLOGICAL NOTES AND LOCAL DETAILS FOR 1:10 000 SHEET SP 20 SW FILKINS, OXFORDSHIRE

INTRODUCTION

The area lies immediately to the north of Lechlade and lies within parts of the counties of Gloucestershire and Oxfordshire. It includes the villages of Filkins with Broughton Poggs, parts of Southrop and Langford, and the northern outskirts of Lechlade. The River Leach flows south-eastwards across the area and for part of its length defines the boundary between the counties.

The district lies at the margin of the Cotswolds, the limestone uplands forming the highest ground along the northern margin of the sheet, where they attain a maximum altitude of 109 m OD in the north-west extremity, to the north-west of Greenhill Barn. The summit altitudes decrease southwards, first giving rise to a low undulating topography with gravel-capped hills and then to the terrace flats north of the River Thames. The district is dissected by four south or south-easterly flowing streams; an unnamed brook through Great Lemhill, the River Leach, the Langford Brook and, in the north-east, the Broadwell Brook.

The land is now very largely arable although permanent pasture is present on the floodplains of streams. Even in summer, the streams are constant, being fed by springs, and are liable to flood during winter.

The geological sequence exposed is:

DRIFT		
Peat Alluvium Older Alluvium Calcareous Tufa and Head	Flandrian	QUATERNARY
River Terrace Deposits: Terrace 1, 2 and 3 Head (Older and Younger) Head Gravel	Pleistocene	

SOLID

Oxford Clay			
Kellaways Sand	Ancholme Group	Callovian	
Kellaways Clay			
Cornbrash			JURASSIC
Forest Marble Formation	Great Oolite Group	Bathonian	
White Limestone Formation			

OXFORD CLAY

The formation crops out over the southern part of the sheet, south of a line from the vicinity of Little Lemhill Farm [207 011] to Langford. It consists almost entirely of soft mudstones and its outcrop is occupied by the Thames valley. Locally, where the outcrop is protected by thin patchy deposits of terrace gravel, there are small, low, gravel-capped hills. Much of the low-lying Oxford Clay outcrop is masked by extensive, younger terrace deposits.

Up to 27 m of the formation are represented at outcrop and these probably belong entirely to the Lower Oxford Clay. The shallow, weathered exposures show pale yellowish grey mottled, smooth clay with secondary selenite ($CaSO_4.2H_2O$) crystals. The latter result from the interaction of sulphate ions (derived from the oxidation of pyrite) and calcium ions (produced by the leaching of shells). At greater depths these weathered beds give way successively to medium grey, disaggregated mudstone and then interbedded medium to pale grey mudstones with olive to brownish grey, more fissile, shelly, shaly, bituminous mudstones which contain sporadic thin ammonite-rich layers and pyritic shell-beds.

A thin, apparently impersistent, pale olive-brown micritic limestone was traced for a short distance on the hill-slope at the south-west of Little Farringdon Wood [228 020]. This is thought to represent the Acutistriatum Band-Comptoni Bed marker horizon developed within the Oxford Clay to the north-east in the Witney district, and exposed in brick pits at Calvert, Bletchley and Peterborough (Callomon, 1968). The Acutistriatum Band-Comptoni

Bed was proved in boreholes and sections associated with the construction of the Witney Bypass where it occurred about 20.5 m above the base of the formation. In the North Leigh Borehole [SP 3829 1296], 4.5 km to the north-east of Witney, it was some 19.7 m above the base of the formation.

In the Witney area, at least two nodule beds are also present in this formation. These consist of pale grey argillaceous micritic limestone nodules up to 0.6 m in diameter with clear calcite septarian veins. At the Witney Bypass, these occurred about 6 m and 16 m above the base of the formation, ie about 14.5 and 5 m respectively below the Acutistriatum Band-Comptoni Bed. These were not recorded at surface during the present survey, but fragments were noted in the gravel deposits.

KELLAWAYS BEDS

The Kellaways Beds give rise to a very low escarpment or gentle feature to the south-east of the Cornbrash dip-slope. The outcrop is extensively obscured by Drift deposits and it is only near Great Lemhill Farm [209 020] and south of Broughton Poggs, that a feature is clearly developed. The Kellaways Beds have been traced by augering; no sections were recorded during the survey. Evidence of the thickness of these beds has been derived from well-sinkers' records. The lithological detail in such logs is generally inadequate and it is generally not possible to distinguish the Kellaways Clay and Kellaways Sand units. The total thickness of Kellaways Beds in this area appears to be of the order of 10 to 12 m.

KELLAWAYS SAND

The Kellaways Sand comprises 5 to 7 m of pale grey fine-grained sand. At the surface it gives rise to a pale brown loam, and in shallow exposures it locally consists of very pale grey or pale yellowish grey-mottled sand. Its presence in ditch sections is often marked by a slow seepage of water and a resultant growth of *Equisetum* both on the ditch sides and on the associated spoil. Although no unweathered material was recorded locally, in adjacent areas it commonly consists of interbedded pale grey, indefinitely laminated, often intensely bioturbated, silty sandstone and sand with subordinate silty mudstones and siltstones. The coarser beds are commonly weakly lime-cemented

but tend to be decalcified at outcrop. Thick-walled shells, particularly bivalves including *Gryphaea*, occur throughout.

The Kellaways Sand is of marine origin and accumulated in relatively shallow current-swept waters.

KELLAWAYS CLAY

The Kellaways Clay occurs locally as outliers on the Cornbrash dip-slope, but generally it forms the lower part of the rising ground down-dip from this feature. At outcrop it gives rise to a heavy clay soil which overlies a darker grey smooth clay. Unweathered material was not exposed at the time of the survey, but in adjacent areas it comprises dark grey, smooth mudstone with scattered pyrite traces. It is very poorly fossiliferous and does not yield the large idiomorphic selenite crystals which characterise the weathered zone of the Oxford Clay.

Estimates of the thickness of the formation are based on borehole evidence (Table 1); they range between 0.15 and 6.7 m. The true thickness is probably of the order of 3 to 5 m, which compares with the 3.63 m recorded in the North Leigh Borehole [3829 1296].

The Kellaways Clay was deposited in a quiescent marine environment. Micaceous or silty partings are rare and bioturbation uncommon. The paucity of the fauna suggests conditions inimical to animal growth and stagnant or near-stagnant bottom conditions.

CORNBRASH

The limestones of the Cornbrash crop out extensively across the northern part of the district from north of Great Lemhill to Filkins. The basal beds give rise to a strong topographic feature, rising above the Forest Marble outcrop. The overlying beds extend down-dip eastwards to the Kellaways Beds outcrop. The Cornbrash generally overlies the clay division of the Forest Marble. Where thin but extensive layers of the basal limestone rest on the clay, they have commonly been extensively cryoturbated during the Pleistocene Period causing small (up to 1 m) pockets of limestone to be enclosed in clay outcrops.

Consequently it is difficult to define the boundary between the Cornbrash and the Forest Marble in such areas.

Larger scale superficial structures may also be present. North-east of Coates Mill, the Cornbrash [202 048] appears to be cambered, forming a drape across the small ridge. Again, to the north-west of Broughton Poggs, the south-easterly dipping Cornbrash on the ridge above the Broadwell Brook is cambered.

The Cornbrash gives rise to a reddish brown loamy to clayey soil with abundant brash in some areas; where more deeply weathered, particularly on the dip-slope, there may be little brash. The outcrops of the lowest and the highest beds are commonly marked by an abundance of fossils in the soil.

The Cornbrash was briefly described by Hull (1857), but more comprehensively by Woodward (1894), Blake (1905) and subsequently by Douglas and Arkell (1928) and Richardson (1933, 1946). Many of the sections then described have been obscured and others extensively degraded. Incomplete sequences are still visible, however, in the quarries at Southrop [2012 0293] (p 8), west of Broughton Poggs [226 041] (p 9) and at Broughton Copse [2273 0317] (pp 9-10), south-west of the village.

The thickness of the Cornbrash is difficult to estimate from surface evidence because of its broad outcrop. There is no consistency in the classification of the well-sinkers' borehole records (Table 1). The thickness probably lies between 2.5 and 3.7 m: this compares with the 4 m estimated on sheet SP20NW, immediately to the north, and the 2.55 m in the Station Quarry, Long Hanborough (Richardson, 1946, p 76). In the Ducklington Lane Quarry, Witney, the incomplete thickness of Lower Cornbrash was 2.74 m (Douglas and Arkell, 1928, p 132).

Douglas and Arkell (ibid) recognised four successive brachiopod faunas within the Cornbrash and related these to the two ammonite zonal faunas which had been previously recognised. The ammonite zonal boundary approximately coincides with a lithological break between the Upper and Lower Cornbrash. It has not been possible to map these lithostratigraphic divisions although their persistence throughout the area can be inferred from quarry sections and field

evidence including both brash lithologies and loose fossils. The entire Cornbrash is included in the Great Oolite Group.

LITHOSTRATIGRAPHIC UNIT	AMMONITE ZONE	BRACHIOPOD BIOZONE	STAGE
Upper Cornbrash	*Macrocephalites macrocephalus* (pars)	*Ornithella lagenalis* *Ornithella siddingtonensis*	CALLOVIAN
Lower Cornbrash	*Clydoniceras discus* (pars)	*Obovothyris obovata* *Cererithyris intermedia*	BATHONIAN

The Lower Cornbrash consists of rubbly, fine-grained, shell-debris-rich, slightly micritic limestones. The matrix is slightly olive or greenish grey tinted giving the rock an overall speckled greyish brown colour. It is intensely bioturbated; debris-free pockets commonly represent burrows. Locally the matrix is partially recrystallised to microspar. Flaggy-weathering limestones are rarely developed at this level.

Some 0.15 m of shell-debris micritic limestone of the *intermedia* (brachiopod) Zone is still visible in the Southrop Quarry [2012 0293] (p 10). The field brash immediately to the north contains a rich fauna which includes *Cererithyris intermedia*, *Pseudolimea duplicata* and serpulids. Cornbrash is exposed in the disused quarry [2046 0362] east of Southrop where about 0.3 m of pale flesh-grey shell-debris micritic limestone is present. Lower Cornbrash probably crops out over most of the limestone plateau within the faulted block, north and east of Greenhill Barn [2090 0423]. The outcrop extends eastwards to Broughton Poggs. Shell-debris-rich, rubbly limestones are exposed in disused quarries at [2170 0390] and [2245 0446]. Up to 2 m of

fine-grained, pale flesh-grey, shell-debris limestone with a microspar matrix at the top but becoming micritic downward is still visible in the large shallow quarry [2261 0407] west-north-west of Broughton Poggs. These beds were attributed to the *obovata* (brachiopod) Zone by Douglas and Arkell (1928, p 133). Lower Cornbrash consisting of pale flesh-brown, shell-debris, micritic limestone resting on Forest Marble clay was exposed in a temporary roadside section [2335 0445] north-west of Filkins. The fossils included *Cererithyris intermedia*, the index of the lowest brachiopod zone. Similar rocks were exposed up to 1.5 m thick in a roadside ditch [2495 0478] north-west of the village.

The Upper Cornbrash comprises sandy limestones and tends to crop out on the more southerly parts of the dip-slope. Numerous Upper Cornbrash brachiopods were seen in the field-brash [2017 0184] west of Great Lemhill, whilst the same beds are present in the overburden of a long-disused quarry [2045 0211] north of the hamlet. The fauna includes *Ornithella* [*Microthyridina*] *calloviense*, *O.* [*M.*] *lagenalis*, *O.* [*M.*] *siddingtonensis*, *O.* [*M.*] *sublagenalis*, *Gresslya peregrina* and *Nucleolites orbicularis*. The brachiopods abound in a bed of shell-debris, micritic limestone, but it was not possible to establish a faunal sequence in this exposure.

A more complete sequence in the highest beds was exposed in a ditch section [2294 0322] to the east of Broughton Copse:

	Thickness m
Alluvium	
Grey-brown clay with basal gravel seam	0.6
Cornbrash	
Ironstone horizon: reddish brown, soft, ferruginous loam with weathered decalcified ironstone fragments in a clay matrix	0.15
Marl: hard, nodular, argillaceous limestone masses enclosed in grey clay matrix; very fossiliferous	0.4
Limestone, flesh-tinted grey to pale fawn, fine-grained, oolitic, with shell debris	seen to 0.1

The sequence is probably directly overlain by Kellaways Clay which floors the ditch 60 m downstream. The lowest bed of the above section was also exposed in the disused quarry [2273 0317] west of the Copse, where the section probably continued downward:

	Thickness m
Cornbrash	
Limestone, pale to reddish brown, with coarse ooliths or superficial ooliths and some shell debris in a fossiliferous micritic matrix. Weathered to nodular masses in reddish brown clay	0.2
Limestone, pale fawn, compact, fine-grained, with superficial ooliths and some shell debris in a fine-grained matrix. Bored surface at top with narrow brown clay-filled burrows. Very poorly fossiliferous	seen to 0.7

This can be compared with the section described by Douglas and Arkell (1928, p 132):

		Thickness m
	Soil, with fragment of *Ornithella lagenalis*	
3	Marly rubble, with an admixture of clay, containing decayed nodules composed of *Ornithella siddingtonensis*; also *Macrocaphalites (Kamptokephalites) herveyi, Gresslya peregrina, Anisocardia minima, Lopha marshii, Meleagrinella echinata, Nucleolites clunicularis,* and *Holectypus sp.*	0.3
2	Sandy ferruginous layer	0.08
1	Barren, grey to purplish flags (as at Black Bourton)	0.91

Douglas and Arkell pointed out that Bed 1 is a common lithology of the Upper Cornbrash of the district. The marl horizon in the adjacent ditch yielded a *siddingtonensis* (brachiopod) Zone fauna which included a specimen of *Macrocephalites (Dolikephalites)* cf. *typicus,* associated with *Goniomya sp.,*

Gresslya peregrina, *Pleuromya uniformis* and *Protocardia*. Loose debris from the ditch yielded, in addition: *Ornithella [M.] sublagenalis*, *O. [M.] siddingtonensis*, *Pseudomelania sp.*, *Nucleolites orbicularis*, with ostreids and serpulids.

The present survey confirmed Douglas and Arkell's recognition that locally the bulk of the Upper Cornbrash *siddingtonensis* (brachiopod) Zone is represented by fine-grained flaggy limestones. Poorly fossiliferous brash composed of fine-grained, shell-debris, oolitic limestone of this type covers the fields east and south-east of Langford Downs Farm [222 033], and north [207 026] of Great Lemhill Farm where fragments of finely bored limestone fragments are present.

Both Upper and Lower Cornbrash were proved in excavations for a new house [2329 0385] at Broughton Poggs. No sections were visible at the time of the survey, but evidence suggests that the deeper beds consist of richly fossiliferous, rubbly, marly, fine shell-debris limestones with greenish grey debris-free micrite pockets, possibly after burrows, and clay wisps. Flaggy, poorly fossiliferous, fine shell-debris limestones dominated the material from the reputedly shallower excavations. Two types of mudstone were present amongst the spoil: the first, a dark grey, shelly, shell-debris lithology, probably belonged to the Cornbrash; whilst the second, an olive to greenish grey, smooth, waxy mudstone, was of Forest Marble type. The fauna includes the zonal indices of the *intermedia*, *obovata* and *lagenalis* (brachiopod) zones: *Cererithyris intermedia*, *Obovothyris obovata*, *O. magnobovata*, *Ornithella [Microthyridina] lagenalis*, *Kallirhynchia sp.*, *Rhynchonelloidea cerealis*; with *Chlamys (Radulopecten) sp.*, *Gervillella* cf. *monotis*, *Gresslya peregrina*, *Liostrea sp.*, *Limatula?*, *Meleagrinella echinata*, *Nanogyra?*, *Pholadomya (B.) deltoidea*, *P. (B.) lirata*, *Pleuromya uniformis*, *Protocardia buckmani* and *Nucleolites quadratus*. A fragment of an ammonite outer whorl of *Procerites* or *Choffatia* type, was also found.

The Cornbrash was deposited in a marine environment. During Lower Cornbrash times, deposition was slow and sediment was constantly reworked by currents and burrowing organisms. Subsequently the currents increased in strength, quartz sand was introduced and gently cross-bedded sandy oolitic limestones accumulated. At the close of Upper Cornbrash times, quiet-water conditions were established locally, with the deposition of calcareous muds.

FOREST MARBLE

This formation comprises interbedded limestones and clays and has limited outcrops in this area; in the north-west it crops out on the valley-slopes of the River Leach, from whence a narrow outcrop extends east-south-eastwards on the upthrow side of the Greenhill Barn Fault, south of Greenhill Barn [209 042]. It also crops out on the uplands north of the King's Hay Fault, between Kings Hay [204 048] and Oxleaze Common [221 047] and thence along the upper reaches of the Broadwell Brook.

There is insufficient evidence to determine the formational thickness from outcrop information, although it must be at least 13 m thick north of Fyfield. Estimates based on the subjective classification of the records of water-boreholes range from 14.0 to 20.1 m with a mean of about 17 m (Table 1).

The local Forest Marble is predominantly argillaceous, although it contains a higher proportion of limestone in the west than in the east. The thicker limestones generally occur in the lower part of the formation and are commonly oolitic and shell-detrital. Those in the upper part are thinner and less persistent, and consist predominantly of sandy limestone. At Southrop Quarry [2012 0293] this situation is reversed:

	Thickness m
Cornbrash	
Limestone, flesh-coloured, speckled, with much shell debris and medium-grained ooliths in olive-green micrite containing grain-free pockets. Shelly, rubbly weathering	0.15
Forest Marble	
Limestone: pale fawn, shell debris, oolite; much decalcified	0.1
Limestone: pale brown, medium-grained oolite with few shell debris and scattered bivalves, particularly oysters, in a spar matrix. Distinct grain-size banding marking incipient cross-stratification	0.6

Marl, brown, soft, thinly-bedded, platy and oolitic; much decalcified	0.02-0.03
Limestone, fawn, coarse shell debris with ooliths in spar matrix	seen to 0.2

The Forest Marble limestone seen in this quarry is a lenticular unit; farther afield to the south-west and south-east a seam of clay separates it from the Cornbrash. The unit thins markedly in these directions; to the south-west of the quarry there are some old limestone workings within 200 m, but beyond this the limestone unit is less than 0.5 m thick.

A second seam of clay underlies these limestones and separates them from a complex limestone unit which extends northwards through Southrop. The latter crops out on the valley-slopes north and east of Southrop Quarry. There are no exposures but the soil is very sandy, suggesting the presence at depth of decalcified sandy limestones, probably with thin interbedded mudstones. Traced northwards there appears to be a change in lithology and pale fawn, shell-debris, oolitic sparry limestones are exposed [2001 0349] near the Swan Inn, Southrop.

Lower beds crop out north of the village and comprise grey mudstones with thin, flaggy, locally slightly oolitic and shelly, sandy limestones. A limestone forms the basal bed of the Forest Marble in the north-west extremity [201 049] of the sheet. This bed was not detected on the opposite or eastern valley slopes of the River Leach until north of the King's Hay Fault. This eastern outcrop consists almost entirely of mudstones with only thin limestones, most of which could not be individually mapped.

At Well Heads, east of Oxleaze Common, fawn, flaggy, shell-debris, oolitic, sparry limestone crops out on the floor of a ditch [2256 0462] and probably belongs to the uppermost beds of the basal limestone unit of the Forest Marble. This bed was dug from beneath grey clay containing thin, sandy and oolitic limestone ribs in shallow pits to the north-west [2237 0474] and north [2251 0467].

The Forest Marble as seen at outcrop in this area represents two contrasting environments. The first, in which the basal limestones accumulated, was one

of high energy with powerful currents which swept a shallow sea in which shell shoals and oolith sand-dunes existed. Locally, erosion of the underlying White Limestone occurred and here the Forest Marble sediments filled tidal channels. The upper part of the Forest Marble was deposited in a marine shelf environment where mud accumulation was dominant. Periodic currents swept in silt and small disarticulated shells which were deposited as fine partings. Longer term periods of current activity resulted in the deposition of ripples of silty sand, which, with an increased input, formed thicker, lenticular, cross-bedded units, which are now represented by beds of sandy limestone. At times calcareous muds were deposited.

OLDER MIDDLE JURASSIC FORMATIONS

Most of the deeper water wells penetrate the Forest Marble and terminate in the White Limestone. The records are poor and it is possible that the White Limestone Formation may be more than 20.7 m thick. The thickness of 27.4 m given from the Lechlade Waterworks Borehole [2143 0055] is probably too great and may include beds which should be classified with the underlying Hampen Marly Formation (see Appendix).

DRIFT DEPOSITS

About one third of this area is covered by superficial deposits. The most extensive spreads comprise river gravels laid down by the River Thames and its tributaries. The higher level Head and Head Gravel, which are probably the oldest deposits, are of limited extent. The youngest deposits: Calcareous Tufa, Peat and Alluvium, are commonly associated with the modern floodplains. Pebbles of quartz and quartzite and others, all of 'Bunter'-type, derived from the Triassic conglomerates of the Midlands, occur scattered throughout the area (Lucy, 1872, 1880).

HEAD AND HEAD GRAVEL

Two groups of Head deposits have been recognised. The oldest group occurs above 80 m OD on the hill top, at Bryworth Lane [around 201 011]. It consists of Head, comprising reddish brown loamy soil on grey or greyish brown clay, and Head Gravel, consisting of clayey flint gravel. The clay component of

the Head is locally slightly gritty, with race (small secondary calcium carbonate nodules), and a few small pebbles of bleached flint, with rare quartz, quartzite and oolitic limestone. A solitary large argillaceous limestone nodule (up to 0.5 m) of Oxford Clay derivation was recorded in a ditch section [2002 0113] west of Little Lemhill Farm. Generally the clay deposit, up to 1 m thick, rests on a thin seam of ochreous flinty gravel, but in places this basal deposit thickens. A ditch [2008 0120] adjacent to Byworth Lane showed:

		Thickness m
Greyish brown clay		0.3
Reddish brown clayey gravel		0.3
Greyish brown pebbly sand	seen to	0.2

Comparable Head deposits blanket the southerly slopes, between about 82 and 86 m OD, at Great Lemhill Farm, where greyish brown clayey sand, at least 1 m thick is associated with brown sandy clays and grey clays containing scattered pockets of flinty gravel. Here the relationship with the Third Terrace gravel is uncertain but they appear to be older than the Second Terrace deposits.

These older Head deposits rest on, and to some extent reflect the lithologies of the underlying Solid formations, here Oxford Clay and, to the west of the sheet, Kellaways Sand. They are overlain by deposits of Third Terrace Gravel and appear to form a thin sheet or veneer. The presence of small quantities of exotic pebbles is indicative of movement of the deposit, although the matrix indicates that this was of limited extent. No evidence of *in situ* origin by cryoturbation was noted. The deposits which include an ill-sorted basal gravel, resemble solifluction fans in composition, but it is difficult to envisage the slopes from which such a material could have been derived. Alternatively, the deposit could have been laid down by ice derived from a localised snow-field. Deposits of superficial clay which occur in the Swindon district (Sheet 252) to the south, have been classified as boulder clay. The presence of pebble of 'Bunter'-origin, mostly of quartz and quartzite, scattered throughout the Cotswolds (Lucy, 1872), including the present district, are possibly indicative of an ancient glaciation but there is no evidence to relate the local deposits to such an event.

Other Head deposits occur in association with the terrace deposits south-west of Langford. The outcrop at [240 024] occurs on a very gentle slope and comprises pockets of gravel enclosed in brownish grey silty clay. The deposit may have originated by cryoturbation of a residual gravel-veneer on Oxford Clay. Another outcrop at [240 019] blankets the slope to the south of the Little Faringdon - Langford Road. It consists of reddish brown silty clay and clay up to at least 1.3 m thick, resting upon poorly sorted sandy gravel. This deposit may be the result of solifluction, possibly before the deposition of the Second Terrace gravels.

Younger Head deposits are associated with the modern valleys. Small blanket deposits of sandy clay floor the small tributary hollow and form an apron sloping down to the floodplain of the River Leach north of Coate Farm [200 042]. Solifluction material floors the valleys at Oxleaze Common [220 047] and Well Heads [220 047], and also the seepage/spring hollows north-west of Filkins Mill [2411 0355]. Deposits of red-brown clayey silt and silty clay blanket the lower valley slopes [249 031] of the Broadwell Brook north of Langford and of the River Leach south-east of Little Faringdon Mill [222 012]. Peaty loam fills the seepage hollow [222 000] south of Manor Farm, Lechlade.

TERRACE DEPOSITS

The river gravel deposits are associated with four terraces, of which the older Fourth and Third Terraces have limited outcrops. The Second Terrace deposits are the most extensive whereas the deposits of the First Terrace are largely restricted to the southern margin of the sheet. The geology and economic potential of these deposits has been discussed by Robson (1976).

FOURTH TERRACE

Deposits of Fourth Terrace have not been depicted on the published map (SP 20 SW), but residual gravels of probable equivalence cap the hill [230 024] north-west of Little Faringdon Wood, forming a summit bench at about 93 m OD. The deposit has been intensely cryoturbated and up to 0.5 m of flint-quartzite-rich pebbly clay overlies pockets of partly decalcified limestone gravel, which may be up to 0.7 m thick. Despite its thinness, this terrace remnant was sufficiently resistant to limit erosion and give rise to a

prominent topographic feature above the aggradation plain of the younger deposits.

THIRD TERRACE

Deposits of Third Terrace occur in small patches as follows: Bryworth Lane [201 010] at c 82 m OD, Great Lemhill Farm [208 020] at c 86 m OD, and at the same height to the west [213 034] and south-west [220 030] of Langford Down Farm; north-east [227 018] of Little Faringdon at c 82 m OD, Hulse Grounds Farm [233 020] at c 80 m, [240 023] at 80 m OD, [233 028] at c 79 m OD, south-west and west of Langford. Two small outcrops occur north of the Broadwell Brook, one north-west [245 038] (c 81 to 82 m OD) and the other [250 034] (c 82 m OD) north of Langford. The surface of the terrace appears to lie generally about 9 to 11 m above the modern alluvium. The deposit at Great Lemhill Farm lies at about 14 m above the Thames alluvium, but is also the most distant from the river and may be more closely related to a proto-Leach tributary of the ancestral Thames. These gravels are less weathered and consequently contain a higher proportion of limestone than the Fourth Terrace deposits.

SECOND TERRACE

The southern part of the area contains a broad expanse of Second Terrace deposits which slopes south and south-east towards the River Thames.

The most westerly outcrops at Bryworth Lane [201 015; 201 005] are the dissected remnants of a spread that at one time enclosed the small hill now capped by Third Terrace deposits. The margins of the southern outcrop are ill-defined because intense cryoturbation has intermixed thin marginal gravels with the Oxford Clay. The northern outcrop slopes gently northward down to almost alluvial level and probably incorporates deposits of both Second and First Terraces. This outcrop is almost everywhere covered by 0.3 m of greyish brown alluvial clay. The underlying gravel forms a continuous sheet usually less than 1.3 m thick. It appears that during Second Terrace aggradation the proto-Thames had branches flowing either side of this hill. Subsequent downcutting appears to have been active in the south with truncation of the Second Terrace deposits. In contrast, progressive erosion in the north kept

pace with aggradation so that, in this backwater, sedimentation appears to have been continuous. In the southern outcrop the terrace surface lies at about 79 m OD whilst the northern outcrop slopes from about 81 m to about 79 m OD.

The Second Terrace forms an extensive bench feature north of Lechlade: this rises northwards from 77 m OD to about 84 m OD north of Great Lemhill Farm [209 020], and on both sides of the River Leach to about 86 m OD south of the Southrop [203 032] and 85 m OD north of Langford Downs House [213 029]. These northerly deposits were laid down directly by the Leach whose gradient was probably steeper than that of the main river.

Difficulties were encountered in surveying the sinuous outcrops in the vicinity of Little Faringdon. The terrace feature slopes south-eastwards from 83 m OD near Langford House to about 74 m OD near the Langford Brook [240 011] and declines further at the southern margin [240 000] of the sheet. The gravel patches are separated by outcrops of the underlying Oxford Clay with only minimal changes of relief. This suggests that the base of the deposit is uneven, with gravel-filled channels penetrating below a regional planar basal surface. The limited borehole evidence and outcrop data indicate that the basal surface slopes south-eastwards, indicating a progressive downcutting of the tributary streams and possible southwards migration of the proto-Thames.

The thickness of the terrace deposits increases from up to 3 m along the northern margins to between 5.9 and 7.5 m around Stud Farm [212 004] and Manor Farm [221 002]. Here the base lies at 70.2 to 71.2 m OD and this may correspond to the channel axis of the ancestral Thames. However, this cannot be confirmed. The possible former occurrence of comparable deposits southwards towards the Corallian escarpment, which have since been eroded, might negate this conclusion.

Although the terrace deposits are primarily composed of gravel, channels infilled with brown silty sand and grey clayey silt, comparable with Kellaways Sand lithologies, also occur. These were augered to depths of at least 2 m [2306 0094] and to 2.5 m, resting on at least 0.1 m of gravel [2371 0125]. They were also proved in Mineral Assessment Borehole SP 20 SW 11 (see Appendix), where sand, silt and clay seams were interbedded with sandy gravel.

These may form part of a north-easterly trending silt-filled channel (Robson, 1976).

In these southern areas the surface of the gravel is marked by prominent ridges. Similar features occur on the extensive Second Terrace outcrop east of the Langford Brook. Some of the ridges coalesce. They may have originated as the infill of an anastomosing channel system during the final stage of the Second Terrace aggradation. The ridges represent the gravel infill of the channels whose relief has now been accentuated by the subsequent illuviation of the original overbank clay deposits (alluvium) which were present between the channels. There is no information on the relation of these surface features to the sub-drift topography.

FIRST TERRACE

The present district lies just north of a broad expanse of the First Terrace of the River Thames. Small areas of First Terrace deposits extend up the valley which leads to Great Lemhill, and up the valleys of the River Leach and Langford Brook. Very small patches of gravel at less than 1 m above the alluvium at Southrop and again north of Coate Farm [2014 0495] have been attributed to this stage. Similarly, a small outcrop [242 031] north-west of Langford has been mapped as First Terrace. During the previous survey of the Upper Thames Valley, the upper surface of the terrace was divided into two facets which were about 0.3 m apart vertically. This separation was not recognised in this area. However, the outcrop [234 001] on the east bank of the River Leach has a sloping surface which could perhaps be divided. The First Terrace deposits extend beneath the modern alluvium.

The First Terrace deposits consist primarily of limestone gravel, although seams of sand, silt and clay may be present locally. Some 2.5 m of clean, well-graded limestone gravel with lenses of humic silt were exposed in a disused gravel pit [2169 0168] south of Common Barn Farm.

Boreholes drilled on the floodplain of the River Leach proved thick gravel sequences: The first [2076 0296] (SP 20 SW/13) north-east of Rottonborough Copse proved 0.4 m of peaty soil on 4 m of gravel and the second [2164 0207] (SP 20 SW/4) south-west of Common Barn Farm penetrated 0.5 m of alluvium and

3.4 m of gravel. Robson (1976) suggested that the First Terrace deposits are thickest where the main northern tributaries, for example the Leach, enter the Thames, and will in such places fill buried channels.

OLDER ALLUVIUM

Deposits of Older Alluvium occur on the west bank of the River Leach near Southrop. A further example occurs north-west of Langford. The deposits consist of greyish to slightly reddish brown clay and differ from alluvium only by the slight difference in height between their upper surfaces. It is probable that slight localised rejuvenation of streams has left isolated patches of this Older Alluvium in sheltered embayments.

ALLUVIUM

The youngest fluvial sediment consists of dark grey to greyish brown clay. It floors all the valleys and probably merges upstream, beyond its mapped limit, into undefined bodies of soliflucted silts and silty clays (Head). In this area it is generally less than 1 m thick and in the smaller valleys commonly contains a thin clayey gravel at its base. In the large valleys, such as the Leach, it may include seams of calcareous silt and peat, generally near the base.

The alluvial clay in the Leach valley commonly contains freshwater molluscan shells. These increase in proportion downwards and locally, with increasing calcareous silt content, the clay passes into a tufaceous deposit which may in turn rest upon peat. Where present this tufaceous seam is less than 0.5 m thick whilst the peat is commonly less than 0.2 m. These basal alluvial sediments are associated with impeded drainage and springs, north and east of Great Lemhill Farm. Downstream the two lithologies merge and humic tufaceous loams and clays occur within the alluvium. Upstream from the spring-zone the alluvium comprises uniform brown-mottled grey clay. Throughout the Leach valley these alluvial deposits rest directly on First Terrace gravels.

CALCAREOUS TUFA

Five surficial deposits of tufa have been recognised. Four lie along a north-easterly trending line from Great Lemhill [204 018] to Broughton Copse [229 032]. These lie near the Cornbrash-Kellaways Clay boundary and are associated with strong springs that were previously thrown out at this level. These springs and associated seepages developed at the overflow point of water which had completely filled the Cornbrash limestone aquifer.

At Great Lemhill, a spring [0235 0182] is still effective, though lime deposition is now restricted to the coating of plant debris in the ditch. Here the tufa extends northwards on to the Cornbrash and southwards on to deposits of the Second Terrace and the Kellaways Sand. It forms a thin veneer which rises away from the small patch of alluvial clay.

The largest occurrence of tufa is in the floor of the Leach valley, north-east of Great Lemhill Farm. This is the only deposit which gives rise to a mound, up to 1.5 m high, of tufa. Although disturbed by man, this apron of tufa appears to be an original feature. The tufa consists of silt-grade calcareous particles. It also occurs beneath alluvial clay downstream and upstream of the outcrop and as such was probably redistributed by fluvial activity.

The tufa north of Common Barn Farm [219 024] fills a shallow valley which extends northwards into two shallow hollows: the first occurs on Second Terrace deposits whilst the second extends eastwards on to the Kellaways Sand. The main depression probably arose by erosion after the deposition of the Second Terrace gravels. These gravels and also the Kellaways Sand are probably in hydrogeological continuity with the Cornbrash and it is likely that ground-water from this source precipitated the tufa. This occurrence and the deposit discussed below are slightly higher above the alluvium and may represent an earlier phase of tufa accumulation than the previous examples.

The tufa [231 032] east of Broughton Copse largely overlies the Kellaways Clay, but extends on to the Cornbrash and Second Terrace deposits. Here the highest deposits fill a slight hollow between the Cornbrash and the river gravels. Again ground-water from the Cornbrash was the probable source of the deposit. The tufa is generally less than 1 m thick and wedges out downstream

within the alluvial sediments.

The fifth deposit of tufa [227 003] east of Manor Farm, Lechlade, lies on a very gentle slope extending down from the Second and First Terraces to the alluvium. It is generally less than 0.5 m thick and contains a significant proportion of clay and loam. This tufa rests, where proven, on river gravel. It may be coextensive with the humic and tufaceous clays within the alluvium to the north and probably originated by fluvial deposition rather than by predominantly *in situ* precipitation.

PEAT

A thin veneer of peat overlies the First Terrace deposits south-east of Southrop. Although generally less than 0.8 m thick, it was proved to 1.5 m at a point [2058 0306] north of Rottonborough Copse. Hereabouts it appears to rest upon up to 0.3 m of tufa, overlying limestone gravel. The outcrop gives rise to poorly drained grassland and it lies only just above the alluvium which probably impeded its drainage. The seepage that facilitated its growth was probably derived from the associated terrace deposits.

STRUCTURE

The prevailing dip is to the south-south-east at about 1 in 20 or 2½°. In the north, the generally simple structure is broken by two east-south-easterly disturbances, the King's Hay and the Greenhill Barn faults. These both downthrow to the south. The former has a throw of at least 2 m, but this appears to be reversed near where the fault dies out [2134 0458] west of The Bungalow. The Greenhill Barn Fault has a greater throw of up to 17 m.

Two other disturbances are less well authenticated. The first, to the south of Langford Downs Farm [222 033], is shown as an east-west fault with a downthrow to the south of about 3 m. The second, to the south-east of Fyfield, has been shown as a gentle flexure with slightly increased dip to the south, but it could represent a strike fault between the Cornbrash and Kellaways Clay and thus be related to the previous structure.

Superficial structures may be superimposed on the regional dip. Cambering of the Cornbrash is probably present and valley-bulge structures within the predominantly clay formations are also likely.

HYDROGEOLOGY

The main water-bearing horizon, the Great Oolite Group aquifer, includes beds from the basal Forest Marble limestone to the Taynton Stone. Only the uppermost part crops out locally. The thickness of the aquifer is variable, partly due to changes in the White Limestone, but predominantly to the facies variation within the Forest Marble Formation. Where the latter contains a basal limestone sequence, it forms part of the Great Oolite Group aquifer. However, where clays occur at this level they destroy the hydraulic continuity. The Inferior Oolitic Group is also a major aquifer, but is at depth in this area. The Cornbrash contains water but is generally too thin to yield significant quantities.

The water boreholes generally tap the Forest Marble-White Limestone aquifer. Boreholes sited on the Kellaways Beds and Oxford Clay first strike water in the Cornbrash limestone, but the main flow, often under artesian head, is found at the Forest Marble-White Limestone level. Deeper wells tap the Inferior Oolite Group. There is no water resource below that horizon.

The present landscape developed during a period of much wetter climate than today when water-tables were high and there was enhanced run-off, enabling the streams to carve valleys across the limestone uplands.

Dry valleys are common in the main Cotswolds to the north, but stream drainage is important in this area. Rainwater infiltrates the porous Cornbrash, the Forest Marble limestones and the White Limestone Formation. Some escapes as seepage at the base of the formations, but most is stored in the aquifer down dip and appears as major springs when the aquifer is full. An important example is seen at Well Heads where an inlier of basal Forest Marble limestone occurs, largely beneath the alluvium. During summer the upstream valleys are dry, but water rises [2262 0457] through the Forest Marble oolitic limestone in the ditch floor and gives rise to the Broadwell Brook.

At Great Lemhill a spring [2026 0175] rises in the floor of a ditch at the boundary between the Cornbrash and overlying Kellaways Clay. In the past the overspill from the Cornbrash aquifer appeared as springs whose waters deposited the local calcareous tufa. Similarly in the valley of the River Leach, Cornbrash spring water gave rise to a tufa mound north of Great Lemhill Farm and a spring may still rise in a mire [039 026] 250 m to the west. Other springs occurred at points south-west of Langford Downs Farm, and water still rises west of Broughton Coppice, both associated with tufa deposits. There is no evidence of springs from the Cornbrash in the Broadwell Brook, south of Filkins. This may result from dissipation of the ground-water into the extensive gravel deposits hereabouts. Certainly the 'issues' noted on the Ordnance Survey Map in this area occur in the floors of ditches in gravel. Farther east a spring-line has led to the formation of the Head deposits north of Langford.

The drainage of the district has two components; the base flow which is relatively constant and is derived from springs, and the seasonal flow which is dependent on rainfall and snow melt. The River Leach is maintained by springs issuing from the White Limestone-Forest Marble aquifer to the north of the present district, which is probably supplemented by ground-water from the Cornbrash. The same is true for the Broadwell Brook, whilst the Great Lemhill Stream and the Langford Brook originate from springs in the Cornbrash.

TABLE I Thicknesses of strata proved in boreholes

Formation \ Borehole	1 Butler's Court	2 Manor Farm	48 Littlehey	50 St Peters	53 Lechlade	54 Little Lemhill Farm	55 Langford Downs	56 Langford Downs	57 Southrop Lodge	60 Manor Farm	61 Church Farm	62 Great Lemhill Farm
Oxford Clay	11.3+	17.7+			5+	2.1+						
Kellaways Sand	8.0	4.9	2.7+		-	8.8						1.2+
Kellaways Clay	2.7	6.7	5.8		-	3.0/3.7						2.7
Kellaways Beds (combined thickness)	10.7	11.6	8.5+		?10.4	11.9/12.5	with OxC 13.4				with OxC 21.7	3.9+
Cornbrash	1.5	2.4	2.4	<6.1	5.2	4.1/4.7	5.2	3.1+		4.3+	?7.0	2.7
Forest Marble	17.4	11.4(?+)	14.0	12.2+	20.1	16.6	5.8+	13.1	19.2+	16.5	?10.7	19.8
White Limestone	1.5+	?touched	2.4+	3.0+	27.4	1.8+		8.2+		5.3+	20.7+	13.7+

Thicknesses are shown in metres; for locations see Appendix.

APPENDIX SELECTED BOREHOLES

Thicknesses and depths in metres. SL refers to surface level.

SP 20 SW 1 [2065 0003]
Butlers Court, Lechlade
SL c + 73.2 m

	Thickness	Depth
Alluvium	0.76	0.76
First Terrace deposits	4.12	4.88
Oxford Clay (with basal nodule bed)	11.27	16.15
Kellaways Beds	10.67	26.82
Cornbrash	1.53	28.35
Forest Marble Formation	17.37	45.72
?White Limestone Formation seen to	1.52	47.24
(Artesian, water struck at 28.0 and 41.2 m)		

SP 20 SW 2 [2204 0025]
Manor Farm, Lechlade
SL c + 51.8 m

First Terrace deposits	7.01	7.01
Oxford Clay (with basal nodule bed)	17.68	24.69
Kellaways Sand	4.88	29.57
Kellaways Clay	6.70	36.27
Cornbrash	2.44	38.71
Forest Marble Formation	11.43	50.14
Forest Marble/White Limestone formations seen to	1.68	51.82
(Artesian, water struck at 42.1 to 51.8 and 50.9 to 51.8 m)		

SP 20 SW 3 [2114 0042]
Stud Farm, Lechlade
SL + 77.7 m

		Thickness	Depth
Made Ground		0.2	0.2
First Terrace deposits		7.3	7.5
Oxford Clay	seen to	0.5	8.0

SP 20 SW 4 [2164 0207]
South-west of Common Barn Farm
SL + 80.2 m

Alluvium		0.5	0.5
First Terrace deposits		3.4	3.9
Kellaways Sand	seen to	0.5	4.4

SP 20 SW 5 [2135 0100]
Rough Grounds Farm, Lechlade
SL + 79.6 m

Made Ground		0.2	0.2
Second Terrace deposits		2.3	2.5
Oxford Clay	seen to	0.5	3.0

SP 20 SW 7 [2261 0146]
Little Faringdon
SL + 82.3 m

Made Ground		0.3	0.3
Second Terrace deposits		1.8	2.1
Oxford Clay	seen to	0.6	2.7

SP 20 SW 8 [2341 0350]
Broughton Poggs
SL + 82.0 m

		Thickness	Depth
Second Terrace deposits		1.5	1.5
Oxford Clay		0.8	2.3
Kellaways Sand	seen to	0.7	3.0

SP 20 SW 9 [2348 0054]
Little Faringdon
SL + 76.2 m

Made Ground		0.6	0.6
Second Terrace deposits		2.3	2.9
Oxford Clay	seen to	0.5	3.4

SP 20 SW 10 [2421 0271]
West of Langford
SL + 79.9 m

Made Ground		0.4	0.4
Second Terrace deposits		1.0	1.4
Oxford Clay	seen to	2.1	3.5

SP 20 SW 11 [2417 0184]
Tillington, Langford
SL + 75.3 m

Second Terrace deposits		6.2	6.2
Oxford Clay	seen to	0.3	6.5

SP 20 SW 12 [2481 0104]
South of Langford
SL + 75.6 m

		Thickness	Depth
Second Terrace deposits		6.1	6.1
Oxford Clay	seen to	0.5	6.6

SP 20 SW 13 [2076 0296]
South-east of Fyfield
SL + 83.8 m

Alluvium		0.4	0.4
First Terrace deposits		4.0	4.4
Forest Marble Formation	seen to	1.0	5.4

SP 20 SW 14 [2396 0302]
South-east of Broughton Poggs
SL + 79.9 m

Second Terrace deposits		3.0	3.0
Oxford Clay	seen to	1.0	4.0

SP 20 SW 15 [2466 0259]
Langford
SL + 79.2 m

Second Terrace deposits		1.8	1.8
Oxford Clay	seen to	1.6	3.4

SP 20 SW 16 [2372 0064]
South-east of Little Faringdon
SL + 75.6 m

		Thickness	Depth
Made Ground		0.4	0.4
Second Terrace deposits		3.1	3.5
Oxford Clay	seen to	1.0	4.5

SP 20 SW 48 [2491 0345]
Littlehey, Broadwell
SL c + 82.0 m

Kellaways Sand		2.74	2.74
Kellaways Clay		5.79	8.53
Cornbrash		2.44	10.97
Forest Marble Formation		14.02	24.99
White Limestone Formation	seen to	2.44	27.43
(Water struck at 24.99 m)			

SP 20 SW 49 [2377 0426]
Village Hall, Filkins
SL c + 83.8 m

Cornbrash and Forest Marble Formation (part)		4.27	4.27
Forest Marble Formation (part)		9.45	13.72
?Forest Marble and White Limestone formations	seen to	13.71	27.43

SP 20 SW 50 [2363 0413]
St Peters, Filkins
SL c + 82.3 m

		Thickness	Depth
Cornbrash and Forest Marble Formation (part)		6.10	6.10
Forest Marble Formation		12.19	18.29
White Limestone Formation	seen to	3.05	21.34
(Artesian, water struck at 18.29 m)			

SP 20 SW 53 [2143 0055]
Lechlade Waterworks
SL c + 78 m

Second Terrace deposits		8.08	8.08
Oxford Clay and Kellaways Beds		15.39	23.47
Cornbrash		5.18	28.65
Forest Marble Formation		20.12	48.77
White Limestone Formation		27.43	76.20
?Hampen Marly Formation	seen to	5.49	81.69

SP 20 SW 54 [2078 0116]
Little Lemhill Farm
SL c + 80.5 m

Second Terrace deposits		1.52	1.52
Oxford Clay		2.14	3.66
Kellaways Sand		8.84	12.50
Kellaways Clay		3.04/3.65	15.54/16.15
Cornbrash		4.12/4.73	20.27
Forest Marble Formation		16.61	36.88
White Limestone Formation	seen to	1.83	38.71
(Artesian, some water struck at 24.38 m, most at 36.9 m)			

SP 20 SW 55 [2284 0267]
Langford Downs Farm
SL c + 83.5 m

		Thickness	Depth
Oxford Clay and Kellaways Beds		13.41	13.41
Cornbrash		5.18	18.59
Forest Marble Formation	seen to	5.79	24.38

SP 20 SW 56 [2212 0335]
Langford Downs Farm
SL + 85.3 m

Cornbrash		3.05	3.05
Forest Marble Formation		13.10	16.15
White Limestone Formation	seen to	8.23	24.38

SP 20 SW 57 [2009 0350]
Southrop Lodge
SL c + 90.5 m

Forest Marble Formation		19.20	19.20
?White Limestone Formation	seen to	1.22	20.42
(Water struck at 20.42 m)			

SP 20 SW 59 [2352 0438]
Goodfellows, Filkins
SL c + 85.0

Forest Marble Formation (part)		9.14	9.14
?Forest Marble (basal) and White Limestone Formation	seen to	10.67	19.81
(Water struck at 9.1 and 19.8 m)			

SP 20 SW 60 [2324 0378]
Manor Farm, Broughton Poggs
SL c + 84.1 m

		Thickness	Depth
Cornbrash		4.27	4.27
Forest Marble Formation		16.46	20.73
White Limestone Formation	seen to	5.33	26.06
(Artesian, water struck at 24.99 m)			

SP 20 SW 61 [2258 0152]
Church Farm, Little Faringdon
SL c + 82.5 m

Alluvium		0.91	0.91
Oxford Clay and Kellaways Beds		21.65	22.56
Cornbrash and ?Forest Marble Formation (part)		7.00	29.56
Forest Marble Formation (part)		10.67	40.23
?White Limestone	seen to	20.73	60.96
(Artesian, water struck at 54.9 m)			

SP 20 SW 62 [2082 0199]
Great Lemhill Farm
SL c + 85.3 m

Third Terrace deposits		2.44	2.44
Kellaways Sand		1.22	3.66
Kellaways Clay		2.74	6.40
Cornbrash		2.74	9.14
Forest Marble Formation		19.81	28.95
White Limestone Formation	seen to	13.72	42.67
(Water struck at 9.1, 32.0 and 38.4 m)			

REFERENCES

BLAKE, J F. 1905-1907. A Monograph of the Fauna of the Cornbrash. *Monogr. Palaeontogr. Soc.* 1905, pp. 1-100, 1907, pp. 101-102.

CALLOMON, J H. 1968. The Kellaways Beds and Oxford Clay. Pp. 264-290 *in* Sylvester-Bradley, P C and Ford, T D (Eds). *The Geology of the East Midlands*. Leicester University Press: Leicester, 400 pp.

DOUGLAS, J A and ARKELL, W J. 1928. The stratigraphical distribution of the Cornbrash: I. The South-Western Area. *Q. J. Geol. Soc. London.*, Vol. 84, pp. 117-178.

HULL, E. 1857. The Geology of the Country around Cheltenham (Sheet 44). *Mem. Geol. Surv. G.B.*, 104 pp.

LUCY,W C. 1872. The Gravels of the Severn, Avon and Evenlode, and their extension over the Cotteswold Hills. *Proc. Cotteswold Nat. Field Club*, Vol. 5, pp. 71-142.

---------. 1880. On the extension of the Northern Drift and Boulder Clay over the Cotteswold Range. *Proc. Cotteswold Nat. Field Club*, Vol. 7, pp. 50-61.

PLOT, R. 1677. The Natural History of Oxfordshire. Oxford.

RAMSEY, A C, AVELINE, W T and HULL, E. 1858. Geology of parts of Wiltshire and Gloucestershire (Sheet 34). *Mem. Geol. Surv. G.B.*, 46 pp.

RICHARDSON, L. 1930. Wells and Springs of Gloucestershire. *Mem. Geol. Surv. G.B.*, 292 pp.

---------. 1933. The Country around Cirencester. *Mem. Geol. Surv. G.B.*, 119 pp.

---------, ARKELL, W J and DINES, H G. 1946. Geology of the Country around Witney. *Mem. Geol. Surv. G.B.*, 150 pp.

ROBSON, P. 1976. The sand and gravel resources of the Thames Valley, the country between Lechlade and Standlake. Description of 1:25 000 resource sheet SP 30 and parts of SP 20, SU 29 and SU 39. *Miner. Assess. Rep. Inst. Geol. Sci.*, No. 23, 141 pp.

TIDDEMAN, R H. 1910. Water Supply of Oxfordshire. *Mem. Geol. Surv. G.B.*, 108 pp.

WOODWARD, H B. 1894. The Jurassic Rocks of Britain. Vol. IV. The Lower Oolitic Rocks of England (Yorkshire excepted). *Mem. Geol. Surv. G.B.*, 628 pp.

BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/88/30

Onshore Geology Series

TECHNICAL REPORT WA/88/30

Geological notes and local details for 1:10 000 Sheets TL75SE and TL85SW: Denston and Hartest. Part of 1:50 000 Sheet 206 (Sudbury)

J Pattison

Geographical index
UK, East Anglia, Suffolk

Subject index
Geology, Cretaceous, Quaternary
Crag, Anglian, post-Anglian

Bibliographic reference
Pattison, J. 1988. Geological notes and local details for 1:10 000 sheets TL75SE and TL85SW: Denston and Hartest. *British Geological Survey Technical Report* WA/88/30.

 Keyworth, Nottingham British Geological Survey 1988

1 INTRODUCTION

This account describes the geology of the upper Glem valley in south-west Suffolk. The district is almost entirely covered by Drift deposits which overlie Crag and Chalk. The geology was originally surveyed by F J Bennett at one inch to one mile and published at that scale as part of Old Series Sheet 51 in 1882. The 1:10 000 and 1:10 560 geological resurvey, upon which this report is based, was carried out by B Young in 1980 and J Pattison in 1986-7. Uncoloured dyeline copies of the 1:10 000 maps accompanying the report can be purchased from the British Geological Survey (Map Sales), Nicker Hill, Keyworth, Nottingham NG12 5GG.

The district is part of the dissected glacial till plateau of south-west Suffolk. It includes some of the highest land in East Anglia reaching over 120 m above OD in the south-west corner and 115 m near the northern edge. The plateau is capped by chalky till up to 70 m thick which produces stiff tenacious clay soils over the greater part of the district. Other Drift deposits, including much Glacial Sand and Gravel underlying the till, are mostly exposed only along the lower parts of the deepest valleys although there are also scattered small pockets of Glacial Sand and Gravel which overlie or are interbedded with the till.

In the valleys the glacial deposits are commonly covered by poorly sorted, clay to gravel, Head deposits, a product of mass down-slope movement in late Pleistocene periglacial conditions. The main valleys are also largely floored by modern alluvial silt and clay.

The top of the underlying Chalk is exposed only in some small adjacent inliers along the valleys of the River Glem and Hawkedon Brook in the centre of the district. Chalk has been proved by several boreholes elsewhere but none was drilled to its base. There is some borehole evidence for outliers of Crag sand and gravel overlying the Chalk below the drift cover on the interfluves both north and south of the Glem valley.

Most of the district is drained via the River Glem which flows from west to east across it, turning south towards the Stour south-east of Boxted. Some valleys along the southern boundary drain directly to the Stour as does Chad Brook which flows across the north-east corner. The district is

thinly-populated and is almost totally given over to arable cultivation, largely of wheat. The main exceptions are the water meadows along the main streams and the scattered woodland. The largest village is Hartest on a tributary of the Glem near the district's eastern boundary. The other main settlements, including Stansfield, Hawkedon and Denston, are barely more than hamlets. Nevertheless, as elsewhere in Suffolk, there are a number of fine churches and handsome half-timbered halls built in the heyday of the Tudor wool trade.

2 SOLID FORMATIONS

2.1 Chalk

Chalk underlies the entire district but appears at surface only in two adjacent 'windows' near Hawkedon, in the valleys of the River Glem and Hawkedon Brook respectively, and in the River Glem farther upstream near Stansfield. Elsewhere it is covered by up to 70 m of drift deposits and, in some central areas, by Crag as well. From regional evidence it is inferred that the subcropping Chalk belongs to the Upper Chalk throughout and this is supported by fossil evidence from the exposed 'windows' and the resistivity log of the Anglian Water Authority borehole at Boxted (TL85SW/15)[1] [8272 5119][2]. Most of the other water boreholes in the district proved chalk but the logs provide no additional information other than some references to whiteness and flint content.

The chalk outcrops near Hawkedon appear to be brought about by a slight local rise, to above +50 m OD, in the rockhead surface which otherwise slopes gently from west to east across the district. Such a rise is also indicated by a borehole (TL85SW/6) [8046 5385] at Langley's Newhouse where rockhead is 53.34 m above OD. All the exposed chalk near Hawkedon is either very soft or apparently reconstituted, or may show evidence of distortion. It may merely represent 'rafts' within glacial sediments but the local concentration of chalk exposures and their persistent position at the bottom of the exposed sequences suggests that these are part of 'solid' outcrops.

The chalk exposures in Hawkedon Brook are within a 250 m long stretch [8029 5245 to 8048 5232] downstream from the stream confluence about 650 m south of the disused Dean Farm. The best, near the upstream end, shows over a metre of soft white chalk, with flints. It yielded the following foraminifera, identified by Mr I P Wilkinson: *Globotruncana bulloides, G. linneiana, Globorotalites michelinianus, Reusella szajnochae* cf *praecursor, Gavellinella pertusa, Stensioeina granulata polonica, Lenticulina sp* and *Saracenaria sp.* Mr Wilkinson comments that *G. linneiana* 'is indicative of an

---

1 Boreholes and wells are identified by their BGS records file number.

2 National Grid references are given in the form [ ] throughout. The district lies wholly within the 100 km square TL.

age no older than Santonian, as it first occurs in the highest part of the *M. coranguinum* macrofossil zone' and *S. granulata polonica* 'is confined to the Lower and Middle Santonian'.

Most of the chalk exposed nearby in the River Glem is along an 80 m-long artificially-cut channel downstream from the weir [7999 5212] about 600 m ENE of Thurston Hall. Although the exposures are up to 4 m high, much of the chalk appears to have been re-worked and includes soft 'putty' chalk with irregularly distributed flints, and chalk breccias comprising hard, sub-angular chalk pebbles in a soft, fine chalk matrix. Mr Wilkinson identified the following foraminifera from one locality [8005 5207]: *Gyroidinoides nitidus, Eggerellina mariae, Stensioeina granulata granulata, S. granulata polonica, S. exsculpta, Gavelinella pertusa, G. stelligera, Globotruncana bulloides, Globorotalites michelinianus, Neoflabellina suturalis* cf *praecursor, Whitinella baltica, Lingulogavelinella sp* a (*sensu* Bailey, M S; = *L.* cf *vobensis* of Bailey and Hart 1979), *Lenticulina sp, Heterohelix sp* and *Arenobulimina sp.* He comments that the occurrence of *Lingulogavelinella sp* a with *S. granulata granulata* and *S. granulata polonica* indicates an age 'within the lower part of the Santonian, foraminifera zone 'D' or basal 'E'. The highest part of the *M. coranguinum* macrofossil zone is indicated by inference, although the very base of the *U. socialis* zone cannot be ruled out entirely'.

Soft white chalk is exposed at water level in the River Glem [7822 5222] about 200 m upstream from the road bridge at Stansfield.

The AWA[1] borehole at Boxted proved chalk from 9.2 m depth to the bottom of the hole at 85 m. 'Hard chalk' bands noted from depths 49.3 m to 50.8 m and 70.2 m to 71.4 m approximate with zones of relatively high resistivity shown by the 16" normal resistivity log for the borehole and they are correlated with the 'Top Rock' and 'Chalk Rock' respectively. The Chalk Rock marks the lowest part of the Upper Chalk and assignment of the beds below 71.4 m to the Middle Chalk is supported by the characteristic change to an overall lower resistivity about that level. A particularly low resistivity 'spike' within the inferred Middle Chalk at about 78 m depth may indicate the position of the 'Twin Marls', one of several marl bands in the Middle Chalk which can be traced by use of resistivity logs across much of East Anglia.

---

1 Anglian Water Authority

2.2 Crag

Following the work of the BGS Industrial Minerals Assessment Unit (IMAU) in the region, new interpretations of the sand and gravel underlying the 'Chalky Boulder Clay' by Bristow (1983) and Mathers and Zalasiewicz (1988) have extended the recognised distribution of Crag across much of south-west Suffolk including parts of this district. The latter authors divide the local Crag into a lower unit: the Red Crag Formation comprising reddish brown (green when fresh), medium to coarse-grained, poorly-sorted, shelly sand over a basal pebble bed, and a higher unit: the Chillesford Sand Member of the Norwich Crag, consisting of well-sorted fine sand. Their Chillesford Sand, of ?Bramertonian age, in the areas around this district was previously referred, by IMAU and others, to the Kesgrave Sands and Gravels of probable Beestonian age.

No Kesgrave Sands and Gravels have been firmly recognised within this district either during the resurvey or previously and no surface outcrops of Red Crag have been mapped. The distribution of Crag as shown on the 1:10 000 maps is based partly on overall Red Crag distribution as inferred by Bristow (1983) and Mathers and Zalasiewicz (1988) and partly on references to 'green' sand in local borehole logs. The logs, however, contain no mention of shelly sands - the other principal criterion for inferring the presence of Crag. The tentative conclusion is that Red Crag is largely confined to the interfluves on either side of the River Glem in the central part of the district. It is also thought to underlie drift deposits in the south-east corner of TL85SW: Reddish-brown, coarse-grained sand in a small exposure at Cranmore Green about 2 km farther south has been referred to the Red Crag. Eleven metres of 'green sand' in a borehole at Hooks Hall (TL85SW/3) [8056 5068] are assigned to the Crag but at least part of that thickness probably consists of Crag sands re-worked in Anglian glacial or fluvio-glacial conditions. Elsewhere in the district the thicknesses of inferred Crag are less than 5 m.

3 DRIFT DEPOSITS

3.1 Till

The greater part of the district is covered by glacial till informally referred to as 'Chalky Boulder Clay'. The Chalky Boulder Clay of west Suffolk is generally correlated with the Lowestoft Till of the East Anglian coast and considered to be of Anglian age. The till forms a thick cover over most of the district and has a maximum recorded thickness of 69 m, in a borehole near Wickham Street (TL75SE/2) [7537 5388]. It is absent in places along the main valleys, partly as a result of erosion by modern streams, partly because the valleys appear to follow the line of sub-glacial streams which deposited sand and gravel contemporaneously with till deposition. The till is thus thickest below the interfluves: an average of 55 m north of the River Glem and 35 m to the south of the river, with an overall eastward thinning on both sides.

The unweathered till is mostly a stiff, grey to bluish grey clay, variably silty and sandy, but everywhere with a large calcium carbonate content which comprises abundant chalk pebbles, from about 5% of the total volume upwards, and profuse chalk fines. Locally, chalk pebbles constitute 50% or more of the volume and may represent the *in situ* shattered remains of large chalk 'rafts'. Flints, as angular to rounded pebbles or cobbles, are also almost ubiquitous. Clasts of other lithologies are much less common and more variable in distribution. Limestone and fine-grained brown sandstone erratics of probable Jurassic age, the limestones sometimes as 'solid' oyster shells, are the most abundant. Clasts of dolerite and other igneous and metamorphic rocks of pebble to boulder size have also been noted.

The till produces brown, sandy to silty, somewhat tenacious, clay soils. The depth of weathering varies from about 0.2 m, usual in the skeletal soils of hill shoulders, to 2 m. The colour changes from the unweathered grey to the brown at surface through shades of khaki with increasing upward decalcification.

The only clean exposures of unweathered till seen during the resurvey were in the basal part of stream sections and in a few newly-dug trenches. The most notable were:

1 A 0.9 m deep ditch on the north side of the A143 road [7510 5335 to 7500 5319] near Stradishall showing grey clay with chalk pebbles constituting up to 10% of the volume in general, but with discrete pockets of chalk gravel.

2 A gulley on the right bank of the River Glem [7702 5237] near Elm Farm, Assington Green:

Clay, reddish brown, sandy (Head)	2.0
Gravel	1.3
Clay, dark bluish grey; 10% of volume in chalk pebbles; chalky streaks (Till)	1.0

3 Hartest Brook [8225 5317 to 8272 5273] near Pickles Farm: up to 1.5 m of bluish grey chalky clay (Till) below Head.

4 Re-excavated ditches in area [c 820 521] ENE of Somerton Hall, showing very chalky till including abundant rounded chalk pebbles, interbedded with lenses of chalk gravel comprising up to 70% of volume in pebbles in a sand matrix.

The only significant lithological variability noted was in chalk content and no bedded till, as observed in adjacent districts, was recorded. Other variation in till lithology can only be inferred from the quantities and lithologies of the stones in ploughed fields, such as the abundant flints on the northern edge of the Glem valley in the south-east corner of the district [c 836 510 to 845 501] and the many sandstone and limestone boulders of probable Jurassic age [c 7675 5400] north-west of Gifford's Hall.

3.2 Glacial Sand and Gravel

Sand and gravel closely associated with the till is widespread in the district. It is most common, in very variable thicknesses, immediately below the till but this sub-till layer is missing in some areas, notably on either side of the Wickhambrook valley and north of Hartest. Sand and gravel low within the till as well as below it are especially concentrated along the line of the Glem valley and the lowest 2 km of Hawkedon Brook. Stratigraphically higher, but smaller, bodies of flint gravel also form north-west to

south-east-orientated trains across the till plateau in the eastern part of the district.

The greatest recorded thickness of sand and gravel at the base of the Drift in the district is 29.9 m in a borehole at Wickhambrook (TL75SE/1) [7539 5442]. Although little Glacial Sand and Gravel has been mapped along the sides of the valley from there to Denston, the very high sand content in the alluvium and an exposure [7610 5360] showing 0.7 m of flint cobble gravel below sandy clay alluvium in the stream near Deersley's Farm indicate the presence of sand and gravel below the valley bottom. However, boreholes proving thick till resting directly on chalk on both sides (TL75SE/2 and 3) [7537 5388 and 7658 5478 respectively] suggest that the sand and gravel is aligned along the valley.

A section in the lensoid body of fine to coarse-grained sand and some flint gravel which is horizontally disposed within the till south-west of Wickham Street was recorded in a ditch adjacent to the A143 road [7533 5371 to 7531 5364]:

Clay, grey, with chalk pebbles (till)	2.0
Sand, white to pale brown, medium to coarse-grained, fining downwards	1.5

From Denston to the neighbourhood of Stansfield, sand and gravel below or near the base of the till crops out almost continuously on one or both sides of the Glem valley. Field brash suggests flint cobble gravel is the most common lithology but a river section [7695 5235] near Elm Farm shows 1.8 m of orange-brown clayey sand with a variable proportion, up to 30%, of pebbles and cobbles overlying chalky till.

Sand and gravel is also mapped almost continuously along the lower Glem valley sides from near Thurston Hall to the confluence with Hawkedon Brook. Flint cobbles are again conspicuous in the field brash but stream exposures show flint and chalk pebbles to be common as well, eg 30 m downstream from the road bridge north of Thurston Hall [7949 5212]:

Patchily exposed interbedded sand and gravel with flint and chalk pebbles and cobbles	4.0
Chalky till	0.8

Sand and gravel also crop out along the lower flanks of the Hawkedon Brook valley from Purton Green down to its confluence with the River Glem. There is no borehole evidence to indicate whether the sand and gravel also underlie the till spur between the two streams although lensoid bodies of gravel have been mapped there higher within the till. A stream section [7862 5306] near Burnt Ash Cottage showed:

Clay, brown, with gravel intercalations near base	0.5-0.8
Gravel; up to 80% of volume in pebbles and cobbles, mostly flint but including chalk and brown sandstone	0.6-1.1
Chalky till	0.4

There is abundant sand and gravel along the Glem valley between Gallowgate and Moorhouse farms, not only near the valley floor but also in what appear to be widespread beds within or above the till dipping towards the river from 50 m or more above it on each side. These are mostly of flint pebble and cobble gravel, especially on the south bank near Lodge Farm, but also include much chalk pebble gravel on the north side of valley around Somerton Hall.

Along the valley sides downstream from Moorhouse Farm, lenses of flint and chalk gravel do occur below and within the till but are subordinate to and interbedded with orange-brown, fine to medium-grained sand. Typical exposures include:

1 A ditch [8279 5126] at Boxted showing 1.4 m of flint and chalk, pebble and cobble gravel overlying 0.4 m of fine to medium-grained, orange-brown sand.

2 A ditch [8350 5020 to 8361 5013] near Park Farm showing pale brown to orange-brown, fine to medium-grained sand containing scattered poorly-sorted, pebbles of varied lithologies but also including lenses of flint cobble gravel.

3 A ditch [c 827 502] in Boxted Park with exposures up to 1.7 m high showing reddish brown, sandy clay (Head) overlying chalk and flint gravels in a mostly clayey sand matrix.

There are many scattered outcrops throughout the district of flint gravel in the eroded till of the plateau surface but they are especially concentrated in north-west to south-east trains across the area of TL85SW: from Scoles Gate towards Hartest and again along the north-east side of the Glem valley south-east of Boxted. No clean exposures of these gravels were recorded. Brash content and augering suggest they consist of concentrations of rounded flint cobbles, commonly surrounded by gravel containing smaller, angular flints, all in a sandy clay matrix.

The greatest thickness of gravel recorded away from the main valleys is in a borehole (TL75SE/15) [7754 5002] at Shadowbush Farm, where 24.5 m of 'flint sand and small drift' lies below, or close to the base of, the till and a higher bed of 'grey sand' within the till was proved between 8.8 and 10.7 m depths.

3.3 Head

All the main valleys and some of the tributary ones contain accumulations of brown to reddish brown, friable, sandy, variably stony clays. These are thought to be primarily the product of solifluxion during two or more phases of periglacial conditions, both post-dating the Anglian glaciation, but probably supplemented by modern, temperate climate hillwash. Commonly the sandy clay is largely or completely decalcified. Locally it contains variable proportions of gravel - either generally disseminated, as where the source material includes much Glacial Sand and Gravel, or in lenses or 'stringers', usually low within the Head, representing water-laid or sorted intercalations.

Distribution of the Head is in two distinct loci, namely either in perched side valleys mostly above about 75 m OD, or as infilling of the River Glem valley itself. These are interpreted as dating from respectively before and after a major landscape rejuvenation, possibly in the early Devensian. The Hartest Brook valley, from the village at about 55 m OD upstream, is the largest of the perched valleys and contains the greatest recorded thicknesses of Head (up to 5 m) in the district. Head as thick as 4 m has been observed in the Glem valley.

Characteristic exposures of Head include:

1 Ditch [7585 5190] south of Denston Park, showing 1.1 m of pale brown stony clay with about 5% of its volume in flints, and a 0.2 m thick lens of flint gravel at the base, all overlying chalky till.

2 Ditch [7876 5306 to 7878 5296] near Burnt Ash Cottage showing a continuous section with two separate exposures of Head (reddish brown, sandy, stony clay), respectively underlying a bench on the valley side and the floor of the valley, divided by an inlier of Glacial Sand and Gravel.

3 Ditch [7777 5208] west of Stansfield Lower Street showing 1.1 m of poorly sorted, flint pebble and cobble gravel with a mixed sand and clay matrix, overlying chalky till.

4 Right bank of Hawkedon Brook [8008 5263] south of Dean Farm:

Clay, reddish brown, sandy, stony; with pebble gravel stringers (Head)	1.5
Gravel; pebbles and cobbles with imbricate disposition; bedding visible	0.7
Chalky till	

3.4 River Terrace Deposits

River terrace deposits extend into the district along the side of the Glem valley from TL84NW. They comprise very sandy clay containing some cobbles, with a top surface at about 1 m above the flood plain probably representing Terrace One of the Stour and lower Glem valleys. A terrace feature farther upstream in Boxted Park [c 828 507] is underlain by sand and probably equates with Terrace Two.

The upper valley of Hartest Brook grades to a nick point within Hartest village and the flat valley floor surface around the village may correlate with one of the higher terraces of the Stour valley. It is underlain by up to 3.5 m of brown silty clay with gravel lenses.

3.5 Alluvium

Modern stream deposits underlie the flat valley floors along nearly the entire course of the River Glem, as well as by the lower part of Hawkedon Brook, and patchily in some of the smaller valleys. They mostly consist of brown silty clay with some thin lenses and stringers of gravel towards the base. There may be a large sand content in the alluvium adjacent to Glacial Sand and Gravel, as in the valley between Denston and Wickham Street. Maximum thicknesses are uncertain but are unlikely to exceed 3 m. As much as 1.5 m of brown silty clay alluvium is exposed in the banks of the River Glem between Boxted and Somerton Hall.

4 ECONOMIC GEOLOGY

4.1 Sand and Gravel

The remains of small-scale past sand and gravel working have been recognised in at least a dozen places in the district but there are no active operations. Most of the disused pits are in the Glacial Sand and Gravel along the Glem valley. Flint pebble and cobble gravel appears to have been the principal product. The largest operations were probably the pits [c 8114 5143] south of Lodge Farm, from which the flint gravel was transported into the valley by tramway, and east of Sheepcote Farm, Denston [7692 5261 to 7713 5256] where flint gravel was extracted into the 1970s. Sand has been dug at both ends of the district; from pits near Boxted (at Park Farm [8339 5035] and in Boxted Park [8294 5080]), and near the A143 road [7526 5364] south-west of Wickham Street.

4.2 Clay

Till clay has been extracted from several localities but probably mostly for direct use in nearby embankments etc. The only place where evidence of clay being dug for making bricks was noted is beside Brickiln Cottage [7875 5387] near Windolph Farm where clay from both Till and Head may have been used.

5 REFERENCES

BRISTOW, C R. 1983. The stratigraphy and structure of the Crag of mid-Suffolk, England. *Proceedings of the Geologists Association*, 94, 1-12.

MATHERS, S J and ZALASIEWICZ, J A. 1988. The Red Crag and Norwich Crag formations of southern East Anglia. *Proceedings of the Geologists Association*.

British Geological Survey

Keyworth
Nottingham NG12 5GG

Plumtree (060 77) 6111
Fax ☎ 060 77 6602
Telex 378173 BGSKEY G

With compliments

Rec'd from author 20/7/89

Price Code A