BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/88/23

Onshore Geology Series

TECHNICAL REPORT WA/88/23

Geological notes and local details for 1:10000 Sheet SP51NE: CHARLTON-ON-OTMOOR

Part of 1:50000 sheets 219 (Buckingham) and 237 (Thame)

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Geographical index:
UK, Central England, Oxfordshire, Buckinghamshire, Charlton-on-Otmoor

Subject index:
Geology, Middle Jurassic, Upper Jurassic, Drift, Lower Oxford Clay

Bibliographic reference:

AMBROSE, K. 1988. Geological notes and local details for 1:10000 sheet SP51NE: Charlton-on-Otmoor. *British Geological Survey Technical Report* WA/88/23

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 KEYWORTH, BRITISH GEOLOGICAL SURVEY 1988

CONTENTS

1. INTRODUCTION

This report covers 1:10000 sheet SP 51 NE (Charlton-on-Otmoor) which is included in 1:50000 geological sheets 219 (Buckingham) and 237 (Thame). The original geological survey was part of Old Series One Inch Sheet 45 surveyed by E. Hull, H. Bauerman, W. Whitaker and T.R. Polwhele and published in 1863. An account of the geology is given in Green (1864). The area south of grid line 155 was surveyed at the 1:10560 scale (Buckinghamshire County Sheet 26 SW) by T.I. Pocock in 1905 as part of the Oxford Special Sheet. The geology is described in an accompanying memoir (Pringle, 1926).
The 1:10000 survey was by K. Ambrose in 1986 under the direction of R.G. Thurrell, Regional Geologist. Stratigraphical palaeontology was carried out by B.M. Cox (Lower Oxford Clay) and H.C. Ivimey-Cook (Cornbrash). The project was jointly funded by BGS and the Thames Water Authority.

The area lies within the counties of Oxfordshire and Buckinghamshire between the towns of Oxford and Bicester. It is entirely rural with the villages of Wendlebury, Merton, Charlton-on-Otmoor, Fencott and Murcott being the main settlements. The district is dominated by low-lying terrain of the River Ray basin and the northern fringe of Otmoor. It is underlain for the most part by Oxford Clay within which nodular limestones produce local dip and scarp features. The Charlton Anticline trends NE-SW across the area producing a series of periclinal domes in Great Oolite Limestones (Cornbrash and Forest Marble).

Concurrent with the mapping, a site investigation for the proposed extension of the M40 motorway from Oxford to Birmingham was in progress. The author is greatly indebted to the staff of Sir William Halcrow and Partners and Exploration Associates (Warwick) Limited for allowing access to boreholes and trial pits for core logging, sample collecting and gamma ray logging (using a Mount Sopris portable logging instrument). The data collected has enabled a very detailed correlation of the sequence at depth to be made and individual marker beds to be mapped at the surface. An EM 31 conductivity meter was used to delimit geological boundaries beneath alluvium.

Parallel reports covering adjacent 1:10000 sheets are:

- SP 51 NW and SP 51 SW (Weston-on-the-Green and Islip)(Wyatt and Ambrose, 1988)
- SP 51 SE (Beckley and Horton)(Horton, in press)
- SP 61 NW (Arncott)(Ambrose, 1988)

2. GEOLOGICAL SEQUENCE

DRIFT			
Quaternary	Alluvium		
	First Terrace	)	River
	Third Terrace	)	Gravels

SOLID			
Jurassic	Ancholme Clay Group		
	Oxford Clay Formation		
	Middle Oxford Clay Member		
	Lower Oxford Clay Member		
	Kellaways Formation		
	Kellaways Sand Member		
	Kellaways Clay Member		
	Great Oolite Group		
	Cornbrash Formation		
	Forest Marble Formation		
	White Limestone Formation	)	
	Hampen Marly Formation	)	proved
	Taynton Limestone Formation	)	in
	Sharps Hill Formation	)	boreholes
	Inferior Oolite Group	)	only
	?Grantham Formation	)	

3. SOLID GEOLOGY

3.1. CONCEALED STRATA

Palaeozoic rocks have been proved at shallow depths in a number of boreholes encircling the area. The Bicester No. 1 Borehole [SP 5272 2081], sited just north of the district, proved 172.52m of Upper Devonian sandstones, siltstones and mudstones from 168.55m depth resting on 44.50m of Silurian (Upper Llandovery) sandstones and mudstones at 341.07m. These in turn overlie a suite of lavas and tuffs of unknown age, of which 128.32m were proved from 385.57 to 513.89m. The Devonian strata continue westwards and were proved in the Noke Borehole [SP 5386 1285] (Falcon and Kent, 1960) from 116.8m to 247.8m. West and north-west of Noke, a Carboniferous basin overlies the Devonian and was proved at Apley Barn near Witney (Poole, 1969), at Steeple Aston (Poole, 1977) and in several confidential boreholes. To the north-east the Devonian strata die out and the Mesozoic rocks rest on strata of Tremadoc age, proved in boreholes at Calvert [SP 6870 2458, 6903 2457] (Davies and Pringle, 1913), Twyford (nos. 1-4) [SP 6803 2568, 6760 2650, 6859 2659, 6697 2561], Marsh Gibbon [SP 6481 2374] and Westcott [SP 7096 1649] (Bulman and Rushton, 1973). Triassic rocks have been proved above the Palaeozoic floor in the Bicester, Noke and Twyford Nos. 1 and 2 boreholes, but they are absent in the Calvert, Marsh Gibbon, Twyford Nos. 3 and 4 and Westcott boreholes where Jurassic Lias Group rocks are the oldest Mesozoic strata. In the Bicester No. 1 Borehole, the Triassic rocks comprise 6.09m of grey-green and red siltstones and silty mudstones between the depths 162.46 to 168.54m. They are overlain by a 0.92m limestone assigned to the Langport Member of the Lilstock Formation (Penarth Group). The boreholes at Twyford and Noke prove only a marginal facies of the Penarth Group, mainly pebbly sandstones and sandy mudstones, named the Twyford Beds (Donovan and others, 1979).
The lowermost Jurassic rocks are Lias Group mudstones with thin limestones, proved in all the boreholes. They range in thickness from 39.5m at Westcott (Sumbler, 1988) to 87.4m in the Bicester No. 1 Borehole. The Lias and underlying Triassic rocks thin and die out south-eastwards onto the London Platform land mass. The succeeding Inferior and Great Oolite Groups are poorly known; the boreholes generally have poor descriptive logs or were not cored. The sequence at Westcott is given in some detail by Sumbler (1988) and that at Noke is further summarised by Wyatt and Ambrose (1988).

3.2. MIDDLE JURASSIC

The oldest exposed strata are from the Forest Marble Formation. Older Middle Jurassic beds have been proved in boreholes.

3.2.1. Inferior Oolite Group

3.2.1.1. ?Grantham Formation

Borehole SP 51 NE/6 [559 194] terminated in 4.1m of "hard grey sand" at a depth of 56.7m which has been correlated with the "White Sands" of north Oxfordshire. Horton (1977) demonstrated that these beds were equivalent to the Grantham Formation (formerly Lower Estuarine 'Series') of Kent (1975).

3.2.2. Great Oolite Group

The nomenclature for the group follows Cope and others (1980). Correlation of the component formations present beneath the district are illustrated in Figure 1. Most of the borehole information comes from drillers logs but the cores of 4 were described by R.J. Wyatt of BGS. The sequences proved are correlated with the quarry section at Woodeaton [533 123] some 3.5km SSW of the district, described by Palmer (1973) and Wyatt and Ambrose (1988).

3.2.2.1. Sharps Hill Formation

This formation has been recognised in two boreholes. SP 51 NE/152 [5711 1715] proved the uppermost 2.31m to a depth of 34.00m without reaching the base. It consists of olive-grey, silty, calcareous mudstones with common shell detrital wisps, thin limestone ribs and traces of lignite to 33.03m. This rests on an oyster-rich mudstone seen to the bottom of the borehole. These lithologies are consistent with those described by Horton and others (1987) for the Chipping Norton area to the north-east. The 1.98m of "marl" above the ?Grantham Formation in Borehole SP 51 NE/6 is correlated with the Sharps Hill Formation (Fig.1).

3.2.2.2. Taynton Limestone Formation

The Taynton Limestone was proved in boreholes SP 51 NE/6 and 152. The thicknesses of 6.7 and 4.4m respectively are similar to those at outcrop (4.5-7.5m) in north Oxfordshire (Arkell, 1947). The formation consists of creamy grey to buff and greenish grey, shell fragmental, commonly oolitic and cross-bedded limestones with muddy wisps and partings. The limestones are interbedded with olive-grey, calcareous siltstones and mudstones usually with shell detritus and abundant oysters at some horizons. Burrows are locally present in both lithologies.

3.2.2.3. Hampen Marly Formation

This formation consists of interbedded pale to dark grey, green and olive, variably blocky and laminated, silty mudstones and calcareous siltstones. Poorly preserved bivalves and traces of lignite and rootlets occur throughout. Complete sequence were proved in boreholes SP 51 NE/6 and 152 where it is 2.6m and 3.9m thick respectively Boreholes SP 51 NE/126 [5826 1658] and 148 [5715 1726] penetrated the top part of the formation only. The thicknesses are similar to the 3.7m at Woodeaton Quarry [533 122] to the SSW, recorded by Palmer (1973) and are thin when compared regionally. In adjacent areas, the formation is 4.0m thick in a borehole [6137 1723] at Upper Arncott (Ambrose, 1988, Tiddeman, 1910), c.4.3 in the Bicester No. 1 Borehole and 5.4m in the Westcott Borehole (Sumbler, 1988). The exact thickness at Calvert is uncertain and may be less than the 12.2+m given by Arkell (1947). The new evidence does not support his suggested eastward thickening of the formation from the 4.5-9.1m at outcrop.

3.2.2.4. White Limestone Formation

The White Limestone has been proved in detail in three cored boreholes, SP 51 NE/126, 148 and 152. Borehole SP 51 NE/6 also proved the full thickness, described in the log only as "rock" and "clay", while boreholes SP 51 NE/20 [5546 1943], 46 [5777 1656], 59 [5714 1722], 60 [5718 1729] and 105 [5954 1563] all penetrated the uppermost part of the formation. The component members and beds defined by Palmer (1979) and modified by Sumbler (1984) have been recognised. The correlation of the boreholes is shown in Fig. 1 and compared to the nearby quarry section at Woodeaton (Palmer, 1973, Wyatt and Ambrose, 1988). Comparative thicknesses are given in Table 1.

The formation consists typically of white or cream, bioturbated, micritic limestones, with varying proportions of pellets, ooliths, shells and shell debris. Oolites occur at some levels and recrystalised hard grounds are present at intervals. Subordinate clays and marls occur throughout. The hardgrounds commonly have bored upper surfaces and may be encrusted with shells. They indicate pauses in sedimentation. The fauna is dominated by bivalves and gastropods with brachiopods, corals and lignite also present. The gastropods are commonly of the high-spired genus *Aphanoptyxis*. They occur in abundance a certain horizons, particularly hardgrounds, and provide useful marker beds (Arkell, 1931, 1947, Barker, 1976, Palmer, 1979, Sumbler, 1984).

The White Limestone varies in thickness from 13.6m (borehole 126) to 16.4m (borehole 148). Borehole 6 proved either 16.6m or 14.2m, the boundary with the overlying Forest Marble Formation being unertain. The maximum thickness recorded at Woodeaton varies from 8.2m (Palmer, 1973) to about 12m (Wyatt and Ambrose, 1988) and at outcrop to the north and north-west it varies between 10 and 15m (Sumbler, 1984). The variations are mainly due to channeling of the overlying Forest Marble into the upper part of the formation.

Borehole	20	59	60	152	148	46	126	105
Bladon Member	3.90	2.50	3.57+	4.03.	4.14	?1.4	1.99	1.08
Upper Epithyris Bed	2.45	1.45	1.59	1.53	1.56	?0.8	1.78	0.43
Fimbriata-Waltoni Bed	1.45	1.05	1.98+	2.50	2.58	?0.6	0.21	0.65
Ardley Member	?6.90	0.35+		6.50	6.10	?1.5	6.45	5.20+
A. ardleyensis Bed				0.25	0.38		0.55	0.66
Roach Bed				0.55	0.48		0.95	
Shipton Member				5.38	6.02		5.15	

Table 1. Comparative thicknesses of the component members and beds of the White Limestone Formation proved in boreholes on sheet SP 51 NE.

3.2.2.4.1. Shipton Member

This member has been proved in three boreholes, nos. 126,148 and 152. A fourth, borehole 6, proved a complete sequence of the White Limestone but the component members could not be distinguished. The base has been taken at the bottom of the last limestone bed overlying the mudstones and siltstones of the Hampen Marly Formation. The top is marked by a bored hardground immediately below the Roach Bed of the overlying Ardley Member, prsumed to be the *A. excavata* Bed of Barker (1976), although the diagnostic gastropod has not being identified. Boreholes 148 and 152, sited only 60m apart, show a very good correlation of individual beds (Fig. 1) and include several bored hardgrounds. The thickness variation of the member between the two boreholes is 0.64m, due almost entirely to the appearance of an extra bed of limestone in borehole 148 immediately above the lowest bored horizon at 20.95m. In addition to bivalves gastropods and lignite, a few rhynchonellids were noted plus a solitary coral at 37.13m in borehole 126. *Chondrites* burrows occur at 21.23m in borehole 152.

3.2.2.4.2. Ardley Member

The Ardley Member was proved in 7 boreholes (Fig. 1) while another (borehole 46) may extend into the top of the member. Three of the boreholes (126, 148 and 152) prove a complete and detailed sequence. The Roach Bed of Odling (1913) and Arkell and others (1933), a distinctive sandy, shelly limestone which is brown and cavernous when weathered, occurs at or near the base of the member, sometimes underlain by a thin marl (borehole 126) or marly limestone (borehole 152). The *A. ardleyensis* Bed of Barker (1976) was identified in borehole 105 at 39.70m, while in boreholes 126, 148 and 152 it position is less certain. Cross-bedded limestones were noted in boreholes 126 and 152.

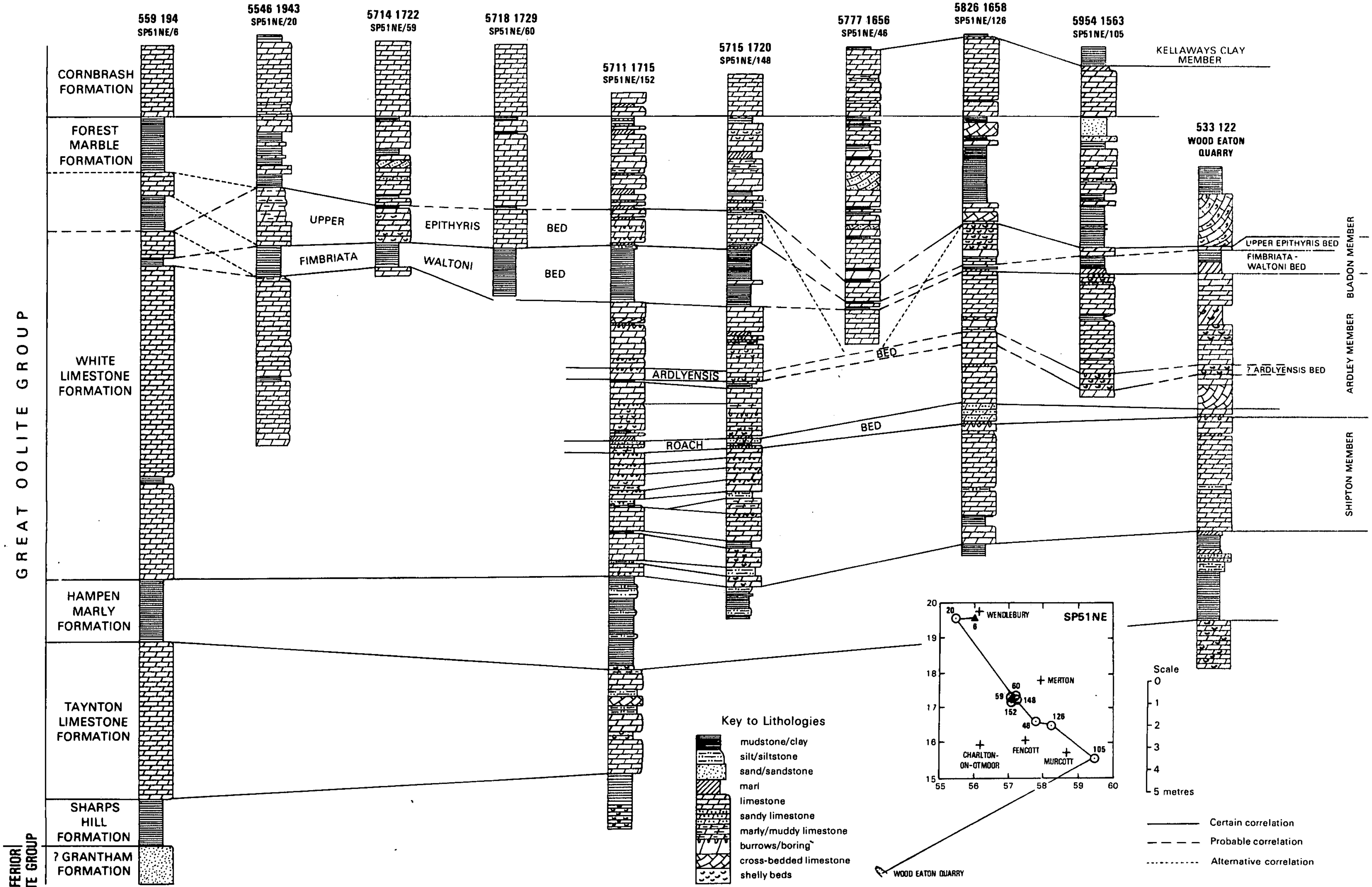

Fig. 1 Correlation of boreholes proving the Great Oolite Group

Gastropods and bivalves are common in some of the beds and scattered lignite fragments occur.

3.2.2.4.3. Bladon Member

This member has two component beds, the Fimbriata-Waltoni Bed and the overlying Upper Epithyris Bed (Arkell 1931), which have been included in either the White Limestone or Forest Marble by past workers (see Sumbler, 1984, Table 2).
The member was encountered in 8 boreholes (Fig. 1). In borehole 6 there are two possible correlations and borehole 46 may have proved the member. In the latter, the strata may all be Forest Marble Formation which locally channels down into the White Limestone, sometimes eroding the entire Bladon Member. In both boreholes, the logs are not detailed enough to ascertain the correct correlation.

3.2.2.4.3.1. Fimbriata-Waltoni Bed

This bed forms a distinctive marker horizon near the top of the White Limestone. It consists of pale and dark green, olive and grey, silty, blocky mudstones, commonly containing bivalves, burrow traces and locally, much lignite. Marl occurs at the base in borehole 105 and thin limestones are present in two boreholes: in borehole 148, a 0.14m bed of pale greenish grey, shell detrital, sparsely oolitic limestone and in borehole 126, a 0.08m bed of grey, shell detrital, muddy limestone. In borehole 20, the basal bed is an old soil horizon consisting of a weakly cemented very silty limestone with clay wisps, carbonaceous specks and roots.
The Fimbriata-Waltoni Bed is present in most boreholes (Fig. 1), varying in thickness from 0.21 to 2.58m (Table 1). The variations appear to be depositional rather than the result of erosion as there are no high-energy limestones immediately overlying the bed where it is thinnest.

3.2.2.4.3.2. Upper Epithyris Bed

This bed consists of a variety of limestone lithologies some of which contain the large brachiopod *Epithyris oxonica* from which the bed derives its name. In the boreholes, the limestones are variably pale grey, greenish grey, olive-grey or cream in colour. Shelly and shell detrital micrites predominate, containing varying amounts of pellets and ooliths and more rarely clay wisps. Subordinate lithologies include sparry limestones, marly limestones, marls and mudstones. Bioturbation is common and bored surfaces are sometimes present. Borehole 148 proved a 0.07m bed of greenish grey, silty, shell debris-rich, oolitic mudstone. The upper part of the bed in borehole 20 consists of a 1.40m psuedo-breccia of pale grey, silty, micritic limestone in a matrix of pale greyish green, hard, silty clay with black

clay-filled root holes. The only noted occurrence of epithyrids was in the uppermost 1.10m of the bed in borehole 126, where they occur in abundance. Elsewhere, the fauna is dominated by bivalves. Also noted were a few gastropods in boreholes 148 and 152 and colonial corals in borehole 126.
The bed has been proved in most of the boreholes (Fig. 1), varying in thickness from 0.43m to 2.45m (Table 1). Its presence is inferred in boreholes 6, 59 and 60 but, as in borehole 46, the lithological descriptions are insufficient to separate the White limestone from the overlying Forest Marble.

3.2.2.5. Forest Marble Formation

The Forest Marble crops out in the core of the Charlton Anticline at Oddington in the south-east corner, and Charlton-on-Otmoor. A third inlier north-east [584 185] of Merton is located on the north-west limb of the anticline and is associated with faulting and minor folding. The classification follows Palmer (1979) and Sumbler (1984). Some of the previous workers have included the Bladon Member within the Forest Marble e.g. Pringle (1926). Arkell (1944) divided the formation in the Islip - Noke - Charlton area into two broad subdivisions: a lower unit dominated by flaggy limestones ("Kemble Beds") and an upper unit of predominately shaly beds ("Wychwood Beds"). He included the Upper Epithyris Bed in the Kemble Beds. Allen and Kaye (1973) included both the Fimbriata-Waltoni Bed and the underlying Middle Epithyris Bed in the Forest Marble. The detailed borehole logs illustrated in Fig. 1 and the nearby Shipton-on-Cherwell quarry (Allen and Kaye, 1973) clearly show that the facies variations are extremely rapid and result from both lateral variation and erosion. The sequence ranges from over 90% limestone (borehole 60) to over 50% mudstone or marl (boreholes 6, 20 and 126). Mudstones or marls are also present at all levels within the formation.
The limestones are mainly pale cream to grey, sparry, shell detrital and oolitic. Muddy partings, wisps and clasts are common, with burrows visible in some beds. Subordinate lithologies are fine-grained, sandy limestones and muddy, micritic limestones. Borehole 105 proved 0.08m creamy grey, shell detrital oolite. Some horizons show well developed cross-bedding. The mudstones and marls are typically greenish to olive-grey, commonly containing silt or sand laminae and calcareous sandstone lenticles. Some contain ooliths, pellets and fine shell detritus. Lignite is found in both the limestones and the mudstones. In borehole 105, a 0.79m bed of fawn, fine-grained, weakly cemented sandstone with clay laminae occurs near the top of the formation.

Nine boreholes (Fig. 1) prove complete sequences through the formation. One of these (borehole 46) may not reach the base (see section 3.2.2.4.3.), while in three others (6, 59 and 60) the position of the base is not certain. Known thicknesses range from 3.05m in borehole 20 to 5.62m in borehole 105 with at least 7.0m and possibly as much as 9.65m in borehole 46. Pringle (1926) gave an average thickness of 3.7m (12'), including all of the Bladon Member while Arkell (1944) quoted 4.3-4.6m (14-15') for the Forest Marble in this area (including the Upper Epithyris Bed).

The formation is poorly exposed at outcrop. At Oddington, ploughed fields showed mainly clay with some debris of both the shell detrital oolitic and sandy limestone facies. Both are typically flaggy when weathered. At Charlton, the outcrop shown on the map is largely taken from Arkell's (1944) map. He marks a number of exposures all of which are no longer visible. The outcrop has been extended north eastwards on the evidence of Forest Marble-type clays being augered. They are greenish grey and contain abundant race unlike the weathered Lower Oxford Clay which is pale grey with little or no race.
Green (1864) recorded the following section in Forest Marble from quarries and a brick pit by the windmill at Charlton:

	m
Rubbly Cornbrash limestone	0.61 (2'0")
Flaggy Forest Marble, oolitic	0.15 (0'6")
Yellowish marl	0.07 (0'3")
Solid whitish oolitic limestone	0.91 (3'0")
Pale blue clay	

The locality is near the windmill marked on Arkell's map [5842 1612].
The small inlier north-east of Merton is mainly in clay. A greenish grey, shelly, oolitic clay was augered at one point [5837 1864] beneath up to 1m of sandy wash.

3.2.2.6. Cornbrash Formation

The Cornbrash outcrop is restricted to the core of the Charlton Anticline. It is discontinuous owing to both faulting and the local periclinal doming of the anticline. In places, notably at Charlton-on-Otmoor and in the north-east, the upper boundary of the formation has been located beneath alluvium using an EM 31 conductivity meter (see section 5.).
The Cornbrash is a blue-grey, shell detrital, micritic, bioturbated limestone. Clay partings and mud-filled borings are common, and sparry limestones occur locally. When weathered, the bed is characteristically rusty brown and rubbly. Ooliths are rare in the Cornbrash. It forms a very distinctive marker. When fully developed, the formation comprises the Lower and Upper Cornbrash. The boundary between the two coincides with the Bathonian - Callovian Stage boundary (Middle - Upper Jurassic). Arkell (1944) and Douglas and Arkell (1932) used a two-fold brachiopod zonal classification for the Lower Cornbrash, the *Cererithyris intermedia* Subzone overlain by the *Ornithella obovata* Subzone. The current ammonite zonal classification follows Torrens (1974), the *Clydoniceras (Clydoniceras) discus*, Zone and Subzone. Douglas and Arkell (1932) found no trace of the Upper Cornbrash in this area, however recent cored boreholes suggest it may be present locally (see below).

The fauna of the Cornbrash is varied, dominated by bivalves and brachiopods. Ammonites are usually rare, along with other life forms which include echinoids, nautiloids, ostracods and saurian remains.
The thickness varies from 2.19 (borehole 105) to over 3.76m (borehole 148).

The Cornbrash is easily traceable across the district forming a series of gentle elongate domes rising a few metres above the surrounding flat ground which is underlain by Kellaways and Oxford Clay Formations and river deposits. The formation provides good arable land, the fields being littered with rubbly limestone debris.
Between Oddington and Charlton, there are traces of several old quarries. In one [5560 1549] about 0.5m of rubbly weathering, shell detrital, micritic limestone is still visible. Cornbrash is also visible below the water level in a pond [5605 1595] in Charlton. Arkell (1944) reports that the Cornbrash is principally of the *obovata* Zone in this area and has two facies: a poorly fossiliferous slabby facies and a richly fossiliferous rubble. Douglas and Arkell (1932) noted a basal bed in the formation belonging to the *intermedia* Zone, a hard limestone densely packed with the zone fossil. They report it to be dark grey at Oddington and creamy white at Charlton. They give the following section from a quarry on the western outskirts of Charlton:

LOWER CORNBRASH		m
3	Cream-coloured, hard, flaggy limestone with *"Pseudomonotis echiata, Chlamys vagans, Lima duplicata"*.	0.3 (1'0")
2	Grey and white marl and marly rubble, highly fossiliferous. *"Ornithella obovata, P. echinata, L. duplicata, C. vagans, Homomya, Pleuromya, Pygurus michelini, Kallirhynchia yaxleyensis"*.	0.7 (2'3")
1	Soft, cream and grey limestone, a packed mass of *"Cererithyris intermedia"*; also *"Clydoniceras sp., C. vagans, Gervillia subcylindrica, Limatula cerealis, Ceratomya concentrica, Pleuromya"*.	0.3 to 0.6 (1'to 2'0")

The *K. yaxleyensis* in Bed 2 is reported to come from Oddington where the bed is 1.52m (5') thick.
At Merton there are no natural exposures although there is evidence of many former quarries, particularly to the north-east of the village. Temporary exposures were seen in trial pits for the M40 site investigation at the south-west end of the village. Six pits were excavated either side of the road [570-2 170-2] (SP 51 NE/145-7,149,151,153) and showed an upper weathered zone consisting of fragments of cornbrash limestone in a brown sand and sandy clay matrix which varied from 1.3m in pit 146 [5718 1713] to 2.3m in pit 151 [5712 1716]. In pit 145 [5726 1703], the weathered zone rested abruptly on unweathered limestone at 1.4m,

while in pit 146, 0.2m of orange-brown and grey silty clay occurred between the weathered and fresh material. Both of these pits are to the south of the road. The remaining four, on north side of the road, all proved a bed of dark grey clay with many shell fragments immediately below the weathered zone and resting on fresh limestone. The clay varied between 0.05 and 0.2m thick. Two boreholes in the same locality (nos. 60 and 148) proved one of thickest known sequences in Oxfordshire, at least 3.76m. In a third borehole (152), the base of the formation was uneven and erosional with small pebbles and mudstone clasts.
To the west of the outcrop at Merton, there is a small inlier [570 172-4] of Cornbrash beneath the alluvium of a tributary of the River Ray. Debris of shell-fragmental limestone dredged from the stream bed yielded the following fauna: *Meleagrinella echinata,* (Wm Smith), *Modiolus sp., Pleuromya subelongata,* (d'Orbigny), *Pseudolimea sp.,* small oysters, terebratulid fragments, *Pygurus michelini* Cotteau and other echinoderm debris and a worm burrow . The fauna indicates the Lower Cornbrash (Cox, 1988). The samples are probably from the topmost part of the Cornbrash, suggesting that the Upper Cornbrash is absent here. Elsewhere, two boreholes (105 and 126) proving a complete cored sequence through the formation indicate a possible thin representative of the Upper Cornbrash although this has still to be confirmed by biostratigraphical evidence. Both showed a dark greenish to brownish grey, shell-detrital marl passing down to a marly, shell detrital limestone with an erosive base. In borehole 126 the limestone is sandy with common burrows at the base. Sandy limestones are characteristic of the Upper Cornbrash.
Along the line of the proposed M40 a number of boreholes have proved the Cornbrash, mostly only the top few centimetres. North-east of Merton, minor folding parallel to the Charlton Anticline has produced a small inlier of Cornbrash [590 183]. A second inlier [593 187-595 188] beneath alluvium has been located using the EM 31 conductivity meter, although a thin capping of Kellaways Clay cannot be ruled out. In the extreme north-east, faulting has produced a disjointed outcrop.

3.3. UPPER JURASSIC

3.3.1. Ancholme Clay Group

This group comprises all the predominantly mudstone formations of the Upper Jurassic from the Kellaways Formation up to the Kimmeridge Clay Formation. The term was introduced for the Hull - Brigg area (Gaunt and others, in press) where difficulty was encountered in separating the formations in the field.

3.3.1.1. Kellaways Formation

Both the Kellaways Clay and Sand Members are present, cropping out as discontinuous fault-bounded inliers along the flanks of the Charlton Anticline and in the north-west corner where the main outcrop crosses the area. Much of the formation is at crop beneath alluvium and boundaries have been located using an EM 31 conductivity meter (see section 5.). The average thickness of the formation is between 5 and 6m with up to at least 7.65m recorded in borehole 155 [5662 1778]. Arkell (1947) previously estimated 6.1-9.1m (20-30') for Oxfordshire. The minimum thickness proved, 2.1m in borehole 140 [5743 1693], results from part of the formation being faulted out. Most of the proven thicknesses are from percussion boreholes and the boundaries are only approximate being based on drillers descriptions. Gamma ray logs run in a few boreholes enable the boundaries to be more precisely delimited.

3.3.1.1.1. Kellaways Clay Member

The Kellaways Clay is a dark grey, smooth to silty, commonly fissile, poorly fossiliferous, pyritic mudstone which is locally sandy at the top. Rare pale or dark grey cementstone nodules occur. It is distinct from the Lower Oxford Clay which usually has a green or brown tint and is much more fossiliferous. Sand-filled burrows are common at the top, and pyritic trails occur elsewhere. The sparse fauna is dominated by bivalves together with a few ammonites and gastropods. The thickness of the member is mostly in the range 2.9 to 4.0m. A number of boreholes indicate thicknesses outside this range but the upper boundary may not be precise. Borehole 155 shows a maximum of over 5.25m while borehole 53 [5744 1696] proved a minimum of 2.0m. In borehole 140, only 0.6m were proved, most of the member having been faulted out. Arkell (1947) gives an average of 4.6m (c.15') for Oxfordshire.

There are no exposures of Kellaways Clay in the area but the outcrop is easily traceable as a narrow tract of clay where the Cornbrash and Kellaways Sand can be identified. The latter is faulted out in some areas, placing the Kellaways Clay in juxtaposition with the Lower Oxford Clay. The outcrop is broken by a number of faults, particularly in the extreme north-east. In the same area, the member forms the core of the Charlton Anticline. A considerable proportion of the outcrop here and around Charlton is masked by river deposits.

3.3.1.1.2. Kellaways Sand Member

The Kellaways Sand is a pale grey to greenish grey, fine-grained, poorly cemented, silty sandstone with subordinate thin mudstone beds and partings. Cementstone nodules occur locally, and were recorded in sections at Kidlington (Callomon, 1955) to the east of the area. The sandstones are bioturbated and moderately fossiliferous with bivalves being most common. Ammonites, gastropods and belemnites are also present. The member is mostly 2 to 3m thick with a maximum of 4.8m recorded in borehole 73 [5607 1822] and a minimum of 1.5m recorded in 3 boreholes, nos. 138 [5746 1693], 140 and 158 [5547 1902]. In 140 and possibly

138, part of the member is faulted out. Other boreholes show similar thicknesses but the figures are less reliable.

There are no exposures of the formation in the district but it is easily recognised in arable fields by a belt of light, sandy soil with traces of pale grey and ochreous, fine sand. In places, terrace deposits show similar features but are distinguishable by the presence of pebbles at depth. In pasture fields, animal burrows are common, throwing out typical fine sand which is also easily detectable by the auger. Like the underlying Kellaways Clay, the Kellaways Sand outcrop is broken by faulting, and in places, is cut out by NE - SW faulting.

3.3.1.2. Oxford Clay Formation

The Oxford Clay is divided into the Lower, Middle and Upper Oxford Clay Members. Only the lower two are present in this area where they have been separately mapped. Both have a deep weathered profile of 2 to 3m and commonly extending down to 5 or 6m. It is characterised by the development of secondary selenite derived from the breakdown of pyrite and calcite. The selenite crystals usually increases in size with depth from fine sand/silt-size coating fissures near to the surface, to well-formed crystals often several centimetres in length. These die out at 5 to 6m depth. Race may be common in the uppermost 1 to 2m. The Lower Oxford Clay has a distinctive weathered profile usually with sharper boundaries between layers (see below) compared to the more transitional nature of the different zones in the Middle Oxford Clay.

3.3.1.2.1. Lower Oxford Clay Member

The Lower Oxford Clay consists of about 27m of dark greenish or brownish grey, fossiliferous, fissile, bituminous mudstones. A few horizons are poorly fossiliferous. Grey septarian nodules occur at intervals. The fauna is rich and varied with bivalves being most abundant, particularly *Nucula*. Also present are ammonites, most commonly of the genus *Kosmoceras*, gastropods, belemnites, crustacea, fossil wood, fish and reptile remains. The serpulid *Genicularia vertebralis* is common in the upper part of the member. Fish debris is usually common in paler mudstones which have a poor invertebrate fauna. The gastropod *Dicroloma* is abundant at some levels. Shell pavements and ammonite plasters, some pyritic, are common, indicating pauses in sedimentation. The fauna has been studied in detail at the nearby Calvert brick pit by Duff (1975), who identified 10 distinct biofacies and 5 lithofacies types in a palaeoecological analysis of the member. He measured organic carbon contents between 1 and 6.1% in the Lower Oxford Clay.

Five marker beds have been mapped in the area:

	Height in metres above the base of the Oxford Clay.
Acutistriatum Band - Comptoni Bed	18
Blackthorn Nodule Bed	14
Wendlebury Nodule Bed	9-10
Arncott Nodule Bed	4-5
Merton Nodule Bed	2-3

The nodule beds ("Main concretions" of Hudson, 1978) consist of grey, hard, splintery argillaceous limestones which become noticeably pyritic towards the margin (Hudson, 1978). They are septarian, being cut by a network of calcite veins and vary in size up to about 1m in diameter. On weathering they fracture along the calcite veins to subrounded fragments, commonly with a pale grey, limonitic stained surface. The contained fossils are uncrushed, indicating growth started before compaction of the sediment. At Calvert, the nodules make up about 5-10% of the bed. The Acutistriatum Band commonly includes nodular limestones while the Comptoni Bed is a series of cyclic shell-rich mudstones with only rare nodule development. The limestones of the Acutistriatum Band are usually distinctive being pale grey, fissile and argillaceous, weathering to brownish grey, more angular fragments. The nodules are sometimes septarian as at Calvert but more commonly are not. They contain only crushed fossils, indicating that growth started after compaction of the sediment. In a study of the bed at Calvert, Hudson (1978) noted that the nodules are less pyritic and less densely cracked than those at other levels. He estimated that at Calvert, nodules made up about 20% of the Acutistriatum Band.
The Acutistriatum Band - Comptoni Bed is traceable over much of southern England. The remaining four have been given local names and are probably of limited lateral extent. Callomon (1968) pointed out that in the brick pits at Calvert, Bletchley, Stewartby and Peterborough, the main nodule beds occurred at different stratigraphic levels. Three of the marker beds occur at zone or subzone boundaries: the Acutistriatum Band, Blackthorn and Arncott Nodule Beds. The Blackthorn Nodule Bed correlates with Bed 6 at Calvert (Callomon, 1968), at the top of the *Kosmoceras (Zugokosmoceras) obductum* Subzone. The Arncott Nodule Bed is correlated with Callomon's Bed 1d at Calvert and Bed 16 (Callomon, 1955) at Kidlington. At Kidlington, Callomon placed the bed at the base of the *K. (Guliemites) jason* Subzone while at Calvert, it occurs at the top of the underlying *K.(G.) medea* Subzone. This suggests either an imprecision in the subzone boundary or that the nodules grew at slightly different levels in different areas but nevertheless associated with the same event i.e. the subzone boundary, its non-sequences and shell beds. The Merton Nodule Bed is correlated with Callomon's Bed 11b at Kidlington. It is within the *medea* Subzone. The biostratigraphical position of the Wendlebury Nodule Bed has still to be determined precisely but it appears to correspond approximately to the *obductum* - *jason* Subzone boundary.

The outcrop of the Lower Oxford Clay covers most of the district. It is bisected by the Charlton Anticline but is continuous across it at one point south-east of Street Hill [572 167]. A small outlier is present in the extreme north-east.
There are no natural exposures of the Lower Oxford Clay in the area, but partial sequences have been proved in many boreholes, and a number of temporary sections were recorded during the survey. The latter were trial pits excavated during the M40 site investigation. Where not covered by drift, the member shows a distictive weathered profile, typically as follows:

	m
Pale to medium grey, commonly ochreous stained, smooth or silty clay.	1.5-2.0
Chocolate-brown clay, commonly fissile with traces of shells	c.0.2
Dark greenish grey mudstone, usually fissile and fossiliferous; firm and fresh.	

The boundaries between the layers are commonly sharp but may be gradational. Because of the deep weathered profile, it was neccessary to use an extendable Dutch Auger to a depth of at least 2m, to prove the boundary between the Lower and Middle Oxford Clay.

Much of the outcrop shown on the map as solid has a variable covering of drift (see section 6.3.). The nodule beds, with the exception of the Acutistriatum Band, form low, discontinuous features, commonly showing limestone debris. Where covered by alluvium, they may form a bedrock "high" and debris is often dredged from streams and ditches. The lowest beds crop out in the extreme north-east and on either flank of the Charlton Anticline although here they are faulted out in many places. The Merton Nodule Bed was only identified immediately west and south-east of the village of Merton where it forms a gentle dip slope with scattered limestone fragments. The bed has been proved boreholes 143 [5714 1690] and 157 [5616 1832], respectively 2.85m and 3.00m above the base of the Lower Oxford Clay.

South-east of Merton, a nodule bed occurs between the Merton and Arncott Nodule Beds. Its outcrop is shown by limestone debris in ditches and a low feature. The bed is correlated with Bed 12 of Callomon (1955) at Kidlington.

The Arncott Nodule Bed crops out in the south-west beneath alluvium where limestone debris dredged from the New River Ray locates its position. East and east-north-east of Merton, the bed forms a gentle dip slope and limestone debris has been dredged from the River Ray and drainage ditches. At one locality [558 184], fragments of *Kosmoceras* were found. Much of the outcrop in this area is beneath alluvium which was seen to die out across the bed at one point [5938 1791], pale grey clay with limestone fragments being observed immediately below the topsoil. There is no feature marking the outcrop here. The bed has been proved in 6

boreholes, occurring at 4.1-5.4m above the base of the Lower Oxford Clay.
The Wendlebury Nodule Bed forms good features at Wendlebury where it is repeated by faulting. West of the village between two NW-SE trending faults, the bed does not produce a feature. This is probably due to a remanie capping of terrace gravel. However, the bed has been proved in trial pit 178 [5538 1922] and in borehole 164 [5531 1918] at depths of 2.3m and 3.0m respectively. In the latter, the bed is 9.75m above the base of the Lower Oxford Clay. Other trial pits nearby (nos. 174 [5533 1916], 175 [5531 1916] and 179 [5512 1904] yielded the following fauna, all from mudstone which is probably below the bed:
K. ex gr. *jason* (Reinecke)?, *K.(Gulielmiceras) gulielmii* (J. Sowerby), small oysters (?juveniles), *Procerithium*, *Protocardia* juv.?, *Nicaniella (Trautscholdia) phillis* (d'Orbigny), serpulids and other shell fragments and spat. They probably indicate the *jason* Subzone. Another pit, 172 [5569 1877], sited above the Wendlebury Nodule Bed, showed brown mudstone with *Kosmoceras* and *Procerithium*.
The bed is traceable north-west of Charlton where it forms a gentle dip slope in places. Locally it forms a feature beneath alluvium. The nodule bed cropping out on the south-east side of Graven Hill [59 19] is probably the Wendlebury Nodule Bed. No feature is formed but limestone debris was seen at two localities, [5923 1947] and [5952 1986 - 5961 2000], the latter from a pipeline.
In the south-east, the bed has only been located in one area in trial pits 44 [5772 1651] and 45 [5779 1655] at depths of 2.4-3.1m. Two adjacent boreholes, nos. 46 and 47 [5772 1653] proved thicknesses of 12.5 and 12.8m respectively for the Lower Oxford Clay i.e. the bed is about 10m above the base of the member. Three boreholes in the same area also proved the bed, nos. 5 [5786 1566], 105 and 141 [5742 1692], respectively 9.67m, 9.1m and 10.3m above the base of the Lower Oxford Clay.

The Blackthorn Nodule Bed is the most easily traceable at outcrop. It forms pronounced features east and south-west of Wendlebury with nodule debris at the surface in several places. At one locality [558 184] indeterminate *Kosmoceras* fragments together with small bivalves and gastropods were found. In the south-east of the district, the bed has been proved in borehole 116 [5903 1607] and it forms a low feature to the north-west. The main outcrop of the bed extends north-east from Murcott onto the adjacent sheet (Ambrose, 1988), forming a prominent dip slope with limestone debris common in places. *Kosmoceras* fragments and impressions were found at two localities [596 172 and 5855 1633]. South of the Murcott Fault, septarian nodules were found in two trial pits, nos. 110 [5930 1599] and 112 [5909 1602], and in a pipe trench at Murcott [5857 1576]. They are all assigned to the Blackthorn Nodule Bed, here occuring near the surface in the core of a small anticline.

The Acutistriatum Band - Comptoni Bed proved the most difficult to locate as it rarely forms a feature apart from two areas [561

184, 559 179] south of Wendlebury. Much of the outcrop is beneath alluvium and is inferred from Lower Oxford Clay thicknesses proved in boreholes. In the north-west, in trial pit 69 [5655 1772], a 0.10m bed of brownish grey, silty limestone has been assigned to the Acutistriatum Band. It is about 18m above the base of the Lower Oxford Clay as proved in nearby borehole 154 [5664 1776].
A small faulted inlier of the bed occurs [168 573] just south of the Street Hill Fault. Borehole 143 proved 21.2m of Lower Oxford Clay with a very shelly, bituminous layer at 4.2m probaly representing the Comptoni Bed.
In the south-east, the Acutistriatum Band outcrop is indicated by debris of pale grey, brown weathering, silty limestone with common *Bositra buchii* [598 158] and nodule debris located beneath alluvium [5930 1541]. Nearby, it was proved near the top of borehole 105 where it produces a prominent low gamma ray signature. The bed has also been proved in borehole 40 [5804 1592], described as "nodules of dark grey calcareous mudstone with veins of calcite" at 4.50m depth in an incomplete sequence of 20m of Lower Oxford Clay.

The highest beds of the Lower Oxford Clay crop out in the core of the Wendlebury Syncline, between Merton and Wendlebury, in the core of a syncline between Fencott and Murcott and in the extreme south-east. The uppermost beds are probably exposed in trial pits 98 [5993 1934] and 99 [5990 1527] where pale grey mudstone (Middle Oxford Clay) rest on brown, bituminous mudstone at depths of 2.7m and 2.9m respectively.

3.3.1.2.2. Middle Oxford Clay Member

The Middle Oxford Clay is a pale to medium grey, smooth to silty mudstone, with scattered fossils. It weathers to a soft, pale grey, ochreous stained clay. Thin silty limestones are present particularly in the upper part. At many levels, the bivalve *Bositra buchii* is abundant. Other fossils include the oyster *Gryphaea*, small pyritised kosmoceratid ammonites, the serpulid *Genicularia vertebralis* in the lowest beds and pyritic trails. The member is distinct from the darker, bituminous Lower Oxford Clay. The junction is transitional and in boreholes, is taken at the top of the first bituminous bed. In the field, because of the deep weathered profile and the frequent veneer of superficial deposits, the positon of the boundary is arbitrary. The pyritised ammonites are destroyed by weathering down to about 3m.
About 6m of the member crop out in the south-east corner, the total thickness being about 22m on the adjacent area to the east (Ambrose, 1988). The lowermost beds were exposed in trial pits 98 and 99 (see above).

4. STRUCTURE

The area is dominated by one major structure, the Charlton

Anticline, trending NE-SW across the district. Formerly known as the Islip Anticline or Axis, it was renamed by Arkell (1944) because it did not pass through Islip. Faulting and minor folding is associated with the anticline. The main structural features (Fig. 2.) are superimposed on a regional dip of 1 to 2 degrees to the south-east.

4.1. Folding

The princpal fold is the Charlton Anticline which forms a series of elongate periclinal domes trending NE-SW across the district. The anticline is confined by a small horst within which the fold axis is displaced slightly by wrench faulting (see below). Around Charlton, the fold axis is roughly coincident with the Street Hill Fault. In the extreme south-west, the fold is asymmetrical, the eastern limb dipping at about 5 degrees and the western limb at about 2 degrees. Around Merton, it is mostly symmetrical with both limbs dipping at about 1 degree, but locally it is asymmetrical e.g. SSW of the village between two faults where the dip on the south-east limb steepens to 4 degrees. East of the village, the south-eastern limb of the fold appears to steepen to a similar amount along the outcrop of the Kellaways Clay and Sand. It may however mark the continuation of the Street Hill Fault along the clay - sand boundary. Minor folding is associated with the Charlton Anticline north-east [590 183-6] of Merton. The Wendlebury Syncline, complementary to the Charlton Anticline lies about 1km to the north-west and apparently diverges to a NNE-SSW trend. The structure east of Wendlebury is not certain but Graven Hill may lie on a shallow anticline parallel to the Charlton Anticline, as does Arncott Hill [61 17] (Ambrose, 1988). Minor folding occurs in the fault block immediately south of the Murcott Fault. It has been deduced from proven thicknesses of Lower Oxford Clay in a number of boreholes.

4.2. Faulting

There are two main sets of faults and most are associated with the Charlton Anticline. The principal faults are the Merton and Street Hill Faults which define a NE-SW trending horst bounding the anticline. The faults are not continuous at the surface but are probably developed at depth. In the south-west, the Merton Fault has a throw of 7-8m while north-east from Merton, the fault becomes more complex and there are no marker beds detectable in the Lower Oxford Clay with which to determine the displacement. The Street Hill Fault has a throw of over 10m for most of its outcrop, e.g. in Charlton where Lower Oxford Clay is downthrown against Forest Marble. Just north-east of Street Hill, borehole 54 [5743 1697] sited about 10m from the fault, proved Cornbrash at 12.3m with the same formation at outcrop on the upthrow side of the fault. In this area, several boreholes have been drilled and they indicate an apparently localised zone of faulting immediately adjacent to the Street Hill Fault. In the south-west,

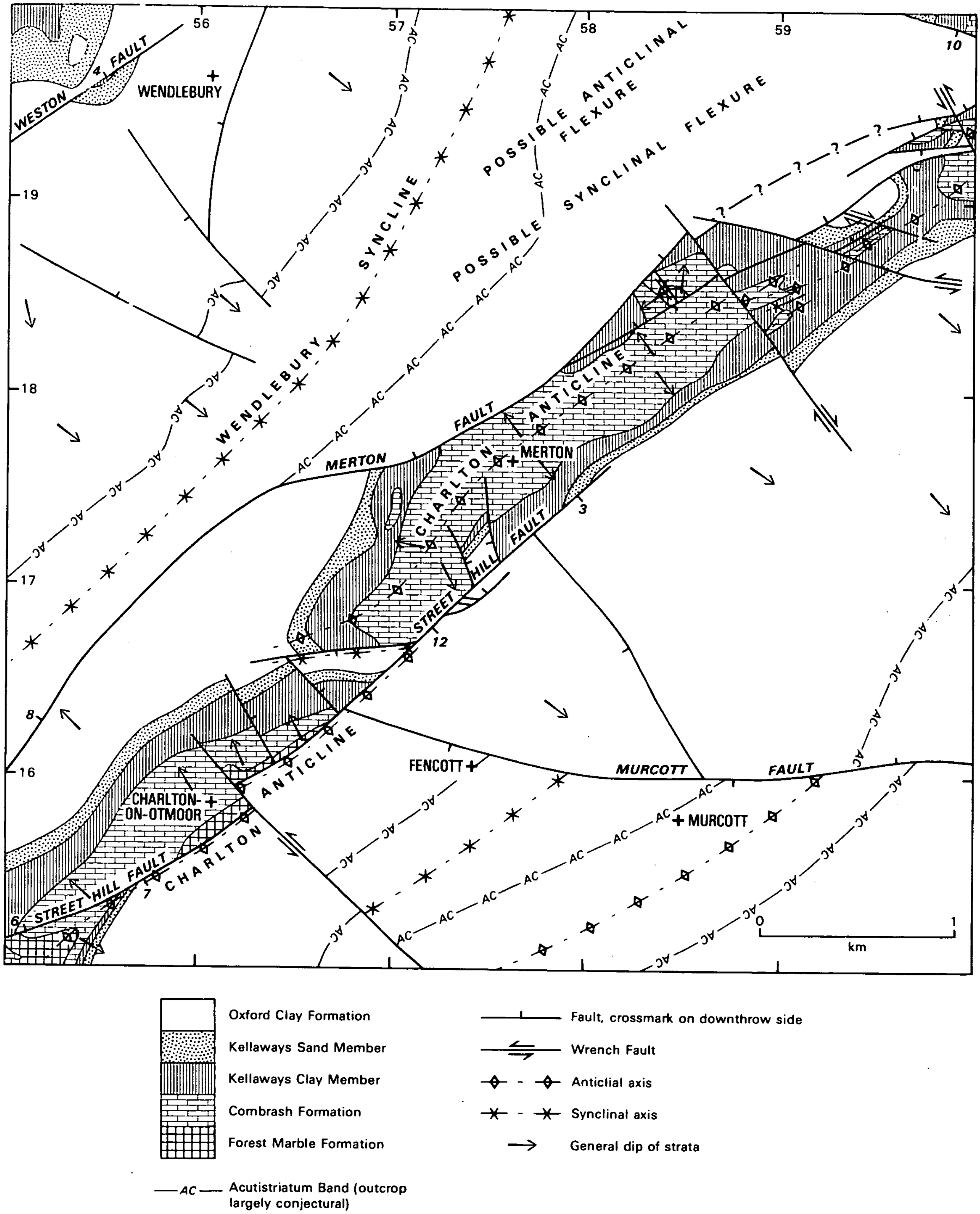

Fig. 2 The principle structural features of sheet SP51NE

the fault displacment is reversed indicating that further movement occurred after formation of the Charlton Anticline.
A second set of faults trends mostly NW-SE, perpedicular to the Charlton Anticline. Many have small lateral displacements with both dextral and sinistral movements represented. Factors indicating wrench faulting are the displacement of the fold axis where the fold is symmetrical, the change in the sense of throw along the faults and the presence of minor folding within the fault blocks e.g. north-east [589184] of Merton. Both the Merton and Street Hill Faults are displaced by these wrench faults, suggesting that the lateral movement was the last episode in the formation of the Charlton Anticline. Arkell (1944) noted the possibility of wrench faulting along the anticline, citing the displacement of the fault (Street Hill Fault) at Charlton as evidence.
The Murcott Fault trends approximately east-west having only small throws of up to 5m. The change in sense of throw eastwards and the presence of folding confined to the fault block immediately to the south indicate lateral displacement along the fault.
Four small faults occur in the Wendlebury area. They have been located using borehole/trial pit evidence and the stratigraphical position of the nodule beds. One, the Weston Fault, has a similar trend to the Charlton Anticline and has been traced for at least 3km in the adjacent area to the west (Wyatt and Ambrose, 1988).

5. EM 31 CONDUCTIVITY SURVEY

Because of the widespread river deposits in the area which mask the solid geology and the difficulty experienced in penetrating the basal gravel layer with the Dutch Auger, an EM 31 conductivity meter was used to locate sub-drift boundaries. The flanks of the Charlton Anticline and the intervening troughs between the periclinal domes are covered by up to 2m of alluvium. The concealed stratigraphy of interbedded layers of contrasting conductivity, namely the Cornbrash and Kellaways Sand with a low conductivity and the Kellaways Clay and Lower Oxford Clay with a high conductivity, provides an ideal situation for tracing sub-alluvial boundaries.
Readings were taken at 5 or 10 yard intervals along most traverses, but equally good results were obtained by leaving the machine on continually and noting sudden changes in conductivity. The latter method had the advantage of being much quicker. The conductivity values recorded are as follows:

Cornbrash
25 - 30 millimho's per metre (mmhos/m) on the outcrop
Up to 40 mmhos/m beneath alluvium

Kellaways Clay
70 - 98 mmhos/m on test run
62 - 98 mmhos/m beneath alluvium

Kellaways Sand
56 - 69 mmhos/m on test run
62 - 78 mmhos/m beneath alluvium

Lower Oxford Clay
70 - 86 mmhos/m on test run
70 - 120 mmhos/m beneath alluvium and on the outcrop

The wide varition in readings can be attributable to the following :

(i) Variations in the thickness of the alluvial clay
(ii) Variations in the thickness of the basal gravel of the alluvium and its water content
(iii) Variations in the thickness of the Kellaways Sand and Clay
(iv) The influence of other layers on the conductivity readings. The instrument measures the average conductivity down to a depth of about 5m.

Despite the variations, boundaries could be identified with confidence by the relative and often sharp changes in conductivity between the beds.

6. DRIFT GEOLOGY

The mapped drift comprises river deposits of the River Ray basin (Terrace Deposits and Alluvium). In addition, thin, unmapped drift covers much of the low lying ground and in places extends on to the lower slopes of hills, notably Graven Hill in the north-west. The main channel of the Ray flows to the south of the Charlton Anticline. A tributary and former main channel to the north of the anticline is termed the Northern Ray.

6.1. River Terrace Deposits

There is a suite of terraces mostly associated with the Northern Ray. The deposits have been mapped at two levels (First and Third Terraces); a remnant of Second Terrace is not shown on the map.

6.1.1. Third Terrace

This terrace crops out in the north-west of the district where two patches [554 199, 550 194-7] have been mapped, identified by sandy soil with a few pebbles. The base of the terrace is at 68-69m AOD and the surface 1-2m higher, some 7-8m above the main tract of alluvium. Trial pit 32 [5534 1986] on one of the outcrops proved 1.4m of orange-brown, clayey limestone gravel overlying Kellaways Sand.
An extensive Third Terrace remnant occurs between Wendlebury Church [558 196] and Wormough Coppice [554 182]. The surface falls southwards from 69m to 66m AOD. The soil is mostly clay but contains pockets of gravel or sand preserved as a result of

cryoturbation. A number of trial pits excavated in the area demonstrate the variation in thickness of the deposit. One, no. 176 [5529 1916] showed a gravel-filled "channel" about 1m wide and 2.3m deep with near-vertical sides. The dimensions of the structure are more suggestive of a frost wedge rather than channeling and/or cryoturbation. Other pits showed up to 1.7m of gravel commonly with an uneven base while a few went straight into Lower Oxford Clay. The gravel is yellow to orange-brown with mainly Cornbrash fragments.

6.1.2. Second Terrace

The remanie Second Terrace occurs north-west [55 16] of Charlton-on-Otmoor on a planar surface about 3m above the alluvium. The soil is variably clayey, sandy or gravelly. A drainage ditch on the west side of the railway [5021 1696 - 5041 1723] showed irregular pockets of gravel up to 0.5m thick on pale grey clay. The pebbles are mostly of local Jurassic Limestones - Cornbrash and Great Oolite, together with septarian nodule, belemnite and *Gryphaea* fragments from the Lower Oxford Clay plus a few flints and quartzites.

6.1.3. First Terrace

The First Terrace crops out in three main areas: on the western margin of the River Ray and along a tributary at Wendlebury; on the northern fringe of Otmoor at Murcott; within the Northern Ray channel between Wendlebury and Merton. The terrace mostly forms very low mounds rarely more than 1m above the alluvium but in places is only distinguishable from the alluvium by the soil as there is no feature between the two. The First Terrace continues beneath the alluvium (see section 6.1.4.). The deposits within the Northern Ray Alluvium show a southward fining. In the north [57 19], the terrace is composed of at least 1.5m of fine gravel (c.1cm diameter) which locally becomes very sandy upwards. The pebbles are mostly of Cornbrash limestone together with other Jurassic limestones (Forest Marble, White Limestone, septarian nodules), ironstone, belemnite and *Gryphaea* fragments, plus a few flints and quartzites. Southwards, the deposit passes to pebbly sand and sand, then silty sand, silt and silty clay with a few pebbles, at Merton. Trial pit 64 [5692 1744] showed 0.8m of brown and orange sandy, pebbly clay on brown clayey, pebbly sand overlying Kellaways Clay at 1.8m.

The remaining deposits are mostly pebbly sands which are variably silty and clayey. A ditch [5872 1551] at Murcott showed the following:

	m
Orange-brown clayey sand	c.1.0
Orange-brown sand, pebbly base	1.6
on Grey clay (Lower Oxford Clay)	

6.2. Alluvium

Extensive alluvial deposits of the River Ray and its tributaries cover the area. The width of the alluvium compared to the present day streams shows that many are misfit streams, most notably parts of the northern Ray stream which flows between Wendlebury and Merton. The broad valleys of the Ray and the northern Ray converge on a narrow gap between Fencott and Charlton before opening out into the broad expanse of Otmoor.
The extent of the mapped alluvium shows several abandoned water courses. A former course of the Ray runs between Fencott and Murcott while the northern Ray probably flowed along the north-west side of Charlton. The latter has several abandoned courses between Wendlebury and Merton. Much of the area is prone to flooding and both the abandoned and present day channels are areas of active though sporadic sedimentation.
The alluvium gives a distinctive clay soil, usually medium to dark grey or brown in colour, with a cuboidal fracture when dry,. The fresh deposit consists of grey to brown, ochreous mottled, silty clay with local sand lenses and a few pebbles. It invariably becomes more sandy and pebbly with depth and gravel commonly occurs at the base. Organic-rich clays and peats are found in places. The basal sands and gravels are a continuation of the First Terrace beneath the alluvium. Locally, more complex sequences occur, e.g. in trial pit 74 [5605 1825]:

	m
Grey-brown sandy clay	0.90
Grey and orange clayey sand	1.25
Grey and orange gravel	1.55
Brown clayey sand	1.75
Brown and grey gravel	1.90
Dark grey silty clay	2.25
Pale brown gravel	2.50
on Lower Oxford Clay	seen to 4.50

The alluvium is generally 1-2m thick. The maximum proved thickness is 2.6m in trial pit 42 [5795 1616]. There are numerous sections of the alluvial deposits in the main stream channels and in the many drainage ditches. Several boreholes and trial pits have also proved sequences through the alluvium.

The basal gravel is particularly well developed on the Northern Ray valley being a continuation of the extensive spreads of First Terrace. The gravels are composed predominately of Cornbrash fragments together with other Jurassic limestones (Forest Marble, White Limestone, septarian nodules), ironstones and fossil fragments (belemnites and *Gryphaea*), plus few flints and quartzites. The alluvial clay in this area is usually 0.5-1.0m thick but in places the gravel comes to the surface e.g. at the southern end of the tributary flowing through Wendlebury. At one point [5618 1869] 1.7m of poorly sorted, unstratified gravel is exposed. Nearby to the south-east, immediately adjacent to the railway, three ponds mark the sites of former shallow gravel workings. Gravel dredged from the bottom of the northern River

Ray and some drainage ditches is spread along their banks in places. The basal gravel continues south-westwards on the northern side of Charlton but it is poorly developed on Otmoor (see below) and in the main Ray valley. In both, the basal deposit is commonly a sand or pebbly sand which may be clayey. The inference from the above evidence is that the bulk of the gravel-laden water, entered the area via the Northern River Ray with most of the gravel originating from the nearby Cornbrash outcrop to the north of the district. The erosive power of the main Ray was much less, indicated by the presence of gentle topographical features up to 1m high, formed by nodule beds in the Lower Oxford Clay with alluvium draping over the feature, e.g. between Merton and Astley Bridge Farm [591 180]. In the same area, a ditch shows the alluvium thinning over the outcrop of a nodule bed [5938 1791] although no surface feature is formed. Despite forming only 5-10% of the bed (Hudson, 1978) the nodules formed a feature sufficiently resistant to the Ray flood waters. They also indicate recent flood levels with water at least 1m deep.

6.2.1. Otmoor

The poorly drained area known as Otmoor extends onto the southern part of the area between Charlton and Murcott. It is drained by the River Ray and floods frequently. Aerial photographs show a dense network of dendritic channels on the moor, some being marked by shallow depressions which are more prone to flooding. The area has been the subject of speculation both in terms of the contained deposits and origin. Local myths and legends talk of peat bogs and "bottomless pits" and both Arkell (1947) and Beckinsale (1954) perpetuated these myths with no firm evidence to support their statements. Arkell (1947) described the lowland as old alluvial deposits with peat and humus, suggesting it originated from ponding of the Ray at Islip and Oddington. Earlier, Phillips (1871) suggested it was the site of an old lake preferring the view that it was not a permanent feature but subject to "innumerable inundations" which spread sediment over the area. Marker and Cooper (1960) undertook an extensive soil analysis of Otmoor and concluded that it was not an alluvial basin but a normal clay lowland in the Oxford Clay. The findings of the present survey here and to the south (Horton, in press) show that Otmoor is an alluvial basin with between 1 and 2m of alluvium throughout.

A typical profile through the alluvium is an upper layer of dark grey to black humic or peaty clay up to 0.5m thick, overlying pale grey, commonly ochreous mottled, silty clay. In the north-east of the moor, between Fencott and Murcott, the clays are more sandy. Sporadic pebbles occur and sand or gravel is locally present at the base. No differences in the lithological sequences beneath the lower lying channels and the adjacent slightly raised ground were detected although the latter are noticably better drained. No thick peat deposits have been found which is in agreement with Marker and Cooper (1960).

A number of trial pits and boreholes sited just west of Murcott have proved complete sequences through the Otmoor alluvium, the thicknesses ranging from 0.9m in pit 33 [5832 1511] to 1.8m in pit 34 [5825 1533] and possibly 2.1m in pit 36 [5816 1565]. All show traces of flint and limestone pebbles, commonly at the base, and sand seams or pockets are present in pits 35 [5823 1541], 36 and borehole 38 [5810 1591]. Selected sequences proved by augering are:

	m
[5622 1515]	
Blue-grey clay	0.5
Pale grey and ochreous cay	0.6
Pale grey and ochreous silt, becoming clayey below 1.0; a few pebbles	1.5+
[5648 1536]	
Dark grey to black humic clay	0.5
Pale grey and ochreous silty clay	1.3
on pale grey clay	
[5692 1519]	
Grey and ochreous silty clay	1.1
Layer of shell fragments	
Ochreous and grey silt becoming sandy	1.4+
[5748 1580]	
Grey and ochreous sandy clay	1.0
Grey and ochreous bedded sand with clayey seams; a few small pebbles	1.5+
[5774 1539]	
Brown peaty clay	0.3
Dark grey clay	0.5
Pale grey sandy clay with a few pebbles	1.3
on pale grey clay	
[5816 1565]	
Pale grey and ochreous clay becoming sandy	1.0
Sand	1.2
on pale grey clay	

6.3. Unmapped Drift

Much of the Lower Oxford Clay is covered by a veneer of drift which has not been mapped. Most of this drift is contiguous with the alluvium, spreading over the flatter areas of ground (older alluvium) or extending onto the lower slopes of hills (head). Remanie terrace gravels also cap some low hills. These are described above in sections 6.1.1. and 6.1.2.

Older Alluvium:

These deposits are most common on the low-lying ground in the south-east of the area. They are lithologically similar to the alluvium, consisting of grey and orange-brown, silty to sandy clay with scattered pebbles. Locally, sand/gravel seams or lenses occur at the base e.g. in trial pit 120 [5888 1616]. The thickness is mostly less than 1m but 1.8m were recorded in trial pits 112 [5909 1612] and 120.

Head:

On the lower slopes of Graven Hill [58-9 19], thin drift extends beyond the natural break of slope marking the edge of the alluvial flat. The deposit is apparently continuous with the alluvium and consists of grey and ochreous sandy clay with a gravelly base composed mostly of worn *Gryphaea* fragments. At one point [5837 1984] the deposit is 0.6m thick and about 4m higher than the alluvium.

Both deposits are assumed to be of periglacial origin. The sand or gravel at the base is interpreted as a lag deposit representing the initial flooding of the low ground. The constuent pebbles are of local origin namely *Gryphaea* from the Oxford Clay, Cornbrash and other Great Oolite limestones, plus flints and quartzites from glacial drift cropping out a few kilometres north-east of the area. The lowermost head clays are probably represent an interdigitation of waterlain and solifluction deposits. water levels were much higher in periglacial times with most of the Oxford Clay outcrop under water.

7. ECONOMIC GEOLOGY

There are now no working quarries in the area but several once existed. Many of the surface deposits have economic potential for the future.

7.1. Limestone

Both the Cornbrash and Forest Marble were extensively worked in the past at Charlton and Merton. The products of individual quarries are not detailed in the geological literature but the most likely use was road metal. Other uses may have included building stone or lime. A more recent use for limestone is the cement industry. A large cement works north-east of the district at Kirtlington uses Cornbrash, Forest Marble and White Limestone.

7.2. Brick Clay

The Lower Oxford Clay provides one of the best counry-wide resources for brick making on account of its relatively high organic content. Its use in the brick industry is described by Callomon (1968). The Lower Oxford Clay has not been worked in this area but Forest Marble clays have been used for brick making nearby at Blackthorn (Woodward, 1894).

7.3. Sand and Gravel

Gravel was formerly worked in three pits south [56 18] of Wendlebury. Substantial spreads of gravel occur in this area but all are thin (c.2m) and are composed predominantly of limestone.

8. HYDROGEOLOGY

The water supply of Oxfordshire was described by Tiddeman (1910). At that time, all the villages were supplied by shallow wells. Charlton and Merton obtained plentiful supplies from the Great Oolite limestones. A recent borehole, no. 152, at the latter village produced slight artesian conditions on penetrating the Great Oolite to a depth of 34m. Fencott and Murcott are both on the Lower Oxford Clay; the former was not well supplied with water while the latter had a plentiful supply. The trial pits excavated for the M40 site investigation confirmed the presence of water issuing from the Lower Oxford Clay at shallow depth around Murcott. One in particular, no. 101 [5967 1573] had a very strong seepage. The Oxford Clay here was very shelly and evidence from nearby borehole 105 suggests it may have issued from the Comptoni Bed. This and other shell beds in the Lower Oxford Clay are likely to form permiable horizons within a largely impermiable clay sequence. Other aquifers of low potential are the Kellaways Sand and the gravels beneath alluvium.

9. ENGINEERING HAZARDS

A potential engineering hazard was revealed during the M40 site investigation, namely the presence of numerous small slip surfaces in the alluvial clay and the uppermost part of the weathered zone of the Lower Oxford Clay. The slip surfaces caused one face of pit 111 [5925 1593] to collapse although others remained stable.

There is very little made ground in the area. One small area was mapped [597 191] beside a man-made pond and is probably material excavated from the pond. Many of the abandoned limestone pits around Charlton and Merton will contain fill.

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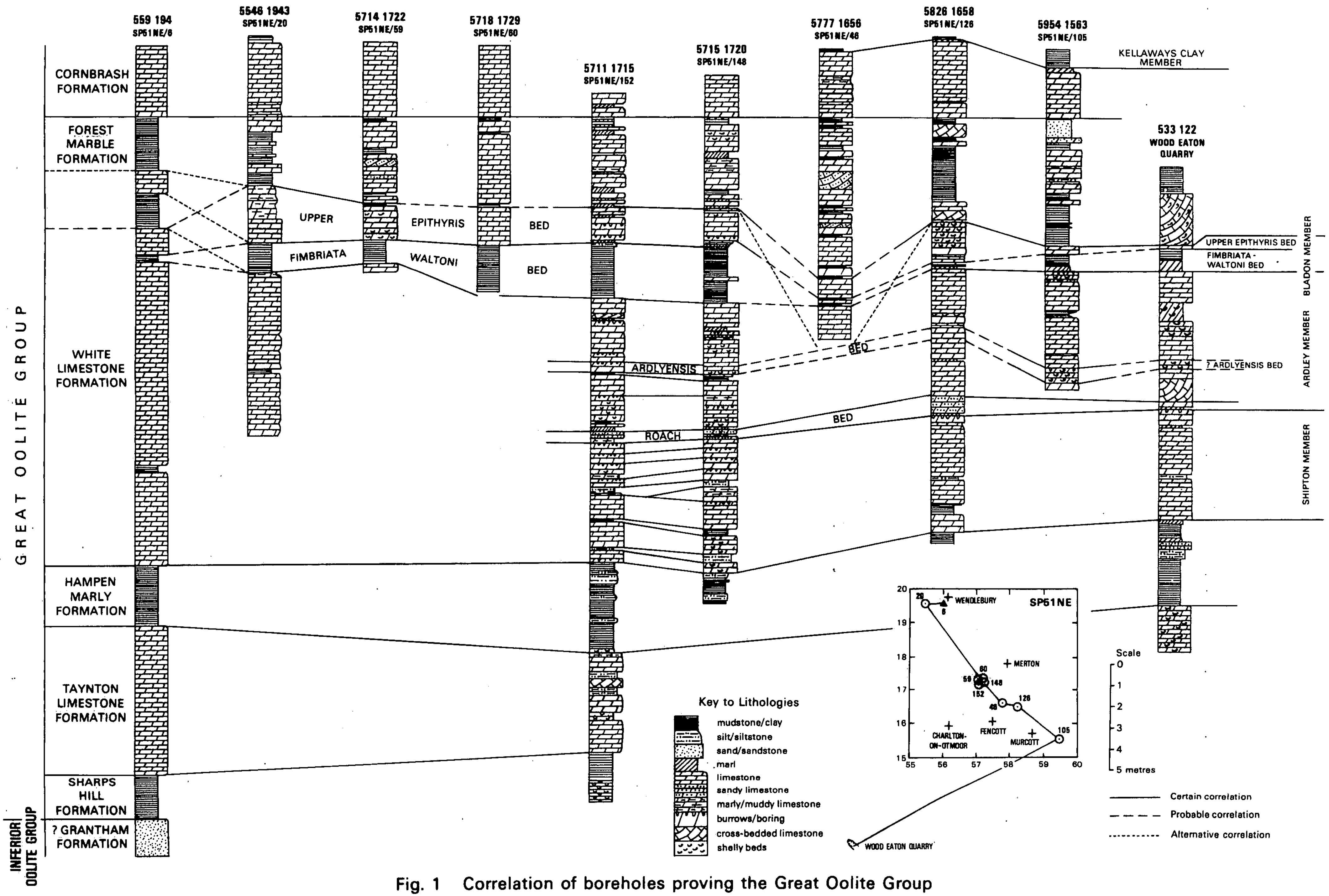

Fig. 1 Correlation of boreholes proving the Great Oolite Group

Martyn

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