BRITISH GEOLOGICAL SURVEY

TECHNICAL REPORT WA/88/22

Onshore Geology Series

TECHNICAL REPORT WA/88/22

Geological notes and local details for 1:10000 Sheet SP61NW: ARNCOTT

Part of 1:50,000 Sheets 219 (Buckingham) and 237 (Thame)

K. AMBROSE

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1. INTRODUCTION

This report covers 1:10000 sheet SP 61 NW (Arncott) 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 was surveyed at the 1:10560 scale (Buckinghamshire County Sheet 26 SE) by G.W. Lamplugh, T.I. Pocock and H.B. Woodward in 1904-5 as part of the Oxford Special Sheet. The geology is described by Pocock (1908) and Pringle (1926).

The 1:10000 survey was by K. Ambrose in 1986 under the direction of R.G. Thurrell, Regional Geologist. Fossils were identified by Dr B.M. Cox and Dr H.C. Ivimey-Cook. The project was jointly funded by BGS and the Thames Water Authority.

The area lies within the counties of Oxfordshire and Buckinghamshire, north-east of Oxford and south-south-east of Bicester. It is entirely rural but includes the Bicester Central Ordnance Depot of the armed forces at the village of Arncott. Ambrosden and Arncott form the principle settlements together with Blackthorn and Piddington. Topographically the area is dominated by Muswell Hill in the south-east and Arncott Hill in the centre of the district. Both rise above the broad Oxford Clay vale which lies at 60-65m AOD. The two hills attain heights of 197m and 108m AOD respectively.

The oldest rocks crop out in the north-west where the topmost Great Oolite limestones form the core of the Charlton Anticline. Arncott Hill is formed entirely of Oxford Clay. Successively higher beds crop out south-eastwards on to Muswell Hill, dominated by Upper Jurassic mudstones. The Arngrove Spiculite forms a local escarpment in the south of the area and Muswell Hill is capped by limestones and sandstones of the Portland, Purbeck and Whitchuch Sand Formations. The beds here are extensively cambered and landslipped.

Parallel reports covering adjacent 1:10000 sheets are:

SP 51 NE (Charlton-on-Otmoor)(Ambrose, 1988)
SP 61 NE (Ludgershall)(Sumbler, 1988a)
SP 61 SW (Oakley)(Horton, in press)

2. GEOLOGICAL SEQUENCE

DRIFT	
Quaternary	Alluvium
	Head
SOLID	
Upper Jurassic	Whitchurch Sand Formation
	Purbeck Formation
	Portland Formation
	Portland Stone Member
	Portland Sand Member
	Ancholme Clay Group
	Kimmeridge Clay Formation
	Ampthill Clay Formation
	Cumnor Formation
	Oakley Member
	Arngrove Spiculite Member
	West Walton Formation
	Oxford Clay Formation
	Upper Oxford Clay Member
Middle Jurassic	Middle Oxford Clay Member
	Lamberti Limestone Bed
	Lower Oxford Clay Member
	Kellaways Formation
	Kellaways Sand Member
	Kellaways Clay Member
	Great Oolite Group
	Cornbrash Formation
	Forest Marble Formation
	(White Limestone Formation
Proved only in	(Hampen Marly Formation
Upper Arncott Borehole	(Great Oolite Group undivided
	(including Upper Estuarine "Series"

3. SOLID GEOLOGY

3.1. CONCEALED STRATA

Palaeozoic rocks have been proved at shallow depths in a number of boreholes encircling the district. The Bicester No. 1 Borehole [SP 5878 2081], sited just north-west of the district, proved Upper Devonian sandstones, siltstones and mudstones from 168.55m depth resting on Silurian (Upper Llandovery) sandstones and mudstones at 341.07m. These in turn overlie a suite of lavas and tuffs of unknown age, proved from 385.57 to 513.89m. The Devonian strata continue westwards and were proved in the Noke Borehole [SP 5386 1258] (Falcon and Kent, 1960) from 116.8m to 247.8m. West and north-west of Noke, a Carboniferous basin overlies the Devonian rocks, 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 [6903 2457](Davies and Pringle, 1913) and at Twyford (nos. 1-4) [6803 2568, 6760 2650, 6859 2659, 6697 2561], Marsh Gibbon [6481 2374] and Westcott [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, 1988b) 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. Details of the succeeding Inferior and Great Oolite Groups are poorly known; the boreholes generally have poor descriptive logs and were not cored. The sequence at Westcott is given in some detail by Sumbler (1988b) and that at Noke is further summarised by Wyatt and Ambrose (1988).

3.2. MIDDLE JURASSIC

3.2.1. Great Oolite Group

The Upper Arncott Borehole (SP 61 NW/1)[6137 1723] (Tiddeman, 1910) proved a complete sequence through the Great Oolite Group. The descriptive log is very poor, consisting only of the terms "clay", "rock" and "sand". A comparison with boreholes in adjacent areas has enabled the Hampen Marly and higher fomations to be separated. The lowest 20m down to a depth of 89.2m cannot be subdivided but includes the Upper Estuarine "Series" and possibly the Grantham Formation (Lower Estuarine "Series").

3.2.1.1. Hampen Marly Formation

In the Upper Arncott Borehole, the Hampen Marly Formation is 4m thick, proved at a depth of 69.2m. Thicknesses from the outcrop in Oxfordshire (Arkell, 1947) and neighbouring boreholes (summarised in Ambrose, 1988) vary from 2.6-9.1m. The borehole log records only "clay" and "rock", but evidence from the area to the west (Ambrose, 1988) shows the formation to consist mainly of grey, green and olive silty mudstones and calcareous siltstones with common lignite and rootlets.

3.2.1.2. White Limestone Formation

The White Limestone is 11.4m thick in the Upper Arncott Borehole where it is only described as "rock" and "clay". In the area immediately to the west, boreholes prove the formation to vary between 13.6 and 16.4m in thickness (Ambrose, 1988). Here it consists mainly of white or cream, bioturbated, micritic limestones with varying proportions of pellets, ooliths, shells and shell debris. Recrystallised hard grounds are present at intervals. Subordinate clays and marls occur throughout.

3.2.1.3. Forest Marble Formation

The Forest Marble crops out in the north-west at Ambrosden where the Charlton Anticline brings the highest formations of the Great Oolite Group to the surface. The outcrop consists of five small, fault-bounded inliers all showing mainly greenish grey clay with race (small calcareous concretions). Some shell-detrital, oolitic limestone debris was also seen. A disused quarry [6035 1991] exposes the following:

	m
CORNBRASH FORMATION	
LIMESTONE, buff to grey, micritic, shell detrital, a few shells. rusty-brown weathered surface. Abrupt, undulating base with horizontal burrows	1.0
FOREST MARBLE FORMATION	
CLAY, grey with some iron staining, smooth race common; bedding visible in basal 0.1m with abundant ooliths and pellets	0.25-0.30
OOLITE, buff to grey with iron staining, micritic matrix, shell fragments, crudely bedded; abrupt channelled base	0.05-0.15
MICRITE, pale creamy buff to greenish grey, oolitic, shells and shell debris; more	

oolitic in top 0.05m;soft in basal 0.08m.
Modiolus? 0.23-0.25
CLAY, blue-grey, smooth, soft, wood fragments 0.1

The micrite is more typical of the White Limestone Formation, but similar lithologies appear within the Forest Marble Formation north-east of Oxford (Sumbler, 1984, Fig. 2). Neighbouring boreholes and former exposures all show the Forest Marble to be at least 3m thick. The Arncott Hill Borehole proved 4m of Forest Marble to 53.8m while a little to the north of the district a railway cutting (Barrow, 1908) and former brickyard (Green, 1864, Woodward, 1894) at Blackthorn Hill exposed between 3.6 and 4.3m of the formation. Barrow gave a total thickness of 6.3m but this probably includes the Upper Epithyris Bed and the Fimbriata-Waltoni Bed which are now included in the White Limestone. To the west, boreholes show between 3.05 and 5.62m of Forest Marble (Ambrose, 1988). The micrite in the above section occurs only 0.35-0.40m below the base of the Cornbrash and is therefore included within the Forest Marble.

3.2.1.4. Cornbrash Formation

The Cornbrash crops out at Ambrosden in the core of the Charlton Anticline. It consists of a blue-grey, shell detrital, micritic, bioturbated limestone. Clay partings and mud-filled burrows are common while ooliths are rare to absent. Sparry limestones occur locally. The weathered rock is characteristically rusty brown in colour and rubbly. The only known thickness is 2.3m in the Upper Arncott Borehole. In the adjacent area to the west, the Cornbrash varies between 2.19 and over 3.76m thick (Ambrose, 1988).
When fully developed, the Cornbrash can be divided into an Upper and Lower unit, the junction coinciding with the Bathonian - Callovian Stage boundary (Middle - Upper Jurassic). Douglas and Arkell (1932) found no trace of the Upper Cornbrash in this area but borehole evidence in this area and immediately to the west (Ambrose, 1988) suggests it may be present locally.
The fauna of the Cornbrash is varied, being dominated by bivalves and brachiopods. Ammonites, echinoids, nautiloids, ostracods and saurian remains have also been found but are generally rare.

The outcrop at Ambrosden is cut by a number of small faults. The fields surrounding the village show evidence of former workings although no sections are recorded in the literature. One disused pit [6035 1991] exposes the lowermost c.1m of the formation and the details are given above in section 3.2.4. Two boreholes have proved the Cornbrash, nos. SP61NW/1 (Upper Arncott Borehole) and 9 [6011 1500]. In the former, 2.3m of "rock" at 49.8m are assigned to the Cornbrash, while the latter proved the uppermost 0.76m of the formation. Here, it consists of a hard, medium to dark blue-grey limestone, with abundant fine shell detritus and larger fragments. The rock is silty down to 39.95m and cross-bedded to 40.00m. Below 39.80m it is recrystallised but contains patches of pale grey, silty micrite. The top is transitional to the overlying Kellaways Clay Member suggesting Upper Cornbrash, although no diagnostic fauna was found. Fossils collected include gastropods, ostracods (abundant to 39.68m) and *Trigonia*.

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 in the Hull - Brigg area (Gaunt and others, in press) where difficulty was encountered in separating the clay formations in the field.

3.3.1.1. Kellaways Formation

Both the Kellaways Clay and Sand Members are present. The outcrop is restricted to the Ambrosden area, mainly on the south-east flank of the Charlton Anticline. The thickness is about 6m, 5.5m being proved in borehole SP61NW/9 [6011 1500] and mostly between 5 and 6m in the adjacent area to the west (Ambrose, 1988).

3.3.1.1.1. Kellaways Clay Member

The Kellaways Clay consists of about 3m of 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. The sparse fauna is dominated by bivalves together a few ammonites and gastropods.

Most of the outcrop is obscured by alluvium but grey clay can be augered or is visible in the bottom of drainage ditches. There are two small outcrops [600 193, 600 195] west of Ambrosden. The former is roughly coincident with the fold axis of the Charlton Anticline while the latter is on the north-west limb. Most of the outcrop in this area has been faulted out.
In the south-west, borehole 9 proved a complete sequence through the member, here 2.63m thick with the base at a depth of 39.39m. The upper 0.13m contained sand-filled burrows; pyritic patches, trails and pins occur throughout; shell debris is bundant in the lowermost 0.19m.

3.3.1.1.2. Kellaways Sand Member

The Kellaways Sand is a pale grey to greenish grey, fine-grained, poorly cemented, bioturbated, silty sandstone with subordinate thin mudstone beds and partings. It is moderately fossiliferous;

bivalves are most common together with ammonites, belemnites and gastropods. The member is mostly 2 to 3m thick with 2.85m being proved in borehole 9.

The Kellaways Sand forms a narrow outcrop on the south-east limb of the Charlton Anticline at Ambrosden. The fine grey sand is easily recognisable in the auger and visible in some ditches. On the north-west limb of the fold, most of the outcrop is faulted out but two small pockets [6006 1956, 6023 1981] have been preserved, both adjacent to faults.
In borehole 9, the member is mostly siltstone which is muddy in the uppermost part, with common bivalves and spat, a few ammonites, belemnites and gastropods. Wood debris was found at 34.75m. A 0.25m mudstone with much shell debris and common pyritic patches and pins occurs at 35.22m. Silty sandstone with angular quartz, mica and rare feldspar grains, occurs below to an erosive base at 36.75m.

3.3.1.2. Oxford Clay Formation

The Oxford Clay is divided into the Lower, Middle and Upper Oxford Clay Members which are all separately mapped. All have a 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 increase 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 is common in the uppermost 1-2m. The Middle and Upper Oxford Clay have a uniform weathered profile. between about 2-3m depth, they weather to a brownish clay with some relic bedding preserved, and cut by a dense network of grey stained fissures. The Lower Oxford Clay has a more distinctive weathered profile usually with sharp boundaries between layers. A typical profile is:

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

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 and some are blocky. 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 common and 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 of between 1 and 6.1% in the Lower Oxford Clay.

Ambrose (1988) recognised 5 marker beds in the Lower Oxford Clay in the area immediately to the west. Four of these beds have been recognised in this area: the Acutistriatum Band - Comptoni Bed, the Blackthorn, Arncott and Merton Nodule Beds.
The nodule beds ("Main concretions" of Hudson, 1978) consist of grey, hard, splintery argillaceous limestone 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, indicatng 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.
Hudson (1978) noted that nodules commonly develop at or near to shell beds, providing a source of lime to sustain growth.
The highest marker, the Acutistriatum Band - Comptoni Bed, is traceable over much of southern England. The others have been given local names and are probably of limited lateral extent. Callomon (1968) pointed out that the main nodule beds in the brick pits at Calvert, Bletchley, Stewartby and Peterborough, occurred at different stratigraphical levels. Three of the beds occur at zone or subzone boundaries: the Acutistriatum Band, the Blackthorn and Arncott Nodule Beds. The Blackthorn Nodule Bed correlates with Bed 6 at Calvert (Callomon, 1968), and lies at the top of the *Kosmoceras (Zugokosmoceras) obductum* Subzone. The Arncott Nodule Bed is correlated with Calloman'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 uncertainty 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 non-sequences and shell beds at or near to the subzone boundary. The Merton Nodule Bed is correlated with Calloman's Bed 11b at Kidlington and lies within the *medea* Subzone.

The member forms a broad tract of flat country running ENE-WSW across the district between Ambrosden and Arncott. It also outcrops immediately weat of Ambrosden, on the north-west flank of the Charlton Anticline. There are no natural exposures of the Lower Oxford Clay in the area. Because of the deep weathering 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.

The lowermost 3.1m of the member were cored in borehole 9 down to a depth of 33.90m. The junction with the underlying Kellaways Sand appeared transitional and rather imprecise in the core. The basal 0.68m are silty, locally a siltstone, and poorly fossiliferous. The Merton Nodule Bed was proved at 32.22m, 0.21m of fossiliferous, silty limestone, overlying a 0.07m bed of highly fossiliferous, pyritic mudstone. The mudstone overlying the nodule contained fish and crustacean debris. The Merton Nodule Bed was also proved in the Upper Arncott Borehole, a 0.1m bed of "rock" at 38.0m. The bed forms a good topographical feature immediately north-west of Blackthorn and traceable to the Ambrosden - Arncott Road [605 188]. Nodule debris was only found in one locality [6083 1899 - 6091 1885] where it had been dug from a ditch. The bed is about 2-3m above the base of the Lower Oxford Clay.

A nodule bed cropping out in the west [600 187] is the succeeding Arncott Nodule Bed lying 4-5m above the base of the member.

The lowermost strata of the Lower Oxford Clay also crop out on the north-west limb of the Charlton Anticline, immediately west of Ambrosden. The outcrop was covered by a network of freshly dug land drains at the time of the survey, exposing pale grey clay. No nodule debris was seen.

The mudstones overlying the Merton Nodule Bed are mostly covered by alluvium. The Blackthorn Nodule Bed, 14m above the base of the member, forms another prominent topogaphical feature and is traceable across the district. The Ray valley crosses the outcrop, but the bed still produces a slight feature with the alluvium thinning across it. Nodule debris was seen dug from ditches in two localities [618 186, 614 182] on the alluvium. Two complete nodules were found, one dredged from the River Ray [6314 1971] and one from a ditch [6045 1788]. The former yielded *Kosmoceras* fragments including *?K. obductum* (S.S. buckman) and the latter *K.* ?ex gr. *obductum* (S.S. Buckman), *Dentalium* and other bivalve fragments. The bed was also proved in borehole 1, a 0.2m bed of "rock" at 27.6m. In borehole 9, the bed was not proved in the percussion samples but it produced a prominent gamma low.

The Acutistriatum Band - Comptoni Bed occurs about 18m above the base and 9m from the top of the Lower Oxford Clay but nowhere

forms a topographical feature in this area. Most of its outcrop is beneath alluvium and its position is conjectural. One auger hole [6317 1900] proved grey clay with silty limestone fragments beneath alluvium, interpreted as the Acutistriatum Band from its position in the sequence.
The uppermost beds of the member are also mostly beneath alluvium apart from an area north [63-4 18] of Piddington and in the extreme west. The Lower Oxford Clay outcrop broadens considerably in the north-east indicating a decrease in the dip of the beds.

3.3.1.2.2. Middle Oxford Member

The Middle Oxford Clay is 22-23m of pale to medium grey, smooth to silty mudstone, with scattered fossils. It weathers to a soft, pale grey, ochreous stained clay which becomes brownish downwards. Thin silty limestones or calcareous siltstones are present particularly in the upper part. At many levels, the bivalve *Bositra buchii* (Roemer) is abundant and its presence can be used to distinguish the member from the overlying Upper Oxford Clay. Other fossils include the oyster *Gryphaea*, small Kosmoceratid ammonites which are usually pyritised, the serpulid *Genicularia vertebralis* in the lowest beds and pyritic trails. The pyritised ammonites are destroyed by weathering down to about 3m. 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 weathering and the frequent veneer of superficial deposits, the positon of the boundary is rather arbitrary. The Lamberti Limestone marks the top of the member.

The Middle Oxford Clay forms a broad tract of country encircling Muswell Hill and the Pans Hill escarpment. A number of gentle, discontinuous topographical features have been produced by silty limestones/calcareous siltstones and shell beds containing the oyster *Gryphaea*. The latter are common on the dip slopes in arable fields while the calcareous beds tend to disintegrate through weathering.
In Upper Arncott, a temporary exposure [6123 1723] on a topographical feature showed 1.5m of interbedded brown, fissile mudstone and silt with grey staining along fissures and bedding planes. On the same feature, calcareous siltstone fragments were augered [6129 1736]. This is one of a series of features in the same area, all occurring in the lower part of the member. An exposure [6166 1625] in the C.O.D. depot shows about 2m of grey, silty mudstone becoming very silty towards the base with fragments of silty limestone. *Bositra buchii,* belemnites and *Gryphaea* were found. These beds occur at about the middle of the member.
The upper c.10m of the Middle Oxford Clay is more silty and contains several beds of silty limestone. Cored sequences and gamma ray logs from boreholes to the south of the district (Horton, in press) show at least three persistent limestones. The features mapped in this part of the sequence can be broadly

correlated with these three horizons. The lowest forms a pronounced feature running from north-east of Red House Farm [614 159] to Lower Panshill Farm [601 151]. The feature splits into two, both dying out at the latter locality. Oyster shells are common on the dip slope and at one locality [604 153] included *?Gryphaea lituola* Lamarck. Nearby [6104 1561], a few fragments of silty limestone were found. The same bed forms an extensive dip slope on the south-east side of Arncott Hill with off-white, unfossiliferous silty limestone debris exposed in a ditch [6140 1633] and *Gryphaea* found in several places. The bed forms a feature locally around the hill e.g. in the north-east. It can also be traced for a short distance east of Arncott Hill [625 172 - 628 173], and is the lower of two limestones mapped to the east of Piddington.
Higher limestones were mapped west [61 15] of Pans Hill, north [625 168] of Clue Hills Farm and east of Piddington. In the former location, a 0.3m bed of pale grey clay with abundant oysters including *G. lituola* and *?G. dilatata* J. Sowerby crops out [6160 1536]. Another shell bed at a slightly higher level forms a small bench in a stream [6200 1569]. Silty limestone fragments were noted in several places but not always associated with topographical features. On the western side of Arncott Hill, up to 2m of grey mudstone with common silty limestone fragments and *G. lituola* is exposed [6133 1675]. The strata are about 5m below the Lamberti Limestone. A nearby excavation [6133 1670] at a slightly lower level showed grey, fissile mudstone with an indeterminate perisphinctid ammonite nucleus. On the south-east slope of Arncott Hill, immediately below the Lamberti Limestone, a pyritised *Kosmoceras* nucleus with looping ribs was recovered from an auger sample [6174 1700]. The ammonite indicates the Middle Oxford Clay.

3.3.1.2.2.1. Lamberti Limestone Bed

The Lamberti Limestone is a distinctive, fossiliferous, silty limestone which defines the top of the Middle Oxford Clay Member. It commonly contains the zonal ammonite *Quenstedtoceras lamberti*, the bed representing a condensed sequence of this zone. Apart from ammonites, the fauna includes bivalves, belemnites and gastropods. In the former Woodham Brickpit situated about 6km east of the district and described by Arkell (1939, 1947), the bed was 0.3m thick and contained more ammonites than matrix, with at least 39 different species present. Rutten (1956) concluded that the limestone represented a littoral facies and that there was no marked change in sedimentation depth between the limestone and the over- and underlying clays. The present author, however, considers that the clays were deposited in deeper water.

The bed is continuous across the south-west of the district but its outcrop is locally difficult to locate. East and west of Piddington the Lamberti Limestone has been located from gamma ray logs run in shallow percussion boreholes and is about 0.2m thick. In borehole 4 [6448 1700], the bed is at a depth of c.4.5m;

borehole 6 [6374 1666] proved the Lamberti Limestone at c.7.5m; in borehole 7 [6325 1692], it is at c. 1.2m. North of Clue Hills Farm [626 162], the Lamberti Limestone is placed on the larger of three topographical features said by the farmer to have a shelly layer at about 0.7m depth. South-westwards from this area, the bed forms a good feature at the foot of the Pans Hill escarpment and in several places shows debris of pale grey, argillaceous, fossiliferous limestone. One locality [617 154] yielded fragments of *?Peltoceras, ?Kosmoceras* and *Oxytoma*, and at another [6168 1709] *Gryphaea* and belemnite fragments were also found.
An outlier of the Lamberti Limestone occurs towards the top of Arncott Hill. Typical debris was found at two localities including *Quenstedtoceras* [M] *sp.* at [6186 1709] and *Gryphaea*, belemnites, gastropods and pectinids at [6145 1679].

3.3.1.2.3. Upper Oxford Clay Member

The Upper Oxford Clay is about 23m of smooth, poorly fossiliferous mudstone with a few calcareous siltstones and silty limestones. In the upper part there are a few thin beds of dark grey mudstone. A distinctive bed of brown mudstone (the Pans Hill Brown Bed) occurs about 4m above the base of the member. This bed was first located in boreholes and trial pits immediately south of the district (Horton, in press) but has proved impossible to map. It includes a thin calcareous bed, the Panshill Siltstone which locally forms a mappable feature as do other siltstones and limestones in the Upper Oxford Clay.
The fauna consists mostly of bivalves including the oyster *Gryphaea dilatata*, pyritised ammonites (mainly cardioceratids) and belemnites. Oysters are sufficiently abundant locally to produce topographical features. The dark grey mudstones contain only crushed, unpyritised fossils.

The Upper Oxford Clay crops out in a narrow belt along the Pans Hill escarpment in the south of the area, continuing along the lowermost slopes to the north of Muswell Hill. In the former area, landslipping has obscured much of the outcrop. Eastwards from Clue Hills Farm [626 162] thin limestones/siltstones and a *Gryphaea*-rich bed have been mapped. The latter forms a near continuous topographical feature from the Bicester - Thame road [630 165] to the county boundary south-east [6471 1674] of Piddington. the bed is exposed in a ditch [633 164] where there is at least 2m of grey mudstone with common *Gryphaea.* To the east, the same fossil is abundant in the beds of two streams [6394 1638, 644 164-5] on and immediately downstream from the outcrop of the bed. The middle of three topographical features mapped above the Lamberti Limestone east of Piddington is correlated with the Pans Hill Siltstone.
Arncott Hill is capped by a c.17m thick outlier of Upper Oxford Clay. The Arncott Hill Borehole (SP61NW/8) [6160 1709] proved 11.9m of the member to a level just below the Brown Bed. The sequence proved is as follows:

	Depth m
MUDSTONE, grey and ochreous mottled, silty, race common at top, selenite from 1.3m becoming coarser with depth; pockets of *Gryphaea*; brownish with grey stained fissures below 1.7m; a few pyritised ammonite nucleii; belemnite fragment at 2.2m; becomes greyer from 3.1m and grey from 4.6m	c.5.3
SILTSTONE, pale grey, calcareous	c.5.5
MUDSTONE, Medium to dark grey, fossiliferous with crushed shells	c.5.9
MUDSTONE, pale to medium grey, a few pyritised ammonites, common pyritic trails	c.8.3
MUDSTONE, brownish grey, a few pyritised ammonites and common pyritic trails; becomes browner downwards; slightly more fossiliferous below c.9.5m; brown at c.10m	c.10.8
SILTSTONE, pale brown, calcareous	c.11.0
MUDSTONE, brownish grey, becoming grey, poorly fossiliferous; pyritic trails	c.11.9

3.3.1.3. West Walton Formation

The term "West Walton Beds" was introduced by Gallois and Cox (1977) for a distinctive mudstone sequence between the Upper Oxford Clay and the Ampthill Clay in Norfolk. Equivalent mudstones crop out in this area which were formerly included in the Oxford Clay. The overlying Cumnor Formation, a sequence of mainly limestones and sandstones, are laterally equivalent to part of the West Walton Formation. In the BGS Brill Borehole [6570 1412] sited about 1km south-east of the district, 2.05m of mudstone between the Cumnor and Ampthill Clay Formations have been correlated with the West Walton Formation (Cox, 1987, Ambrose and others, 1988). Representatives of the Cumnor Formation crop out in the Arncott area and the West Walton Formation is restricted to strata between the top of the Oxford Clay Formation and the base of the Cumnor Formation. Any mudstones above the Cumnor Formation which are equivalent to the uppermost part of the type West Walton Beds, are here included in the overlying Ampthill Clay Formation as no distinction is possible in the field.

The formation consists of about 16-18m of interbedded pale and dark grey silty mudstones with subordinate siltstones. The dark grey mudstones predominate in the upper part and typify the formation in this area. They are richly fossiliferous, the fossils preserved mainly as crushed shells. Downwards, the pale mudstones become more common. They are much less fossiliferous and the fossils are commonly preserved as pyrite casts. The pale mudstones are identical to those in the underlying Upper Oxford Clay. The two mudstone types commonly have interburrowed junctions.

The base of the formation is taken at the lowest recognisable dark mudstone which is about 1m thick. The bed is probably equivalent to Bed 2 of the type sequence (Cox and Gallois 1979). Percussion and rotary cored boreholes logged from the area immediately to the south showed that the mapped base corresponded to that taken in the boreholes.
The fauna is dominated by bivalves, perisphinctid and cardioceratid ammonites. The oyster *Gryphaea dilatata* is common throughout and usually bored and encrusted with serpulids. The latter feature is a useful aid in distinguishing the formation from the underlying Upper Oxford Clay where the *G. dilatata* are not bored or encrusted. *Chondrites* mottling is common throughout. The weathered zone of the West Walton Formation contains selenite, similar to the underlying Oxford Clay. However, unlike the Lower Oxford Clay which weathers to a pale grey clay, the darker beds of the West Walton Formation can be easily detected by augering, thus aiding its recognition in the field.

The formation crops out in the south-west of the district on the upper slopes of the Pans Hill escarpment and on the lower, northern part of Muswell Hill. On the steeper slopes, the formation has slipped in places. Along most of the outcrop, three or four persistent topographical features are developed which probably correspond to siltstones, more indurated mudstones or *Gryphaea*-rich beds. The base of the formation is just below the lowest of the features. The soils are darker than those of the underlying Upper Oxford Clay. Only one exposure was seen [6388 1625]:

	m
CLAY, grey and ochreous mottled, soft	c.0.4
MUDSTONE, olive-grey, blocky, weathered ironstone nodules, darker burrow mottling to base; *Gryphaea dilatata*	c.0.5
MUDSTONE, dark grey, olive-grey burrow mottling; *G. dilatata*. Apparent passage	c.0.2
MUDSTONE, olive-grey, blocky, darker burrow mottling; *G. dilatata*	0.3

Debris from the excavation additionally yielded belemnite fragments, *Grammatodon?* and *Chondrites* mottling in dark grey mudstone.

3.3.1.4. Cumnor Formation

The Cumnor Formation comprises the limestone and sandstone facies formerly included in the "Corallian". The name derives from the Cumnor Borehole south-west of Oxford (Cox, 1978, Wilson, 1978) which is the type section. In the Arncott area, there are two representatives of the formation: the Arngrove Spiculite Member and overlying Oakley Member.

3.3.1.4.1. Arngrove Spiculite Member

This member, formerly called the Arngrove Stone or Rhaxella Chert, was first described in detail by Davies (1907a). It is a very distinctive pale grey, calcareous sandstone or siltstone composed almost entirely of tiny blue and white, siliceous sponge spicules of the tetractinellid sponge *"Rhaxella perforata"*. The spicules are ellipsoidal with dimensions of 0.1 by 0.15mm (Davies, 1907a). The rock is characteristically porous and has a low density. The member is mostly 2-3m thick in the district thinning to about 0.5m in the extreme east.

The member usually gives rise to a good topographical feature and an abundance of rock debris. Between Pans Hill and the lower ground [636 156] to the north-west of Muswell Hill, the member locally forms a moderately extensive dip slope. Small exposures of up to 1m are visible in a number of ditches notably at [6251 1520], [6248 1546 - 6263 1547] partly beneath the Oakley Member, [628 159] and [6302 1619]. The member has been traced at outcrop for at least a further 1.3km eastwards from the location illustrated by Davies (1907a) and Arkell (1933, 1947), to the eastern margin of the sheet. It dies out rapidly in the adjacent area (Sumbler, 1988a). Immediately south of Corble Farm [638 159] and east [644 160-1] of Chilling Place Stud the member is obscured by landslipping. Around the latter the Arngrove Spiculite becomes clayey and locally passes into a silty quartz sand. North [646 164] of the Stud, an outlier of the member caps a low hill where it is at least 2m thick.

3.3.1.4.2. Oakley Member

The term Oakley Member replaces the previously used names "*Exogyra nana* beds/clay/zone" (Davies, 1907b, Barrow, 1908), "Oakley Clay" (Buckman, 1927) and "Oakley Beds" (Arkell 1933, 1942). Green (1864) recognised them as a distinct unit within the "Coralline Oolite", while Davies (1907b) and Barrow (1908) included them in the Ampthill Clay.
The member consists of 2 to 8m of interbedded pale to medium grey mudstones, siltstones and marls with impersistent, sometimes nodular limestones. The beds are usually crowded with the small oyster *Nanogyra nana* which is abundant in the brown clay soils and a useful guide in the mapping of the member. Serpulid worm tubes are also common and ferruginous ooliths may be present. The topmost part of the weathered zone usually contains race.

The outcrop of the Oakley Member skirts the lower slopes of Muswell hill in the south-west of the district. The member is thickest in the west near Oakcroft Farm [631 153]. In places, particularly due north of the farm, the outcrop is partially obscured by thin ironstone head derived from the Whitchurch Sand Formation capping Muswell Hill. Locally [6271 1566 - 6275 1588], a thin bed of dark grey mudstone has been mapped. A bed of grey silt usually occurs at the top of the member, probably the weathered representative of the limestone in the section described next, a ditch [637 155] south of Corble Farm which exposes most of the member beneath the Ampthill Clay:

	m
LIMESTONE, pale grey, ochreous stained, silty weathering to silt	c.0.1
MUDSTONE, pale grey, ochreous stained, silty, blocky, a few *Nanogyra nana*	c.0.5
LIMESTONE, pale grey, silty, interbedded with mudstone	c.0.2
MUDSTONE, pale bluish grey with ochreous mottling,	0.2
G A P	
MUDSTONE, pale grey and ochreous mottled, silty, a few *Nanogyra nana*	c.1.0

These beds overlie dark grey mudstone with *G. dilatata* (West Walton Formation), with a few fragments of Arngrove Spiculite occurring between the two. Northwards towards Corble Farm and west of Chilling Place Stud [646 161], the outcrop is obscured by landslip. A low feature marks the outcrop eastwards from Chilling Place Stud. The member has thinned to 2-3m in this area.

3.3.1.5. Ampthill Clay Formation

The division mapped as Ampthill Clay comprises all strata between the Oakley Member and the Kimmeridge Clay Formation. In the BGS Brill Borehole [6570 1412], 2.05m of strata immediately overlying the Oakley Member correspond to the topmost part of the type West Walton Beds (Cox, 1987, Ambrose and others, 1988).
The formation consists of medium to dark grey, fossiliferous mudstones which are noticably silty in the lower part of the formation. Phosphatic nodules occur mainly in the upper part and nodular cementstones are developed at some horizons. The fauna comprises mainly ammonites (cardioceratid and perisphinctid types), belemnites and bivalves including *Gryphaea dilatata* and, in the upper part, the flat oyster *Deltoidium delta* (Wm Smith). The local sequence can be compared to that in eastern England (Cox and Gallois, 1979, Gallois and Cox, 1977) where individual beds AC1-42 were defined on the basis of their lithological and faunal character.
The Ampthill Clay in this area is thinner (4-15m) than in surrounding districts. To the south (Horton, in press), east (Sumbler, 1988a) and South-east (Barron, 1988) it is mostly around 20m thick. In the Brill Borehole the formation sensu stricto is 20.25m thick (Ambrose and others, 1988) while the unit as mapped would be 22.3m thick (see above).

The outcrop encircles the lower slopes of Muswell Hill in the south-east of the district and is obscured by landslipping in places notably around Corble Farm [638 159] and immediately west of Chilling Place Stud [646 161]. The formation is thickest (c. 15m) in the west around Oakcroft Farm [630 153]. Here there are a number of impersistent topographical features but no associated lithological changes were detected despite a number of ditch sections and local intensive augering. Some of the features may in part be due to a thin covering of ironstone head, derived from the Whitchurch Sand Formation capping Muswell Hill. Augering in a ditch beside the road [635 158-9] to Piddington showed the lowermost part of the formation to consist of about 3m of dark grey mudstone overlain by 2m of paler mudstones. A similar but thinner sequence was noted in a ditch [641-2 161] west of Chilling Place Stud. East-north-east [636-7 155] of Oakcroft Farm, the formation thins rapidly to about 4m. A complete sequence is exposed in a ditch [6371 1548 - 6370 1559] together with the lowermost beds of the Kimmeridge Clay Formation.

	m
KIMMERIDGE CLAY FORMATION	
MUDSTONE, dark grey, fissile	1.0+
CEMENTSTONE, dark blue-grey, finely crystalline, hard and splintery, weakly septarian, bivalves and ammonites. Nodular, separated by pale grey and ochreous, soft silty, argillaceous limestone	0.2
MUDSTONE, dark grey, fissile, fossiliferous	c.1.0
CEMENTSTONE, as above but non-septarian, some burrow mottling	0.2
KIMMERIDGE CLAY & AMPTHILL CLAY FORMATIONS	
MUDSTONE, dark grey, fissile, fossiliferous	c.1.0
MUDSTONE, medium grey with ochreous staining ferruginous, some fossils	c.1.0
MUDSTONE, medium to dark grey	c.1.0
MUDSTONE, dark grey, fissile, fossiliferous	c.0.5
MUDSTONE, medium to dark grey, blocky, flat oyster shells common	0.45
MUDSTONE, pale grey and ochreous, blocky, flat oysters	0.15
OAKLEY MEMBER (see section 3.3.1.4.2.)	

Non-sequences may occur both above and below the Ampthill Clay hereabouts. The broken pieces of flat oyster in the lowest beds are thin shelled and probably *D. delta* but they may be the right valves of *G. dilatata* (Cox, 1988). As none of the larger thick shelled left valves of the latter were found, it is reasonable to assume that they are *D. delta*. This oyster is restricted to the upper part of the formation (Bed AC20 and above), suggesting that beds AC1-19 are not present locally. However, in the Brill Borehole this interval is represented by at least 8.05m of mudstones which are older than bed AC18. Again at Brill, there are 10.75m of strata younger than bed AC22 (Cox, 1987). In the above mentioned ditch section, this interval is either much

attenuated (less than 4m) or has been eroded before deposition of the Kimmeridge Clay. The junction between the Ampthill and Kimmeridge Clay cannot be located precisely but lies below the two cementstones which have been assigned to the Kimmeridge Clay (Cox, 1988, and see section 3.3.1.6.). The apparent thinning of the formation here may in part be due to the effects of dip-and-fault and cambering of the beds capping Muswell Hill and the compensatory squeezing of the underlying clays. Horswill and Horton (1976) noted that the same mechanism resulted in a thinning in the Upper Lias of up to 30% in the Empingham area. The formation thickens eastwards from Corble Farm. In a ditch [6429 1611] shelly cementstone nodules were found containing abundant serpulids together with oyster fragments and cyprinid bivalves. The latter indicate an horizon in the Ampthill Clay, and hte former suggest it may be the Brill Serpulite Bed. This bed forms a distinctive marker, originally thought to occur around the Ampthill Clay - Kimmeridge Clay boundary (Davies, 1907a). The recent work on the Thame sheet coupled with the Brill Borehole has shown that the bed lies within the Ampthill Clay, about 12m above the base of the formation in the borehole, and probably equivalent to bed AC 34 of the standard sequence (Cox and Sumbler, in preparation). The nodules found were probably not in situ but must have been derived from a nearby source.
In the extreme east there are two mappable features. On the lower one, a soft, grey, silty limestone is exposed in the the stream bed [6481 1566] and on the higher one, shelly cementstone nodules with *D.delta*, other oyster and perisphinctid ammonite fragments were found [6475 1553]. These limestones are probably beds AC40-42 of the standard sequence.

3.3.1.6. Kimmeridge Clay Formation

The Kimmeridge Clay consists of 45-55m of interbedded grey, silty mudstones and dark grey, fissile, bituminous mudstones with subordinate oil shales and nodular cementstones. The upper part contains beds of silt and fine sand with a prominent sand unit at the top. Phosphatic nodules occur locally. Most of the formation is richly fossiliferous in ammonites and bivalves. The Kimmeridge Clay of eastern England and Dorset has been described in detail (Gallois and Cox, 1976, Cox and Gallois, 1979, 1981) and a standard sequence of beds (KC1-49) set up. The Brill Borehole sited about 1km south-east of the district, proved 55.6m of Kimmeridge Clay (Ambrose and others, 1988, Barron, 1988). Correlation with the standard sequence shows 39.65m of Upper Kimmeridge Clay and 15.85m of Lower Kimmeridge Clay. The oil shale facies which are well developed over much of the UK outcrop is pooly represented at Brill. Some of the major bituminous mudstones are absent, sands occuring at the same level.

The formation crops out on the middle slopes of Muswell Hill but most of the outcrop is obscured by landslip. Cambering of the overlying strata and the associated squeezing of the clays makes accurate thickness determinations impossible. A ditch exposure

[6371 1549-54] given above (section 3.3.1.5.) shows at least 2.4m of Kimmeridge Clay with two cementstone nodule beds overlying Ampthill Clay. The following fauna was collected from the upper cementstone: *Aspidoceras*, common perisphinctid fragments (*Propectinatites?*), *Nanogyra virgula* (Defrance), serpulid and indeterminate bivalve fragments. These, together with the weakly septarian form of the nodule, indicate bed KC30 of the standard sequence (Cox, 1987). The lower nodule yielded the following: *N. virgula*, *Grammatodon?*, *Modiolus?*, perisphinctid fragments, *Procerithium?*, *Sutneria?* and is probably bed KC24 of the standard sequence (Cox, 1987). In this section probably less than 1m of Kimmeridge Clay underlies bed KC24 compared to 8.70m in the Brill Borehole. Similarly the interval KC24-KC30 is about 1m here but 3m at Brill. This evidence suggests a marked attenuation in the lowermost beds and a non-sequence at the base of the Kimmeridge Clay to the north-west of Muswell Hill. The formation may therefore have thinned to around 45m, assuming a comparable thickness to the Brill Borehole (c.55m) for most of the outcrop. The thinning here may in part be due to the effects of cambering and dip-and-fault (see sections 3.3.1.5. and 4.2.).
The uppermost strata are predominantly grey to greenish grey, yellow-brown weatherng, fine grained sands and silts with clay seams. To the south and west there is a threefold subdivision of sand - clay - sand, the highest sand bed corresponding to the Wheatley Sands of Arkell (1947). Around Muswell Hill, both the upper sand bed and the clay die out locally e.g. [648 153-4], [645 158] respectively. The topmost beds were exposed in the backscar of a landslip [6445 1587] beneath the Portland Sand Member:

PORTLAND SAND MEMBER, UPPER LYDITE BED	m
SILT & SAND, ochreous, lumps of rubbly weathering calcareous siltstone and sandstone; lydite pebbles, a little glauconite	0.2
KIMMERIDGE CLAY FORMATION	
SILT, grey and ochreous mottled, clayey and sandy, common lydite pebbles	0.22
SAND, pale grey and ochreous, silty	0.2

The occurrence of lydite pebbles in the topmost bed of the Kimmeridge Clay was also noted in the Brill Borehole (Ambrose and others, 1988, Barron, 1988) contrary to most past workers who tended to assume all lydite pebbles were confined to the Upper Lydite Bed at the base of the Portland Sand. Davies (1899) does however illustrate the occurrence of lydites in the Kimmeridge Clay in his graphic section of Long Crendon.

3.3.2. Portland Formation

The Portland Formation of Oxfordshire and Buckinghamshire has been the focus of attention in the past. However little is known about the Muswell Hill succession which is poorly exposed. The current classification of the Portland is based on Buckman (1922-26), Arkell (1933, 1947) and Ballance (1963) and is as follows:

CREAMY LIMESTONES	(Blake, 1880)	) Portland
CRENDON SAND	(Buckman, 1926, p35)	) Stone
RUBBLY LIMESTONES	(Blake, 1880)	) Member
GLAUCONITIC BEDS	(Blake, 1880)	) Portland
UPPER LYDITE BED	(Buckman, 1923 p29)	) Sand Member

Earlier workers (e.g. Fitton (1836), Hull and Whittaker (1861), Blake (1880), Woodward (1895) and Davies (1899)) included the topmost sand unit of the Kimmeridge Clay in the Portland Sand. On Muswell Hill, the formation has been divided into a lower Portland Sand and an upper Portland Stone Member, corresponding roughly to the above subdivision. The "Rubbly Limestones" are locally sandy and sometimes glauconitic and may locally be included in the Portland Sand. Past workers have tended to use the absence of glauconite as the criterion for drawing the boundary between the sand and stone subdivisions. Whilst this may be applicable to quarry sections, it is of little value in mapping because of lateral variations and the difficulty in detecting small amounts of the mineral (less than 5%). No representative of the Crendon Sand was found.
The formation is estimated to be about 6m thick but the outcrop is heavily cambered or obscured by landslip, making accurate determinations impossible. The Brill Borehole proved about 7.5m (Ambrose and others, 1988, Barron, 1988).

3.3.2.1. Portland Sand Member

The Portland Sand, about 4m thick, consists predominantly of a buff to greenish grey, fine grained, calcareous, glauconitic sandstone varying to a sandy limestone. Locally the beds are highly glauconitic and in places are weakly cemented. The base is usually marked by a conglomerate (Upper Lydite Bed) up to about 0.2m thick composed mostly of phosphate pebbles with a few phosphatised ammonites both derived from the underlying Kimmeridge Clay, set in a matrix which is reported to vary from typical Portland Sandstone to soft silts, sands and clays. Exotic pebbles reported are black chert, spherulitic felsite, vein quartz and silicified oolite (Davies, 1899, Neaverson, 1925). Neaverson (1925) suggested a northerly origin for the pebbles but Arkell (1933) thought that the London Platform to the south-east was the more likely source. He suggested that the pebbles with an obvious northern source had been transported south in late Palaeozoic - Triassic times and subsequently reworked in the Jurassic.
The upper boundary of the member is arbitrary. In general, the glauconite and sand content diminishes and the lime content increases upwards but lateral variations also occur. Fragments

containing both calcareous sandstone/sandy limestone and micritic limestone lithologies were noted in the topmost part of the mapped Portland Sand, but the relationship of the two facies could not be established. The member contains a rich fauna dominated by bivalves and ammonites.

The base of the Portland Sand is marked by a spring line. It was seen exposed in two localities. One [6445 1587], given in section 3.3.1.6., showed a poorly developed Upper Lydite Bed as a deeply weathered, ochreous silt and sand with cemented patches. The other [6435 1555] exposed a soft, yellow-brown, clayey sand with lydite pebbles beneath glauconitic sand with lumps of sandstone and sandy limestone. Grey clayey sand (Kimmeridge Clay Formation) was augered beneath the Upper Lydite Bed. Immediately behind a spring [6365 1510] about 2m of pale creamy buff, rubbly weathering, glauconitic, silty biomicrite and calcareous sandstone is exposed. *Laevitrigonia gibbosa* (J Sowerby), a small oyster and an indeterminate ammonite fragment were collected. The lowermost beds of the member were not seen. Pringle (1926) recorded a glauconitic limestone with *"Protocardia dissimilis"* and other shells from the basal Portland of Muswell Hill.
In the backscar of the landslip [6428 1581 - 6445 1586] there is a large amount of Portland Sand debris excavated from badgers sets. Most is glauconitic sandstone and sandy limestone but the highest beds include sparsely to non-glauconitic micritic and sparry lithologies, probably more typical of the "Rubbly Limestones" lithology. The fauna collected includes *Glaucolithites* fragments and trigoniid bivalves from the lowermost glauconitic beds and *Camptonectes lamellosus* (J Sowerby), *Lima rustica* J Sowerby, oysters, *Pleuromya uniformis* (J Sowerby), *Protocardia dissimilis* (J de C Sowerby), serpulids, indeterminate bivalves and ammonite from the higher beds.

3.3.2.2. Portland Stone Member

The Portland Stone is about 2m of mainly off-white, micritic, shelly and shell detrital limestone. The rock may be sandy, oolitic or pisolitic and locally varies to a calcareous sandstone. Lateral variation is common. The fauna is dominated by bivalves with a few ammonites.

No exposures were seen but debris from a pipe line [6427 1552 - 6424 1550] showed a variety of lithologies as follows, in ascending order:

LIMESTONE, pale grey, shelly and shell detrital, micritic; scattered sand grains; a few ooliths

SANDSTONE, pale grey with orange-brown staining, scattered shell fragments, a few shells, micrite cement

MICRITE, cream, shells and shell detritus, common ooliths and pisoliths; sandy in parts.

Higher up the slope, debris from an inspection hole [6415 1546] showed similar lithologies together with Purbeck mudstones and limestones. The following fauna was collected: ammonite fragment, *Camptonectes lamellosus* (J Sowerby), *L. gibbosa*, *Liostrea sp.*, mytiloid bivalves, *Pleuromya sp.*, small cyprinid bivalves and *Aptyxiella portlandica* (J de C Sowerby).

3.3.3. Purbeck Formation

This formation, about 4m thick at Muswell Hill, consists mostly of grey mudstone with a pale grey, fine grained, recrystallised, porcellanous limestone at or near the base. Locally [6423 1550] the limestone contains much fish debris and a few pebbles. Another block found probably from the same bed but not in situ was a thinly bedded stromatolitic/algal limestone. A second, impersistent limestone was seen in a pipe trench [6420 1548] and is a shell detrital, oolitic and pisolitic micrite. The same bed occurs in a nearby road cutting [6379 1515] where a pale grey, micritic limestone with numerous shell fragments and scattered ferruginous ooliths is exposed. The entire outcrop is under pasture and in places is obscured by landslip. Past workers (Green, 1864, Pringle, 1926) failed to detect the Purbeck Formation in this area.

3.3.4. Whitchurch Sand Formation

Formerly known as "ironsands" (Fitton, 1836), Shotover Sands (Blake, 1893) or Shotover Ironsands (Davies, 1899), the term Whitchurch Sands was introduced by Casey and Bristow (1964) and here modified to the Whitchurch Sand Formation. An estimated 15m of the formation caps Muswell Hill and is extensively cambered. It consists of orange to brown, fine to coarse grained, well rounded, ferruginous sandstone interbedded with grey silty mudstone. Secondary box ironstone is common at the surface. The deposits have generally been considered to be of fresh water origin, first noted by Strickland (1836, Proc. Geol. Soc., Vol.ii, p6) who found the freshwater mollusc *"Paludina"* on the Shotover Hill outlier near Oxford. Casey and Bristow (1964), however, concluded that the environment of deposition was marine - brackish.

The beds lie between the Purbeck and the Gault and their age has been the subject of much speculation. Early workers principally used lithology and stratigraphical position to correlate the beds but at the same time placing too much emphasis on a very sparse fauna now known not to be diagnostic of any one horizon. Fitton (1836), Green (1864), Woodward (1895) and Davies (1899) referred to the beds as Lower Greensand, while Phillips (1858, 1871) concluded that they may be correlated with the Hastings Sands or an estuarine deposit of Lower Greensand age. Pringle (1926) classified them doubtfully as Wealden while Arkell placed them in the Lower Wealden and Taylor (1959) suggested a correlation with the Hastings Beds. Casey and Bristow (1964) identified a Middle Purbeck (Cretaceous) fauna in comparable strata elsewhere in Buckinghamshire. Morter disagreed and placed the beds close to the top of the Lower Purbeck and the base of the Middle Purbeck i.e. in the Portlandian Stage (Jurassic) as defined by Wimbledon and Cope (1978). Recent work on material from the Brill Borehole has failed to resolve the disparity, and this report follows Barron (1988) in including the formation in the Portlandian.

A number of disused and overgrown pits occur within the formation on Muswell Hill but there are no exposures. Two sections were seen, one [6436 1521] in the backscar of a landslip showing orange to brown, fine grained, well rounded sand with a few ironstone fragments and traces of grey clay. In the road cutting [6385 1513], the following is exposed:

	m
MUDSTONE, very pale grey, silty, ochreous stained; seams of soft, poorly cemented ferruginous siltstone and fine sandstone	c.0.8
SANDSTONE, ochreous, fine grained, silty with clay lenses	0.2

In the same cutting, Blake (1893) described the "Shotover Sands" as "false-bedded, ferruginous, probably manganiferous in places, with occasional doggers and bands of white marl and sand". *"Unio porrectus"* was found in one of the nodules. Lamplugh (1908) noted the occurrence of blocks of ironstone crowded with *"Neomiodon medius"* and *"U. porrectus"* in the road cutting and from ploughed fields on the south-east side of Muswell Hill.

4. STRUCTURE

4.1. Folding and Faulting

The Arncott district lies within a relatively undisturbed area with the rocks dipping gently at up to 2 degrees to the south-east. Local southerly dips occur on the northern slopes of Muswell Hill while the upper part of the hill is extensively cambered (see section 4.2.). The NE-SW trending Charlton Anticline (Arkell, 1944) just clips the north-west corner of the district resulting in north-westerly dips. The fold is roughly symmetrical and has a number of small faults with displacements of up to 5m associated with it. Most of the faults trend perpendicular to the fold axis. Both normal and wrench faults have been identified, the latter displacing the fold axis. One fault is traceable for about 3km from Ambrosden to Arncott and the Cow Leys Fault is presumed to intersect the Charlton Anticline north of the district. Other small faults occur in the south of the area. One, the Murcott Fault, has a maximum throw of about 10m and has been traced westwards to the Charlton Anticline near Charlton-on-Otmoor (Ambrose, 1988).

Arncott Hill, elongated parallel to the Charlton Anticline appears itself to be a very gentle anticlinal dome. The beds capping the hill are approximately horizontal, shown by the outcrop of the Lamberti Limestone at 90-92m AOD and evidence of its inferred position at depth (c.15m, 91m AOD) on the site of borehole 8. Limestones in the Middle Oxford Clay dip parallel to the slope direction on either side of the hill.

4.2. Superficial Structures

The strata capping Muswell Hill have undergone extensive cambering, indicated by the dips which everywhere slope away from the summit. The cambers are probably composed of intensely faulted strata (dip-and-fault structure) with each individual fault block having only a small displacement and the intervening beds dipping steeper than the camber slope as described by Hollingworth and others (1944) and Horswill and Horton (1976). No direct evidence of dip-and-fault structures was seen in this area but sections showing such structures were seen to the south of Muswell Hill (Horton, in press) and on Brill Hill (Barron, 1988). The cambering is best displayed immediately north of Muswell Hill Farm [643 155] where the base of the Portland Sand falls by about 30m in an ENE direction. Cambering has the effect of altering the true thicknesses of the beds. Apparent thicknesses are increased in the topmost, more competent strata, whereas they are decreased in the mudstone formations lower down. These softer beds are effectively squeezed. The scale of the apparent thickness changes is not known as the true thicknesses are not known, but apparent excessive thinning of the Ampthill and Kimmeridge Clay Formations to the north-west of Muswell Hill (see sections 3.3.1.5. and 3.3.1.6.) may in part be due to these superficial movements.

5. DRIFT GEOLOGY

5.1. Head

One small patch of head has been mapped [c.644 191] in the north-east of the district. It is composed of orange-brown, clayey sand and sandy clay, rising about 1m above the surrounding alluvium. As there are no terrace deposits in this part of the River Ray, the deposit is assumed to be head.
Thin, unmapped pockets of solifluction deposits are present on the lower slopes of Muswell Hill. Around Oakcroft Farm [630 153] there are patches of head rich in ironstone derived from the Whitchurch Sand Formation capping Muswell Hill. A narrow ridge in the Middle Oxford Clay immediately west of Piddington is fomed by a thin cap of head, seen at one locality [6388 1754] as 0.5m of ochreous and grey sandy clay with ironstone fragments from the Whitchurch Sand and bored *Gryphaea* from the West Walton Formation. The incised valley [633 162] just north-west of Piddington Gate, contains up to 2m of grey and ochreous sandy clay with a few ironstone fragments.

5.2. Alluvium

Extensive alluvial deposits of the River Ray occur in the northern half of the district. The flood plain is almost exclusively confined to the outcrop of the Lower Oxford Clay, broadening significantly in the east as the dip of the solid rocks decreases slightly. An "island" of Oxford Clay protrudes through the alluvium at Blackthorn, the result of the more resistant Blackthorn Nodule bed. The Cow Leys Fault displaces the nodule bed in the extreme north and produced a line of weakness along which the Ray formerly flowed. This former arm of the river still floods regularly. South-west from Blackthorn, the nodule bed disappears beneath the alluvium but still forms a low feature protruding about 1m above the flood plain surface. The alluvium drapes over the feature, thinning to about 0.5m. Flood waters must therefore rise to a level at least 1m above the flood plain. Between Arncott and Piddington, the margin of the alluvium rises to about 66m AOD, 4m above the main level of the flood plain. This also indicates former flood levels and suggests that a significantly larger area was once under water. Whilst most of the sediments deposited at this time have been removed by erosion, some of lower slopes in the west have a thin covering of alluvial-type deposits. They are particularly well developed in the Central Ordnance Depot depot, immediately west of Upper Arncott [60 16-7]. However, the close proximity of Arncott Hill suggests that these deposits may in part be derived by solifluction.

The alluvium is mostly a grey and ochreous mottled clay which becomes sandy with depth. Locally, the clay varies to pale or dark grey and may be organic-rich e.g. [6445 1942, 6310 1779]. The base is commonly a sand, pebbly sand or gravel with both angular and rounded pebbles. The constituent lithologies in order of abundance are fragmented *Gryphaea*, ironstone, flints and black chert. The thickness varies from less than 1m to over 2m, the thickest development generally being along the present course of the Ray. At one point [6227 1883], 2.3m were recorded without reaching the base. Thicknesses of around 2m were also noted near to the alluvium margin between Arncott and Piddington, and along the tributary stream in the extreme east [64 18-9], the alluvium is 1.5-2.0m thick. Another tributary west of Piddington has an enclosed alluvial flat falling from 90 to 71m AOD. In the upper reaches, up to 2m of grey and ochreous sandy clay with pockets of Arngrove Spiculite at the base is exposed [6337 1655 - 6343 1665] in the banks of the stream.

6. ENGINEERING HAZARDS

6.1. Landslip

Extensive landslipping occurs on the slopes of Muswell Hill, Pans Hill and Arncott Hill. In all cases, the north and north-west facing slopes are worst affected.

The areas shown as landslip are only approximate and do not reflect the relative stability of the ground. Drainage and cultivation has stabalised parts of the landslips and obliterated their suface forms, but they become unstable when the equilibrium is altered either by excavations into the ground or by loading on the surface.

Muswell Hill: Active landslips extend along the north-west slope from Chilling Place Stud [636 161] onto the area to the south with a smaller area on the similarly orientated slope south-east of Muswell Hill Farm [643 155]. Both slopes are inclined at 11 to 15 degrees and show very uneven, hummocky ground with a few fresh slip scars and a well defined back scar and toe. A small area around Corble Farm [638 159] has been drained and stabalised. South from the road crossing Muswell Hill the landslip is less well defined. The principle point of failure is at the base of the Portland Formation from where a number of springs issue. The principal mechanism of movement is by small scale rotational slips. Most of the Kimmeridge Clay and uppermost Ampthill Clay Formations are obscured by the slipped material which extends down to the West Walton Formation at Corble Farm. Locally, the slip extends up to include the Portland, Purbeck, and lowermost Whitchurch Sand Formations.
A ditch [6370 1542 - 6371 1548] exposes deposits at the foot of the slip, a grey and ochreous brecciated mudstone with fragments of Portland limestone and ironstone from the Whitchurch Sand.
On the east facing slopes, ancient, degraded slips have been located. They do not appear to be continuous as topographical features and the solid formations can be mapped in between. An older slip has also been identified [644-6 160-1] below the present toe at Chilling Place Stud. Ditches show brecciated mudstone and Portland limestone debris. The full extent of this deposit is not known, but the comparative gentle slopes would suggest that the ground is likely to be stable and that the deposit represents an ancient mudflow.
A small slip has developed in the sides of the deeply incised valley running past Corble Farm. Failure has occured in the West Walton Formation on slopes of up to 12 degrees, similar to those on Muswell Hill.

Pans Hill: Slipping here has occured on slopes of 8-12 degrees in the West Walton Formation and Upper Oxford Clay Member. All appear inactive and were only recognised on uncultivated ground. The limits of the landslip are somewhat imprecise particularly the lower limit which has been placed on a concave break of slope. The Lamberti Limestone crops out just beyond the mapped limit, precluding any significant down-slope extension of the slipped material. The cultivated ground in the extreme south of the ridge is a continuation of the slip as shown by trial pits dug just to the south. The pits showed a fairly homogenous clay which proved highly unstable in some instances. In other pits, fragments of Arngrove Spiculite were found at up to 5m depth. Failure probably occured as a result of an over steepened slope possibly assisted by water seeping from siltstones/silty limestones, shell beds and, in some places, the Arngrove Spiculite.

Arncott Hill: A degraded slip has been identified on the north-west facing slope of the hill on a slope of 10-11 degrees.

The lower limit and lateral extent of the slip is imprecise. Failure has occured in two places: immediately below the Lamberti Limestone and a higher limestone in the Upper Oxford Clay. Water seeping along these beds almost certainly triggered the slipping.

The initiation of the slips can be equated with the late-Devensian at a time of increased precipitation and run off.

6.2. Made Ground

Seven small areas of made ground are shown on the map [608 157, 623 174, 637 158, 637 160, 641 198, 643 155, 646 161], all consisting of 1-2m of soil and rubble or limestone debris. In addition many of the disused quarries will contain varying quantities of fill. The C.O.D. sites at Arncott have been subjected to extensive earthworks with areas of made and excavated ground. The individual areas are not delineated on the map.

7. HYDROGEOLOGY

The water supply of Oxfordshire was described in detail by Tiddeman (1910). At that time most settlements obtained their water from local wells. The inlier of the Great Oolite in the core of the Charlton Anticline at Ambrosden yielded an abundant supply of water and also supplied Blackthorn. Slight artesian conditions occur in places along the anticline e.g. at Merton to the south-west (Ambrose, 1988). However, the Great Oolite is not a persistent aquifer in this area. The Arncott Hill Borehole (SP61NW/1) sunk in 1907 to provide water for the village, only struck water in the "Upper Estuarine Sands". The yield was 500 gallons per hour but this only reflected the pump capacity. The best surface aquifer is the Portland Formation on Muswell Hill which throws out a number of springs at its base. Water piped from one of these springs originally supplied the village of Piddington. The farms on the top of the hill still derive their water from wells. The Whitchurch Sand and sands in the Kimmeridge Clay form less significant aquifers.

8. ECONOMIC GEOLOGY

Quarrying no longer occurs in the area but traces of several pits remain. Many of the surface deposits have economic potential for the future.

8.1. Limestone

Limestone has been quarried from the Forest Marble, Cornbrash and Portland Formations. The most likely uses were road metal (Cornbrash and Forest Marble) and building stone (Portland).

Other uses may have included burning for lime. A more recent industry to develop around the quarrying of limestone is the manufacture of cement. There is a large cement works at Kirtlington to the west of this area where the Cornbrash, Forest Marble and White Limestone are used.

8.2. Road Metal

In addition to the Cornbrash, the Arngrove Spiculite was worked as a source of road metal but there are no quarries in this area.

8.3. Brick Clay

Most of the area is underlain by mudstone which can be used for brick making. There are a few small pits which may have been dug for this purpose. The Lower Oxford Clay is by far the most suitable for the brick industry on account of its relatively high organic content. Its use in the brick industry is described by Callomon (1968). Just north of the area on Blackthorn Hill, Forest Marble clays were worked for brick making (Woodward, 1894).

8.4. Sand

Sand has been dug from the Whitchurch Sand Formation, presumably for building purposes.

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