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Onshore Geology Series

TECHNICAL REPORT WA/89/32

Geological notes and local details for 1:10,000 sheet SP 71 NE (Fleet Marston)

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

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INTRODUCTION

This account describes the geology of 1:10 000 Sheet SP 71 NE (Fleet Marston). Some aspects (e.g. certain details of stratigraphic classification) are provisional, pending completion of the survey of the adjoining region. The area forms part of the unpublished 1:50 000 Geological Sheets 219 (Buckingham) and 237 (Thame) and straddles the boundary of Old Series One-Inch Sheets 45 and 46, published in 1863 and 1865 respectively, and based on a survey carried out by E. Hull, H. Bauerman, W. Whitaker, T.R. Polwhele and A.H. Green. These maps show the approximate distribution of the Portland Beds and "Lower Greensand" (including Whitchurch Sand), but subdivision of the underlying mudstones is inadequate and the maps show no drift. The geology of Old Series Sheet 45 is described by Green (1864), but there is no published account of Sheet 46. The portion of Sheet SP 71 NE lying within Sheet 46 (i.e. all but the western margin of the area) was resurveyed on the six-inch scale by A.C.G. Cameron, prior to 1898, for a drift edition of that Sheet. These six-inch maps (Buckinghamshire 23 and 28) indicate the approximate distribution of the glacial drifts of the area, but make little improvement to the representation of the solid geology. The area was resurveyed on the 1:10 000 scale by M.G. Sumbler in the spring of 1988, as part of the survey of Sheet 237. Stratigraphic palaeontology was carried out by Dr B.M. Cox (1988b,c, 1989).

The geological lines on the map indicate the outcrop limits of various beds or deposits. These are for the most part concealed beneath soil and vegetation, and so the geological lines are largely inferred from indirect evidence, principally the form of the ground surface. For example, hard limestone beds in a mudstone sequence commonly form minor scarp features. The map is thus the subjective interpretation of the surveyor, and all geological boundaries carry an element of uncertainty. Boundaries which (in the opinion of the surveyor) can be located to an accuracy of c.10m or less on the ground, are shown as unbroken lines on the map; all others are shown broken. This distinction does not apply to boundaries of drift deposits, for which a pecked line (or a thin continuous line on some redrafted maps) is used.

The Fleet Marston area lies within the catchment of the River Thame, which crosses the south-western corner of the area, and the topography is dominated by the valleys of south and south-eastward-flowing tributary streams. The area is underlain mainly by Upper Jurassic mudstone strata, which typically form ground of low relief, although some harder beds form mappable features on the valley slopes. In the south-east corner of the area, the ground rises steeply onto Waddesdon (or Coney) Hill, which is capped by Upper Jurassic limestones and sands. The northern margin of the map includes the lowest slopes of the analogous Pitchcott Hill. The soils of the area are mostly clays formed either directly from the Jurassic mudstones or derived secondarily from alluvium, colluvium, or in the east, glacial till. The limestones and sands of Waddesdon Hill give rise to very variable brashy and sandy soils. There are also some small hilltop outliers of glacial gravel.

The area lies immediately north-west of Aylesbury but, apart from housing estates in the south-eastern corner, the area is almost entirely farmland. At the time of survey, roughly half was pasture, used for sheep and dairy cattle, and the remainder was arable, mostly wheat and barley. There are no villages within the area, and though close to Aylesbury, some parts are quite remote from the roads. The village of Waddesdon lies on the A41 Bicester-Aylesbury road, just beyond the western boundary of the map. Quainton, another sizeable village, is just beyond the north-western corner. The railway which crosses the south-western part of the area, is now used only for goods traffic.

Uncoloured dyeline copies of the 1:10 000 map can be purchased from BGS, Keyworth, where records of boreholes may also be consulted.

Equivalent maps and reports for adjoining areas are:

SP 71 NW	(Waddesdon)	Sumbler (1988)
SP 71 SE and part of SP 81 SW	(Stone and Aylesbury)	Sumbler (1989)
SP 81 NW	(Bierton)	Barron (1988)

GEOLOGICAL SEQUENCE

DRIFT:

QUATERNARY:	Landslip
	Alluvium
	River Terrace Deposits
	Head (Colluvium)
	Glaciofluvial Sand and Gravel
	Till

SOLID:

JURASSIC	Whitchurch Sand Formation
	Purbeck Formation
	Portland Formation
	Kimmeridge Clay Formation
	Ampthill Clay Formation
	West Walton Formation

JURASSIC

Below the Portland Formation, the strata consist overwhelmingly of mudstone, subdivided into the West Walton Formation, Ampthill Clay and Kimmeridge Clay. These argillaceous formations are included in the Ancholme Clay Group. At the surface the mudstones are deeply weathered and form medium to pale grey and fawn clays, commonly containing crystals of selenite (gypsum resulting from the weathering of pyrite in the presence of calcium carbonate) or specks and tiny nodules of race (tufaceous calcium carbonate). Cementstone (argillaceous limestone) bands and nodules occur at many levels, but are generally broken down by weathering and occur only sporadically in the soil, although some topographic features may be formed by them. When fresh and unweathered in boreholes and exposures, three main mudstone types can be distinguished, although gradations between these occur:

1. Dark grey, smooth mudstone, generally well laminated and bituminous; bivalves and ammonites preserved in iridescent aragonite.
2. Pale grey, smooth calcareous mudstone, with cementstone bands and nodules; bivalves and ammonites sparse, and generally preserved in pyrite or as clay casts.
3. Medium grey siltstone and silty mudstone, often intensely burrowed; concentrations of plant and shell debris; thick-shelled oysters often abundant; ammonites in "ghost preservation", consisting of thin whitish films of calcite.

These different types of mudstone form cyclic sequences on various scales. The cyclicity is probably related to water depth, with Type 1 mudstones having been deposited slowly in relatively deep offshore waters, and types 2 and 3 indicating progressively nearer shore, shallower, higher energy conditions (Gallois & Cox, 1977). Type 1 mudstones are common in the Kimmeridge Clay, and Types 2 and 3 in the Ampthill Clay and West Walton Formation.

Gallois & Cox (1974, 1976, 1977) and Cox & Gallois (1979) described the three mudstone formations in the area south of the Wash, and developed a bed-numbered sequence based on boreholes. In the following account, these standard beds are referred to in the form WW1, AC1, KC1 etc. (the initials indicating the relevant formation).

WEST WALTON FORMATION

The term "West Walton Beds" (now "Formation") was introduced by Gallois & Cox (1977) to describe a distinctive sequence of mudstones between the Upper Oxford Clay and the Ampthill Clay in Fenland. In the Fleet Marston area, the West Walton Formation comprises 10 to 15m of interburrowed pale mudstones and darker grey silty mudstones, the latter containing much shell debris and finely divided plant material. Ammonites, mainly cardioceratids and perisphinctids, are commonly preserved in aragonite, although pyrite casts also occur. *Gryphaea dilatata* J. Sowerby is common in some beds. These oysters,

together with sporadic *Lopha, Nanogyra nana* J. Sowerby and rare belemnites are the only fossils sufficiently resistant to weathering to survive in the soil.

Only the upper part of the formation crops out in the Fleet Marston area, forming the floor of the broad valley in the north-western part of the district. Here, the West Walton Formation/Ampthill Clay boundary has been mapped at a pronounced change of ground slope which marks the top of silty mudstone beds. These may equate with the the calcareous Cumnor Formation of the area to the west, which defines the base of the mapped Ampthill Clay. It seems likely that a small thickness of beds at the base of the Ampthill Clay (as mapped) should strictly (i.e. in terms of the type sequence) be included with the West Walton Formation (Sumbler, 1988).

The Formation is very poorly exposed, forming an area of low relief given over entirely to pastureland. Ditches show a dark grey, brown and ochreous clay soil, and auger samples of the subsoil commonly contain abundant race pellets. Dredgings from a pond [7635 1833] show mid grey slightly silty clay with finely divided shell dust. An excavation, reportedly 5m deep, at Lower Farm [7777 1770] is sited on Ampthill Clay, but evidently reached the underlying West Walton Formation. Debris (probably mostly from the deepest part of the excavation) comprised medium to pale grey mudstone and silty mudstone with occasional pyritised trails and blebs, and common small crystals of selenite. Some layers were rich in fine shell debris, but recognisable fossils were very rare. Those collected included small '*Astarte*', *Chlamys*, *Myophorella*, ammonite fragments including *Cardioceras* ex gr. *maltonense* (Young & Bird) and *Perisphinctes*; and common "*Pentacrinus*" columnals. No oysters were observed. The fauna and lithological character of the beds indicates WW 8/9 of the standard sequence.

The uppermost c 8m of the West Walton Formation were penetrated in the BGS Folly Farm Borehole [7958 1904] in the north-eastern part of the map. These beds (from c 22.45m to the bottom of the borehole at 30.50m) comprise pale to medium grey calcareous silty mudstones, with silty cementstones and a sparse fauna of bivalves and ammonites preserved in "ghost preservation". In the lower part, some beds are

mottled with darker burrow-fills of silty mudstone with plant and shell dust. The borehole confirms the absence of the Cumnor Formation locally. A cluster of *Cardioceras tenuiserratum* (Oppel) at 26.22m indicates the Tenuiserratum Zone.

AMPTHILL CLAY FORMATION

The Ampthill Clay comprises c 20m of beds; its outcrop occupies about 60% of the Fleet Marston area. For the most part it forms a rather featureless area of low relief, but in the north-western part of the area it forms a shelf which terminates in a pronounced south-facing feature above a steep slope. The change of gradient at the bottom of this slope has been mapped as the base of the formation but the lowest part of the mapped Ampthill Clay may include a small thickness of beds which should strictly be included with the West Walton Formation (see above). Some confirmation of this was provided by the excavation at Lower Farm [7777 1770]; though sited an estimated 3 to 5m above the mapped base of the Ampthill Clay, debris from the c 5m deep pit consisted predominantly (or possibly entirely) of material from the West Walton Formation.

The Ampthill Clay forms a grey and fawn clay soil. Fresher material from deep ditches and trenches consists of medium to dark grey mudstones and silty mudstones, commonly with selenite, which is particularly abundant in this formation. Some beds in the upper half of the formation are of a distinctive, dull pale blue colour and contain powdery sulphur-yellow patches (natrojarosite). A number of cementstone nodule beds occur (see below), and beds of small phosphatic pebbles, indicative of minor non-sequences, have been found locally, mainly in the upper part of the formation. These pebbles are irregular black and bluish grey mottled reworked nodules, commonly with a worn appearance and white or yellow vermiform markings on the surface. Many replace bivalves or ammonite body-chambers. The formation contains a fauna of cardioceratid and perisphinctid ammonites and bivalves but, due to weathering, the only fossils to be found at the surface are belemnites (notably large pachyteuthids) and oysters. *Gryphaea dilatata* is very common in the lower part of the formation, ranging to within perhaps 5m of the top:

at some levels it occurs in great abundance, locally making feature-forming beds. As in the West Walton Formation, the shells are often bored and heavily encrusted with epifauna. The flat oyster *Deltoideum delta* (Wm Smith) first appears in quantity perhaps 10m above the base of the formation, and replaces *Gryphaea* in the upper part. It can be distinguished even in small fragments, since the shells are typically thin and of a steel-blue colour, in contrast to the thick, dull grey shells of *Gryphaea*. This sequence of oysters has facilitated mapping of a fault in the south-west.

No exposures of Ampthill Clay were observed during the recent survey, but the full thickness of the formation was penetrated in the BGS Folly Farm Borehole (see Appendix). Due to drilling difficulties, core recovery was only 53% in the Ampthill Clay, and comparison with the downhole gamma ray log run on completion of the hole suggests that recorded core depths are very unreliable. In the cores, the Ampthill Clay extends from 3.31m to c 22.45m (19.14m thick) but on the gamma ray log (using the low gamma peaks of cementstone beds as depth controls), the formation extends from 2.95m to 23.30m (20.35m thick). In the borehole, the bulk of the Ampthill Clay recovered comprises medium grey, smooth to slightly silty mudstones containing a fauna of bivalves and ammonites preserved in white or iridescent aragonite. The uppermost beds, underlying grey Kimmeridge Clay, are pale fawn in colour and include a distinctive cementstone bed (see below). Three other cementstones occurred lower in the sequence at 4.5, 7.65 and 8.65m above the base of the Formation (depths from cores). The higher two of these three may correspond with the lowest two mapped (see below).

In places, cementstone nodule beds have been mapped over short distances, where they form weak features or occur in field brash. All comprise pale grey, smooth- textured argillaceous limestone nodules, up to c 0.25m diameter, weathering with a white, buff or yellow skin. Some nodules are septarian, and are veined with colourless or brown calcite. Probably three beds are represented. The lower two, estimated from mapping to be respectively c 9 and 11m above the base of the Ampthill Clay, have been mapped north-west and south-east of Cranwell Farm [757 165 and 771 154], and on the slopes west of Lower Blackgrove Farm [173 760 area]. In the Waddesdon area to the west,

these beds were tentatively correlated with AC14 and AC17 (by Cox in Sumbler, 1988). South-west of the farm [7618 1728; 7619 1718; 7608 1689], the lower bed has yielded segments of large perisphinctid ammonites and a large myid bivalve. Similar cementstone nodules, probably from this bed, have been dredged from the stream for 250m south of the confluence north-east of Fleet Marston Farm [7807 1698], in association with dark blue-grey clay with fairly common *G. dilatata*. This same cementstone bed, possibly in combination with *Gryphaea*-rich beds, appears to be responsible for a prominent scarp-feature surmounted by a dipslope, between Blackgrove Farm [7636 1866] and Whitesfield Farm [7800 1830], and a less prominent feature on the slopes of Pitchcott Hill [between 7662 1986 and 7766 1919]. The higher bed crops out in the stream bed east of Fleet Marston Farm; abundant nodules of pale grey and cream, sometimes septarian cementstone, associated with *G. dilatata* (often with encrusting epifauna) have been dredged for c 200m along the stream. At one point [7793 1642] fragments of slabby, shelly limestone with oysters and serpulids (suggesting AC17) are associated with the cementstone, and at another [7799 1633] large pieces of perisphinctid, preserved in cementstone, have been dredged. It is probably this bed which has been mapped (on the basis of brash and debris from a gas-pipeline) north-west of Folly Farm [between 7807 1941 and 7876 1891].

A third cementstone, estimated to be c 16m above the base of the formation, has been mapped for short distances near Waddesdon Stud [757 160] and north-east of Berryfields Farm [786 170], and sporadic pieces have been found elsewhere. Though generally similar to the other cementstones, it is associated with clays yielding *D. delta*, and occasionally contains fragments of this oyster. Pieces of an unmapped cementstone dredged from a stream by Ladymead Farm [7596 1994] consist of very soft, pale grey and buff silty or finely sandy limestone with fragments of perisphinctid ammonite. The bed was only partially consolidated, and weathered to a loose silty sand. It is estimated to be c8m above the mapped base of the Formation, although it resembles certain horizons in the West Walton Formation. Loose pale grey silt, possibly from this same horizon, was dredged from a ditch north-west of Fleet Marston Farm [7733 1701].

Generally, a bed of clay perhaps 2m thick, with abundant *D. delta*, occurs near the top of the Ampthill Clay. It locally forms a shelf-like feature, as on the lower slopes of Pitchcott Hill. Within this bed, *D. delta* forms a cemented oyster lumachelle south-east of Briar Hill Farm [7527 1695] and west of Fleet Marston Church [7791 1598]; this probably marks the base of AC36. At the latter locality, associated black phosphatic nodules occur. In the Folly Farm Borehole, abundant *D. delta*, probably representing this bed, occur at 7.10m. Pieces of silty textured cementstone from immediately above this bed on Pitchcott Hill [7718 1977] yielded the inner whorls of a perisphinctid ammonite of early "raseniid" form.

At a few localities, a distinctive bed is developed in the topmost 2m or so of the Ampthill Clay, just above the *D. delta*-rich clays; its local occurrence suggests lenticularity. It is characterised by its abundant and distinctive fauna, dominated by *N. nana, Lopha, Sarcinella* and the large, globose, asymmetric brachiopod *Torquirhynchia*. Debris from excavations resulting from the removal of old farm buildings 500m north-west of Waddesdon crossroads [7532 1704] consisted of pale bluish grey clay with race and pieces of fawn to pale grey crumbly cementstone yielding an abundant fauna including bivalves (arcid, *Ctenostreon, D. delta, Lopha, N. nana, N. "virgula", Pleuromya, Trigonia*) clusters of small gastropods (*Dicroloma*?), brachiopods (*Torquirhynchia inconstans* (J. Sowerby) and a terebratulid), ropes of tiny serpulid tubes (*Sarcinella*), pentacrinoid columnals and echinoid spines. It forms a broad shelf-like outcrop to the south of the A41 road near Wormstone Farm [752 164]. Additional fossils here include *Camptonectes, Chlamys, Oxytoma, Serpula*, and locally, various corals including *Thamnasteria* and thecosmiliids. Corals are particularly abundant 250m north-east of the farm [7512 1648], forming large slabs of greyish brown crystalline limestone. Ammonites are rare, though two perisphinctid fragments were found. A similar, though less abundant fauna has been found at the same horizon north of Berryfields Farm [786 168] (*Lopha, N. nana*, a rhynchonellid) and amongst dredgings from the stream 1.5 km to the north-east [7981 1755] (*N. nana* and a rhynchonellid). A similar facies is mentioned by Arkell (1947, p.104) south-west of Oxford (though he assigned it to the Kimmeridge Clay), and has more

recently been recorded in boreholes just east of Oxford, and several localities near Waddesdon (Sumbler, 1988; Cox & Sumbler, in press). It probably correlates with AC40-42 of the standard sequence.

In the Folly Farm Borehole, the topmost 1.2m of the Ampthill Clay consist of pale greyish fawn mudstone with a 0.38m thick fawn cementstone; similar lithologies to those just described. Debris from these beds was excavated from land-drains to the east [7977 1906 to 8000 1893]; they weather to a fawn and very pale grey silt, contrasting strongly with the grey clays above and below, and yield a few *Lopha* and *Nanogyra*. Slightly lower in the sequence nearby [8001 1908], cementstones associated with pale grey clays with race yielded moulds of small gastropods and bivalves, together with *Microbiplices*? and oyster fragments including *D. delta*. These faunas and lithologies are similar to the AC40-42 assemblage described above.

KIMMERIDGE CLAY FORMATION

The main outcrop of the Kimmeridge Clay lies in the south and east of the Fleet Marston area, forming the slopes of Waddesdon Hill in the south-west, and low ground traversed by the River Thame in the south-east. North of this, several subdued, partially drift-capped hills are outliers formed by the lowest beds of the Formation. On the northern margin of the map, a small area of Kimmeridge Clay is part of an extensive outcrop forming the conjoined Pitchcott, Oving and Whitchurch Hills to the north, which are capped by post-Kimmeridgian beds.

The Kimmeridge Clay is poorly exposed. Like the other mudstone formations, it forms a grey clay soil. The base of the formation is inferred to lie just above the *D. delta*-rich beds of the Ampthill Clay (?AC36) or immediately above the *Lopha*-rhynchonellid bed (AC40-42) where present (Cox & Sumbler, in press); these beds typically form a shelf below steeper slopes of Kimmeridge Clay. This change of gradient has been used to map the base of the formation where exposure is particularly poor. Locally, phosphatic nodules have been found at this level, suggesting a non-sequence. The basal bed of the Kimmeridge Clay was cored in the BGS Folly Farm Borehole [7958

12904] (3.13 to 3.31m depth; see Appendix). It consists of grey silty mudstone with angular phosphatic chips including ammonite segments, and rests with a sharp, interburrowed base on the pale mudstones of the topmost Ampthill Clay.

Seen fresh in boreholes, the Kimmeridge Clay consists of rhythmic sequences comprising (in ascending order) siltstone, dark grey mudstone, and pale grey calcareous mudstone, the last commonly with cementstone bands. In some cases in the middle and upper part of the formation, the basal member of these cycles is an oil shale. Thin beds of sand and silt have been mapped on the slopes of Waddesdon Hill.

The full thickness of the Kimmeridge Clay Formation is estimated to be c 45m, somewhat thinner than in the Brill and Hartwell boreholes of adjoining districts (55m and 47m respectively; Cox 1987, 1988a). Reconnaissance mapping suggests that it may be thinner still on Quainton, Pitchcott, Oving and Whitchurch Hills immediately north of the area. Though partly the effect of cambering and sliding of overlying beds, this probably indicates that there was erosion of the topmost part of the Kimmeridge Clay prior to deposition of the Portland Formation.

Unweathered Kimmeridge Clay yields an abundant aragonitic fauna of ammonites and bivalves but, at the surface, fossils are generally rare. Sporadic pieces of thin-shelled oyster occur, but *Gryphaea* and *Deltoideum*, common in the Ampthill Clay, seem to be absent. *Nanogyra nana* occurs rarely in the basal beds, and the distinctive striate *N. virgula* Defrance appears a few metres above the base of the formation, often in association with *Laevaptychus* (the calcitic jaws or opercula of the ammonite *Aspidoceras*).

Pieces of nodular cementstone have been found near the base of the Kimmeridge Clay at a number of localities. They consist of grey silty to very finely sandy argillaceous limestone weathering to a brownish colour, in some cases weakly veined with white or colourless calcite and frequently containing scattered aragonitic shells and shell fragments, preserved as white, finely crazed, films. Mapping suggests that only one bed is represented, c 5m above the base of the

Formation. Fossils suggest that it is KC30 of the standard sequence, proved 7m above the base of the Formation in the Hartwell Borehole (Cox, 1988a). It is locally associated with a weak topographic feature, and seems to cap the hills of Kimmeridge Clay in the eastern part of the map. In many places it overlies pale grey clay with race and abundant *N. virgula* and sporadic *Laevaptychus*. Pieces of the cementstone collected east of Briar Hill Farm [7547 1701], from a gas pipeline trench north-east of Berryfields House [7957 1659], from a ditch and trench south-south-east of Folly Farm [7949 1800; 7960 1787] and from a water pipe trench and debris in the road cutting at Quarrendon [7889 1550; 7872 1551; 7865 1552; 7862 1552], have yielded *Aspidoceras, N. virgula, Protocardia*, an arcid, other indeterminate bivalve fragments, and sporadic serpulids. Associated mudstones (probably KC29 or 31) from the road cutting [7898 1548; 7886 1550] comprised bluish grey fissile shelly mudstone and brownish oil shale, with much selenite. They yielded *Aspidoceras, Laevaptychus, Amoeboceras, Amoeboceras (Nannocardioceras), Aulacostephanus* ex gr. *volgensis* (Vischniakoff), *Sutneria, Bositra, Liostrea, 'Lucina' minuscula* Blake, *N. virgula* and *Protocardia*. Two cementstones mapped for a short distance north-east of Coneyhill Farm [765 152] are probably from a slightly higher level.

Pieces of silty septarian cementstone with honey-coloured calcite-veining were collected from higher in the sequence north of Waddesdon Stud [7541 1593]. They contained perisphinctid ammonite, bivalve and serpulid fragments. Comparison with a section at Watermead, Aylesbury [829 155] (Oates, in prep.) and the Hartwell Borehole suggests that this bed may be KC44 (the upper cementstone of Oates' section), proved c 18m above the base of the Formation in the borehole (Cox 1988c). Nearby [7535 1594], approximately 5m higher in the sequence, nodules of grey porcellanous (non-silty) cementstone with marked *Chondrites* mottling, and black phosphatic nodules and bivalve casts (including myids), occur in pale grey clay soil with race nodules, and a single whorl fragment of a large perisphinctid was found. The lithologies suggest correlation with the Lower Lydite Bed (at 35.6m depth in the Hartwell Borehole, i.e. c 29m above the base of the Formation) and the underlying beds of the Pectinatus Zone.

On the western margin of the map [7500 1592], a thin bed of grey to orange silt and fine sand forms a feature and gives rise to seepage. It lies just above a cementstone bed (probably KC30). Though no sand/silt beds occur in the Hartwell Borehole at this level, it may lie within KC31, which in the Brill Borehole included silty mudstones (at c67m depth). Sand beds higher in the Formation form features [7510 1525; 7500 1580] and give rise to seepage and small landslips [7580 1573]. In auger samples they appear as dull grey, or pale orange and red, very fine sands. Because of the likelihood of slippage and cambering, the stratigraphic position of these sands is uncertain, but it seems likely that they represent a single bed slightly above the mottled cementstone mentioned above, and they may mark the base of the silty "Hartwell Clay" (Sumbler, 1989; Oates in prep.). The most persistent sand bed is at the top of the Kimmeridge Clay, immediately below the Portland Formation. Dull grey to brown fine-grained sand and clayey sand crops out sporadically, but much of the outcrop is obscured by material cambered from above.

PORTLAND FORMATION

The Portland Formation (with overlying beds) caps Waddesdon Hill (=Coney Hill of some authors). The Formation is very poorly exposed, the outcrop being largely pastureland. The beds are strongly affected by cambering, making thickness estimates uncertain. In the terminology used by Cope et al. (1980), the Formation is divisible into five units:

Portland Stone:	Creamy Limestones
	Crendon Sand
	Aylesbury (Rubbly) Limestone
Portland Sand:	Glauconitic Beds
	Upper Lydite Bed

Portland Sand Member

The Portland Sand forms the lower part of the Portland Beds, probably (see below) equating with the Glauconitic Beds and underlying Upper Lydite Bed. It comprises perhaps 5m of yellow-weathering, brown, medium-grained, marly sand and pale grey to cream, nodular, sandy limestones. Typically, the beds contain abundant glauconite as black to olive-green grains. The base of the Portland Sand is commonly marked by a seepage line, as at Waddesdonhill Farm [7555 1557], and the outcrop of the beds is typically marked by animal burrows; there is a large rabbit warren west of North Lodge [758 151] and an extensive badger sett near Waddesdonhill Farm [757 156]. Generally, the Upper Lydite Bed forms a useful marker at the base of the sequence in Buckinghamshire, although within the Fleet Marston area, it has been observed in only one place, 200m south-east of Coneyhill Farm [7644 1501]. Here the soil consists of rust-brown sand with rare rounded pebbles of black chert (lydites *sensu stricto*), quartz and quartzite, typically from 5 to 10mm diameter.

Portland Stone Member

The Portland Stone consists of about 5m of limestones which apparently vary rapidly in lithology, both laterally and vertically. Several different limestone types occur on Waddesdon Hill, though due to lack of exposure and the repetition of beds due to cambering etc., no consistent sequence could be determined. Almost all contain a rich marine fauna. Typical rock types include rubbly bioclastic limestone packed with serpulids and oysters (mainly in the lower part of the sequence, ?Aylesbury Limestone), white to yellow, strongly burrowed micrite and peloidal micrite with large bivalves (*Protocardia*, *Trigonia*) and giant ammonites (*Titanites*), and hard pale grey fine-grained recrystallised limestone (mainly in the upper part of the sequence).

A section in an old quarry [7585 1513] west of Coneyhill Farm (now ploughed over) is recorded by Davies (1899, p.35). Beneath 2.14m of higher beds, it showed c 2.2m of Creamy Limestone:

4. Thin bedded limestone	0.30m
3. Massive creamy and chalky limestone with *"Trigonia, Cardium, Ostrea, Natica"*	0.61m
2. Thin-bedded limestone and marl	0.46m
1. Massive creamy limestone	0.86m

Blake (1880, p.216) also mentions "a very important section" at "Coney Hill", but fails to give details of the location; it may well be the pit already mentioned. His account is disjointed and may include generalizations not specifically applicable to the section. With this proviso, on piecing together his description we have (from the top downwards)

1. Compacted shell brash, in two blocks, the upper with *Trigonia* at the base: ?4 ft=	1.2m
2. Creamy limestone, in three blocks, the uppermost (1ft) very fossiliferous, the middle (4ft) hard, the lowest (4ft) with *Trigonia* and other fossils: 9ft=	2.7m
3. Yellowish brown, non-glauconitic sand, serpulid-rich in the basal 6in: 5ft=	1.5m
4. Rubbly limestone with internal casts of shells: 8ft=	2.4m

Comparison with sections at Aylesbury and Stone (Sumbler, in prep.) suggests that Bed 4 is the Aylesbury (Rubbly) Limestone, Bed 3 the Crendon Sand, and Beds 1 and 2 the Creamy Limestone. However, as the total thickness of the section (7.8m) is rather greater than that estimated (from mapping) for the Portland Stone Member, and as no sign of sand (Bed 3) has been observed within the mapped outcrop of Portland Stone, there is a slight possibility that Beds 3 and 4 have been mapped with the Portland Sand. If so, it follows that either the mapped Portland Sand (at least locally) includes the Aylesbury Limestone and Crendon Sand, or (less likely) that Beds 3 and 4 should be assigned to the Glauconitic Beds, in which case the Crendon Sand is absent hereabouts.

PURBECK FORMATION

The Purbeck Formation, like the Portland, consists of limestones and marls, but differs in being mainly non-marine ("lagoonal"). Fauna is generally sparse, though small bivalves and gastropods are abundant in some beds. Ostracods are common at some levels and are used in biozonation, since ammonites (used in the Portland and underlying Jurassic beds) are absent.

The Formation is very poorly exposed, being largely obscured by wash from the overlying Whitchurch Sand, and the outcrop boundaries shown on the map are generalised. Typical Purbeck lithologies occur in the brash in a few places. West of the old quarry [7572 1517], fissile limestone, comprising alternating layers (5 to 10mm) of grey, slightly sandy shell-fragmental, ostracod-rich limestone and cream, pure micrite, overlies Portland lithologies: this is the Pendle, a useful marker bed at the base of the Buckinghamshire Purbeck. Higher in the sequence to the west [7558 1524], pieces of white and brown-mottled micrite with shrinkage cracks (suggestive of penecontemporaneous subaerial emergence) occur. East of Waddesdonhill Farm [7588 1552], white micrite with stromatolitic laminae again suggest shallow conditions and periodic emergence.

According to Davies (1899, p35), Purbeck beds were exposed above Portland strata in the old quarry [7585 1513] (now obscured; see above):

11.	Soil, with small limestone fragments and lydite pebbles	0.30m
10.	Drift, with abundant limestone fragments	0.30m
9.	Calcareous sand, finely laminated	0.38m
8.	Sandy marl	0.20m
7.	Friable laminated limestone	0.36m
6.	Massive limestone	0.30m
5.	Friable laminated limestone	0.30m

The subsoil, Bed 10, is probably a disturbed in situ limestone, giving a total of c 1.8m of Purbeck Beds. Bed 5 is probably the Pendle, as described above.

WHITCHURCH SAND FORMATION

Ferruginous sands overlie the Purbeck Formation on Waddesdon Hill. Though this outcrop and all others in the region are classified as Lower Greensand [Cretaceous] on the Old Series Geological Survey maps, some have yielded non-marine fossils, whereas the true Lower Greensand is marine. Casey & Bristow (1964) showed that at Quainton Hill [748 221] and Whitchurch [802 207], there are sands of "Purbeck" age as well as Lower Greensand. They introduced the name Whitchurch Sand for these beds and thought that the similar Shotover Ironsands of the Oxford area (Pocock, 1908; Arkell, 1947) were younger (of "Wealden" age). On the basis of its fauna, they correlated the Whitchurch Sand with the basal Cretaceous Cinder Bed of Dorset, although Morter (1984, pp230, 231) concluded that both the type Whitchurch Sands and the Shotover Ironsands are of Lower and Middle Purbeck (late Portlandian), i.e. youngest Jurassic, age.

The Whitchurch Sand outcrop is largely covered by grassland, and there are no exposures. Probably c 4m of beds are present. In the arable field east of Waddesdonhill Farm [758 154], the Formation gives rise to a reddish brown sandy loam soil, locally with a brash of hard, dark brown to purple-black "limonite"-cemented sandstone (commonly hollow "boxstones" containing loose orange sand) and rare concentric nodules of purple "limonite". Fine to medium-grained reddish brown sand with small chips of "limonitic" ironstone is thrown out from rabbit burrows in the road cutting [7584 1528]. The "limonitic" sandstone probably occurs as lenses and concretions in an originally calcite-cemented sand, as in the "Brown Sands" of the Bedfordshire Lower Greensand. The sand is now largely decalcified, although pieces of yellow calcareous sandstone form a brash south of Waddesdonhill Farm [7560 1526]. East of the farm [7576 1552], a thin lens of pale grey and dark brown ferruginous clay has been mapped at the base of the sequence.

STRUCTURE

Over most of the area, the regional dip of the Upper Jurassic beds is calculated at roughly 0.4 (7m/km) to the south-east, but there are local deviations associated with faulting in the south-west corner of the map.

Because of the general lack of marker bands in the Upper Jurassic mudstones, faults are difficult to detect and it is possible that faults other than those shown on the map may exist. The main fault shown, trending south-eastwards through Briar Hill Farm [751 171] is inferred from the northward displacement of the topmost Ampthill Clay *Lopha*-rhynchonellid bed from its main outcrop to the south. The south-eastward continuation of this fault, between Waddesdon crossroads [7575 1672] and Fleet Marston Spinney [7755 1506] has been mapped on the basis of the apparent reversal of the normal sequence of fossil oysters in the Ampthill Clay. The throw of this fault is probably c 5m to the north. Two shorter faults with the same south-east trend have been mapped. That north of Waddesdon Stud [754 160] again displaces the topmost Ampthill Clay; cementstone markers in the Kimmeridge Clay to the south of the fault (see above), suggest a local south-westward throw of c 15m. The fault cutting the Portland outcrop of Waddesdon Hill [755 151] produces a small linear scarp feature in the fields; its south-westward throw is probably no more than 1 or 2m. A fault of north-eastward trend passing north of Putlowes Farm [782 152] is the continuation of a long fracture in the area to the south (Sumbler, 1989).

Superficial structures are common wherever steep slopes of mudstone are capped by resistant beds; the margins of the Portland outcrop are strongly affected in this way. These structures probably developed mainly during the cold stages of the Quaternary epoch. They result from fracturing, squeezing and wastage of the clays, leading to collapse of the overlying beds, which then extend downslope as a "camber" of disjointed blocks which conceal the underlying mudstones. The collapsed material often occurs as large blocks bounded by step faults subparallel to the hill contour ("dip and fault"). In small

exposures, the beds can appear to be in situ, and because cambers extend downslope to levels well below the original base of the beds, this can lead to overestimates of the thickness of a unit.

QUATERNARY

TILL

Thin deposits of till cap the low hills in the east and south-east of the area, near Folly Farm [795 185; 794 177] and near Putlowes Farm [779 153]; these are probably remnants of a once continuous sheet, now dissected by stream valleys. Small remnant pockets of till occur on the hills north-east of Berryfields Farm [785 165; 791 168], but are of insufficient extent to be mapped.

The deposits rarely exceed c 1.5m in thickness, and are strongly affected by weathering. Typically, the till consists of a brown-weathered clay containing abundant flint and Bunter quartz and quartzite pebbles up to 100mm diameter; it is locally quite gravelly. At depth in ditches and auger samples, the till is grey in colour and locally, contains grains and small pebbles of chalk. In some places, particularly near the base of the deposit the till is composed of reworked Kimmeridge Clay with few erratics: it consists of a blue grey clay with deformed lamination and "streaked out" fossils, and commonly contains abundant race. The till deposits of the area are presumably contemporaneous with the more extensive deposits of chalky till to the north and north-east, which are generally thought to be of Anglian age.

In addition to the tills described above, a scattering of flint, Bunter and ironstone pebbles occurs throughout the district; this testifies to the former extent of glacial deposits in the area, and may include remnants of pre-Anglian deposits.

GLACIOFLUVIAL SAND AND GRAVEL

A thin deposit of clayey sand and gravel, presumably genetically related to the tills, caps the hill north of Folly Farm [794 194]. It forms a plateau of brown loam with abundant flint, Bunter and ironstone pebbles, typically from 10 to 30mm diameter. Small pebbles of Portland limestone and chalk occur locally, and are common at depth in auger samples. Similar clayey gravel, composed predominantly of flint and Bunter pebbles caps the hill west of Putlowes Farm [778 150]. Though here classified as glaciofluvial, it may alternatively be an early terrace deposit of the River Thame.

RIVER TERRACE DEPOSITS

Deposits of the River Thame form a terrace adjoining both sides of the modern alluvial floodplain at Quarrendon in the south-eastern corner of the map [793 158; 798 152]. Provisionally designated the Thame First Terrace, from a maximum of perhaps 2m above the floodplain, it slopes gradually down towards the river, and grades imperceptibly into the floodplain. In contrast to the alluvium, the deposits of the terrace consist of a reddish brown sandy gravel, containing mainly flints with subordinate Bunter pebbles. The gravel is locally covered by a reddish brown silty clay. Site investigation boreholes drilled in connection with the housing estates south-east of the river prove up to 3m of deposits; they thus extend well below the level of the alluvium, and are probably contiguous with gravels which occur in the river bed.

ALLUVIUM

Alluvium, i.e. stream and river deposits, occur in the valley of the Thame and its tributaries; particularly extensive spreads have accumulated in the broad valley of the "Blackgrove Brook" [750 185 to 780 170]. The alluvium consists primarily of reworked local Upper Jurassic clays. At the surface it forms a poorly drained, dark brown, slightly loamy, locally peaty clay soil; deeper down in ditches and auger holes it is grey and fawn, and is almost indistinguishable from

weathered in situ mudstone. Locally however, it contains gravelly pods and lenses with small fragments of Gryphaea and belemnites, flint, Bunter pebbles, ironsand and Portland/Purbeck limestone. The alluvium of the tributaries rarely exceeds 1.5m in thickness, but is up to 3m thick in the Thame valley and (locally, at least) overlies sand and gravel (probably a metre or two thick) which may equate with the First Terrace Deposits (see above).

HEAD (Colluvium)

These deposits are formed of material that have moved downslope. It includes materials transported by rainwash or soilcreep (processes which continue to the present day) and solifluxion deposits (which probably date from cold stages of the Quaternary era). Head is widespread on the lower slopes of the hills of the area, although only the thickest and most extensive deposits, which have accumulated in shallow depressions and valleys, have been mapped. The lithology of the deposits closely reflects the nature of the source material; they consist of loamy clays, derived from the Kimmeridge Clay, Ampthill Clay and West Walton Formation, locally with an admixture of subangular debris of Portland and Purbeck limestone, and ironstone from the Whitchurch Sand. In places, head is difficult to distinguish from in situ weathered mudstone, and for this reason deposits other than those shown on the map may exist. The extensive deposits north of Lower Blackgrove Farm [765 176] and south of Fleet Marston Farm [774 158] have almost flat surfaces and have undoubtedly been partially reworked by streams.

LANDSLIP

A small landslip has been mapped on the northern slope of Waddesdon Hill [758 157], where clays have been weakened by seepage from a bed of sand high in the Kimmeridge Clay. The landslip forms an area of wet, hummocky ground, with an extensive growth of rushes. A telegraph pole sited on it leans eccentrically, suggesting that the slip is still active. It is possible that other slips occur which have been disguised by agricultural improvements.

ECONOMIC GEOLOGY

In many places in adjoining districts, the Upper Jurassic mudstones have been worked for brick and tile manufacture, and it is likely that some ponds in the Fleet Marston area may have originated as brickpits, though there are no currently active workings.

The Portland Stone has been worked on Waddesdon Hill. Most of the material was probably used as rubble for road building, as high quality building stone is resricted to a few beds in the upper part of the sequence (Creamy Limestones). Limestone resources are probably insufficiently thick or extensive to be of commercial interest at the present day.

Glaciofluvial and river terrace deposits are probably too thin to be of commercial interest as a resource of sand and gravel. Similarly, the Whitchurch Sand, though locally including fairly clean sands, is very thin and of limited extent.

As most of the area is underlain by mudstone, there is little potential for groundwater abstraction. The Great Oolite Group, the only aquifer of significant capacity, is at a depth of c90m in the north-west of the area, and c180m in the south. The Portland and later beds of Waddesdon Hill form a small aquifer giving rise to small but reliable springs around the margins of the outcrop, as near Coneyhill Farm [7613 152].

Ground conditions over most of the area are unlikely to pose any unusual problems to construction and development provided appropriate building practise is followed. However, care should be exercised when planning developments on the steeper slopes of the area, as these are likely to be unstable, particularly where covered by superficial deposits (notably head) or affected by landslip or cambering. The depiction on the map of head and landslip may not be fully comprehensive.

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Appendix

Folly Farm Borehole, Whitchurch, Buckinghamshire. SP 7958 1904. SL c+91.5

75mm cores examined by M.G. Sumbler, February 1989. Core recovery 63% from 3.13m: all cores sheared by drilling.

	Thick-ness	Depth
Kimmeridge Clay		
No core	3.13m	3.31m
Clay, brown and grey mottled with tiny selenite crystals in ramifying veins	0.11	3.24
Mudstone, silty, medium to dark grey. Much fine shell dust; crushed fossils abundant in some layers. Small black phosphatic chips, up to 5mm diameter from 3.26. Sharp, interburrowed base	0.07	3.31
Ampthill Clay		
Mudstone, smooth to slightly silty, pale greyish fawn, with some brown mottles. Scattered shell fragments and locally abundant shell dust. Pyritic *Chondrites* and burrows infilled with dark mudstone as above with phosphatic chips. Some bluish grey veins with selenite crystals	0.36	3.67
Cementstone, pale greyish fawn, moderately hard. Scattered shell dust and a few small pebbles of dark grey siltstone in lower part	0.38	4.05
Mudstone, slightly silty, pale fawnish grey, veined with tiny selenite crystals. Scattered shell dust; a few *Nanogyra* and *Lopha*	0.47	4.52
Core lost	2.37	6.89
Mudstone, slightly silty, medium to dark grey. Abundant shells and shell debris; many *D. delta* 7.02 to 7.10. Some fawn incipient phosphatic nodules	0.66	7.55
Core lost	3.35	10.90
Mudstone, smooth to slightly silty, dark slightly brownish grey, with abundant fossils including bivalves, serpulids and belemnites	0.51	11.41
Mudstone, smooth to slightly silty, medium grey, with scattered shell dust. Unfossiliferous. Burrows infilled with darker mudstone as below in lower half	0.19	11.60

Mudstone, slightly silty, dark grey. Scattered shell fragments and dust; sporadic crushed bivalves and ammonites; some cryptic burrow mottling	0.80	12.40
Mudstone, smooth to slightly silty, medium grey. Sporadic shells and serpulids	0.30	12.70
Mudstone, smooth to slightly silty, dark grey, with scattered shell dust. Sporadic shell fragments and shells including bivalves and serpulids; burrows of darker silty mudstone	0.35	13.05
Mudstone, smooth to slightly silty, medium grey, with burrows of darker mudstone. Common bivalve and ammonite shells and shell fragments, including *D. delta*	0.45	13.50
Mudstone, silty, medium to dark grey, with shell dust and sporadic bivalves	0.25	13.75
Cementstone, pale grey	0.05	13.80
Core lost	0.90	14.70
Cementstone, grey, with common shell fragments	0.10	14.80
Mudstone, slightly silty, medium grey. Much shell dust; sporadic crushed bivalves	0.13	14.93
Mudstone, smooth, pale to medium grey. Sporadic shells and pyrite trails; burrows of darker mudstone with shell dust	0.41	15.34
Mudstone, smooth to silty, medium grey. Packed with bivalve and ammonite shells	0.05	15.39
Core lost	0.38	15.77
Mudstone, smooth, medium grey. Sporadic pyrite trails and shells including small *Gryphaea* at base	0.25	16.02
Mudstone, silty, medium grey. Much shell dust, shells and fragments; common *Gryphaea*	1.41	17.43
Core lost	0.29	17.72
Mudstone, smooth to slightly silty, medium grey. Sporadic pyrite trails; bivalves including *Gryphaea*	0.20	17.92
Cementstone, medium grey, with *Gryphaea*	0.03	17.95
Mudstone, smooth, pale grey. Sporadic pyrite trails. Sparse fossils including *Gryphaea*	0.55	18.50
Core lost	1.51	20.01
Mudstone, slightly silty, medium to dark grey. Scattered shell fragments including bivalves, ammonites and common serpulids. Slightly silty with shell and plant dust in lower part	0.39	20.40

Mudstone, slightly silty, medium grey, interburrowed with dark grey silty mudstone with plant specks. Common bivalves 0.26 20.66

Core lost 0.24 20.90

Mudstone, slightly silty, medium and dark grey burrow mottled. Scattered shell and plant dust. Sporadic pyrite trails and bivalves 0.22 21.12

Mudstone, slightly silty, medium grey, with much shell dust. Fairly common shells and shell fragments. Sporadic pyrite trails. Interburrowed base 0.38 21.50

Mudstone, silty, medium grey, with much shell dust and some plant specks, becoming coarse and more abundant downwards. Common shells including bivalves and ammonites 0.95 22.45

West Walton Formation

Mudstone, silty, pale to medium grey, with shell dust, shells and shell fragments 0.25 22.70

Mudstone, silty, pale to medium grey; some layers with shell dust. Phosphatic chips at 22.82 0.80 23.50

Cementstone, pale to medium slightly brownish grey. Some small burrows and occasional bivalve moulds and fragments 0.09 23.59

Mudstone, silty, pale to medium grey with sporadic pyrite trails. Scattered plant specks and some shell dust in lower part 0.45 24.04

Cementstone medium to pale grey, with some plant specks 0.16 24.20

Mudstone, slightly silty, pale to medium grey, with diffuse burrow fills of plant speckled mudstone 0.65 24.85

Mudstone, silty, medium grey, with much shell and plant dust. Burrows of smoother paler mudstone. Sporadic shell fragments and fossils including *Gryphaea* 0.26 25.11

Core lost 0.39 25.20

Mudstone,silty, medium grey with shell and plant dust. Sporadic shells and shell debris 1.15 26.25

Core lost 0.22 26.87

Mudstone, silty, medium grey with paler burrows. Much coarse shell and plant dust; rare shell fragments 0.83 27.70

Mudstone, slightly silty, pale to medium grey. Strong burrow mottling. Fossils rare 0.50 28.20

Mudstone, very silty, medium to dark grey with abundant shell dust	0.45	28.65
Mudstone, slightly silty, pale to medium grey. Common pyrite trails, some fine shell dust. Fossils rare. Some more silty layers in lower part	0.80	29.45
Core lost	0.46	29.91
Mudstone, silty, medium grey with burrows infilled with darker more silty mudstone with shell and plant dust	0.32	30.23
Cementstone, very silty, medium grey with scattered fine shell and plant dust; to bottom of borehole at	0.27	30.50

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