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TECHNICAL REPORT WA/89/67

Onshore Geology Series

TECHNICAL REPORT WA/89/67

Geological notes and local details for 1:10 000 sheets SP 71 SE (Stone)

Part of 1:50,000 Sheet 237 (Thame)

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INTRODUCTION

This account describes the geology of 1:10 000 Sheet SP 71 SE (Stone), one of the constituent maps of 1:50 000 Geological Sheet 237 (Thame) which will be published in due course. It is based on a geological survey carried out by M.G. Sumbler in the spring of 1988. Stratigraphic palaeontology was undertaken by Dr B.M. Cox (1988b, 1989). Appendix 1 (an abbreviated lithological log of the BGS Hartwell Borehole) is based largely on work by R.W. Gallois.

The area 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. The geology of Sheet 45 is described by Green (1864), but there is no corresponding account of Sheet 46. All but the western margin of the area was resurveyed on the six-inch scale by A.C.G. Cameron and A.J. Jukes Browne, probably in the mid 1890s, for a drift edition of Sheet 46 (six-inch maps Buckinghamshire 28 and 33). A large-scale (c 1:20 000) map covering much of the eastern part of the area, was published by W.H. Smyth (1864). Probably the work of Smyth's son, the geologist C.P. Smyth, it is superior in many respects to the later Geological Survey maps. The area was included in the study by Ballance (1960, 1963) who surveyed the beds between the Kimmeridge Clay and Gault on the 1:25,000 scale.

Because of inadequacies of these maps, the resurvey of Sheet 237 was commenced in 1986, initially partly funded by the Thames Water Authority.

The geological map gives an indication of the outcrop limits of various deposits. These are for the most part concealed beneath soil and vegetation, and so geological boundary lines are largely inferred from indirect evidence, such as soil type and the form of the ground surface, or are extrapolated on the basis of inferred geological structure. The map is thus the subjective interpretation of the surveyor, and all geological boundaries carry an element of uncertainty. Boundaries of solid geological formations 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. Boundaries of drift deposits are shown as pecked lines.

The topography of the Stone area is dominated by the valleys of the River Thame and its tributaries which are underlain mainly by Kimmeridge Clay. The high ground confining the valleys is made up of more resistant Portland and Purbeck strata, locally capped by late Jurassic and early Cretaceous beds including Gault Clay. The soils of the area are mostly clays formed either directly from the Kimmeridge and Gault mudstones or derived secondarily from alluvium or head, but sandy soils are developed on the highest beds of the Kimmeridge Clay, the lower part of the Portland, and the beds immediately above the Purbeck Formation. The upper part of the Portland Formation and the Purbeck beds give rise to very variable brashy soils.

The north-eastern corner of the area includes a small part of Aylesbury, the county town of Buckinghamshire. Aylesbury has expanded greatly in recent years; there is continuing development in the Rabans Lane industrial area [795 145], and the building of a proposed ring-road in the near future will doubtless encourage further development in the eastern part of the map. However, most of the area is pleasantly rural. Stone, 4km south-west of Aylesbury on the Thame road, is the only major village; the rest of the area is almost entirely farmland. At the time of survey, roughly 40% was grassland used mainly for sheep and dairy cattle. The arable land forming the remainder was used mainly for wheat and barley.

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

Equivalent reports covering adjoining sheets are:

SP 71 NW (Waddesdon)	Sumbler (1988)
SP 71 NE (Fleet Marston)	Sumbler (1989)
SP 71 SW (Chearsley)	Barron (1988)
SP 81 NW (Bierton)	Barron (1989)
SP 81 SW (Aylesbury)	Sumbler (in prep. a)
SP 80 NW (The Kimbles)	Sumbler (in prep. b)
SP 70 NE (Aston Sandford)	Sumbler (in prep. c)
SP 70 NW (Thame & Haddenham)	Lake (1989)

GEOLOGICAL SEQUENCE

DRIFT:

QUATERNARY:	HEAD (Colluvium)
	ALLUVIUM
	RIVER TERRACE DEPOSITS
	GLACIOFLUVIAL SAND AND GRAVEL

SOLID:

CRETACEOUS:	GAULT
	LOWER GREENSAND
JURASSIC:	WHITCHURCH SAND FORMATION
	PURBECK FORMATION
	PORTLAND FORMATION
	KIMMERIDGE CLAY FORMATION
	CONCEALED STRATA

JURASSIC

CONCEALED STRATA (Great Oolite Group to Ampthill Clay)

The oldest strata cropping out in the Stone area belong to the lowest part of the Kimmeridge Clay. Underlying beds were penetrated in The BGS Hartwell Borehole (see below) and also in a borehole drilled before 1855 at Stone Hospital [7782 1206], then the Bucks County Lunatic Asylum. This borehole is referred to by Phillips (1871, p.297), Woodward (1895, pp337, 338) and Whitaker (1921, p.162, 163), but the log is very sketchy, with few bed thicknesses recorded. Below the base of the Portland Beds at 7.6m (25 feet) the bore entered blue clay with limestone bands. "Sandy Clay" (no thickness given) at 530 feet (=161.5m) is almost certainly Kellaways beds, giving a total of 154m for the Ancholme Clay Group (Kimmeridge Clay, Ampthill Clay, West Walton Formation, Oxford Clay, Kellaways Beds). This figure is slightly less than the 161m estimated in the Waddesdon area (Sumbler, 1988). There is no indication of Corallian beds (Cumnor Formation) in the borehole log. Some 12.2m (40 feet) of Great Oolite was penetrated, mainly described as oolitic rock and blue clay. Probably the Cornbrash, Forest Marble and White Limestone Formations were represented.

The upper part of the Ampthill Clay Formation was proved in the BGS Hartwell Borehole [7926 1223], (Figure 1 and Appendix 1). The total thickness of the Formation is probably c 20m (Sumbler, 1989). It consists mainly of medium to dark grey mudstones and silty mudstones, with a number of cementstone nodule beds mostly in the middle and upper part of the formation, and phosphatic pebble beds, indicative of minor non-sequences, mainly in the upper part of the formation. The formation contains a fauna dominated by cardioceratid and perisphinctid ammonites and bivalves, notably oysters. Of these, *Gryphaea dilatata* J.Sowerby is very common in the lower part of the formation, and the flat oyster *Deltoideum delta* (Wm Smith) in the upper part, replacing *Gryphaea*.

Cementstone nodules collected near the margin of the map north of Stone, if correctly identified as bed KC30*, suggest a level low in the Kimmeridge Clay hereabouts. If this is so, beds in the nearby valleys [775 150; 784 150] must be very close to the base of the Kimmeridge Clay, and it is possible that the very highest beds of the Ampthill Clay are exposed.

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*In the following account, bed numbers given in the form AC1, KC1 etc. refer to the standard Ampthill Clay and Kimmeridge Clay sequences established by Gallois & Cox (1974, 1976, 1977) and Cox & Gallois (1979; 1981) in an area south of The Wash.

In the Hartwell Borehole, the upper half of the Ampthill Clay was penetrated between 64.98m and the bottom of the borehole at 76.69 (see Appendix 1 and Figure 1). Below 69.88m, the sequence comprises mainly smooth medium to pale grey, generally poorly fossiliferous mudstones, with pyrite trails and pins, though somewhat darker mudstones between 71.00 and 72.68 are more shelly, with bivalves (particularly *Protocardia*), belemnites and ammonites. These 6.81m of beds have been correlated with AC17-26 (Cox, 1988a). A gritty mudstone with phosphatic pebbles and chips at 69.88m marks a non-sequence at the base of AC36. Beds AC27-35, though absent here, were apparently present in the BGS Brill Borehole [6570 1412], c 14 km to the west-north-west (Cox, 1987). Above 69.88m, the mudstones similar to those below, though generally more shelly. Between 67.90 and 69.02, they contain phosphatic patches, nodules and pebbles and, at 69.50 and 70.90, shell "plasters" of *D. delta*. The topmost 1.82m of the Formation (i.e. 64.98 to 66.80m) comprise very pale grey calcareous mudstones with two smooth pale grey cementstone bands which contrast with the darker mudstone beds below. These lithologies suggest AC40-42, which at outcrop to the north has yielded an abundant and distinctive fauna including brachiopods and corals (Sumbler, 1988, 1989; Cox & Sumbler, 1989).

KIMMERIDGE CLAY FORMATION

The outcrop of the Kimmeridge Clay Formation occupies over half of the Stone area. Almost the full thickness of the Kimmeridge Clay Formation is represented at outcrop, though it is very poorly exposed due to a widespread cover of head and hill-wash. The whole formation was proved in the BGS Hartwell Borehole [7926 1223] (in which it was 47.03m thick; see below) and the topmost part was formerly exposed in the now obscured Hartwell (=Lockes's) Brickpit [805 125] just beyond the eastern margin of the map (Sumbler in prep.a). Other sections at Aylesbury (principally that at Watermead [822 157]) described by Oates (in prep.), prove a very similar sequence to that in the Hartwell Borehole.

The Portland Formation apparently overlies silts and sands of the highest part of the Kimmeridge Clay Formation throughout the area, and it seems probable that the thickness of the latter is fairly constant. However, there was almost certainly some erosion of the topmost part of the Kimmeridge Clay prior to deposition of the Portland Formation, which may give rise to minor thickness variations. The sequence may thus be somewhat thinner (40 to 45m) in the north-western part of the district. In addition, apparent localised thinning around the margins of the Portland outcrop is a result of cambering (see Structure).

Most of the Kimmeridge Clay consists of rhythmic sequences on various scales comprising (in ascending order) siltstone, dark grey mudstone, and pale grey calcareous mudstone, the last in some cases (mainly in the lower

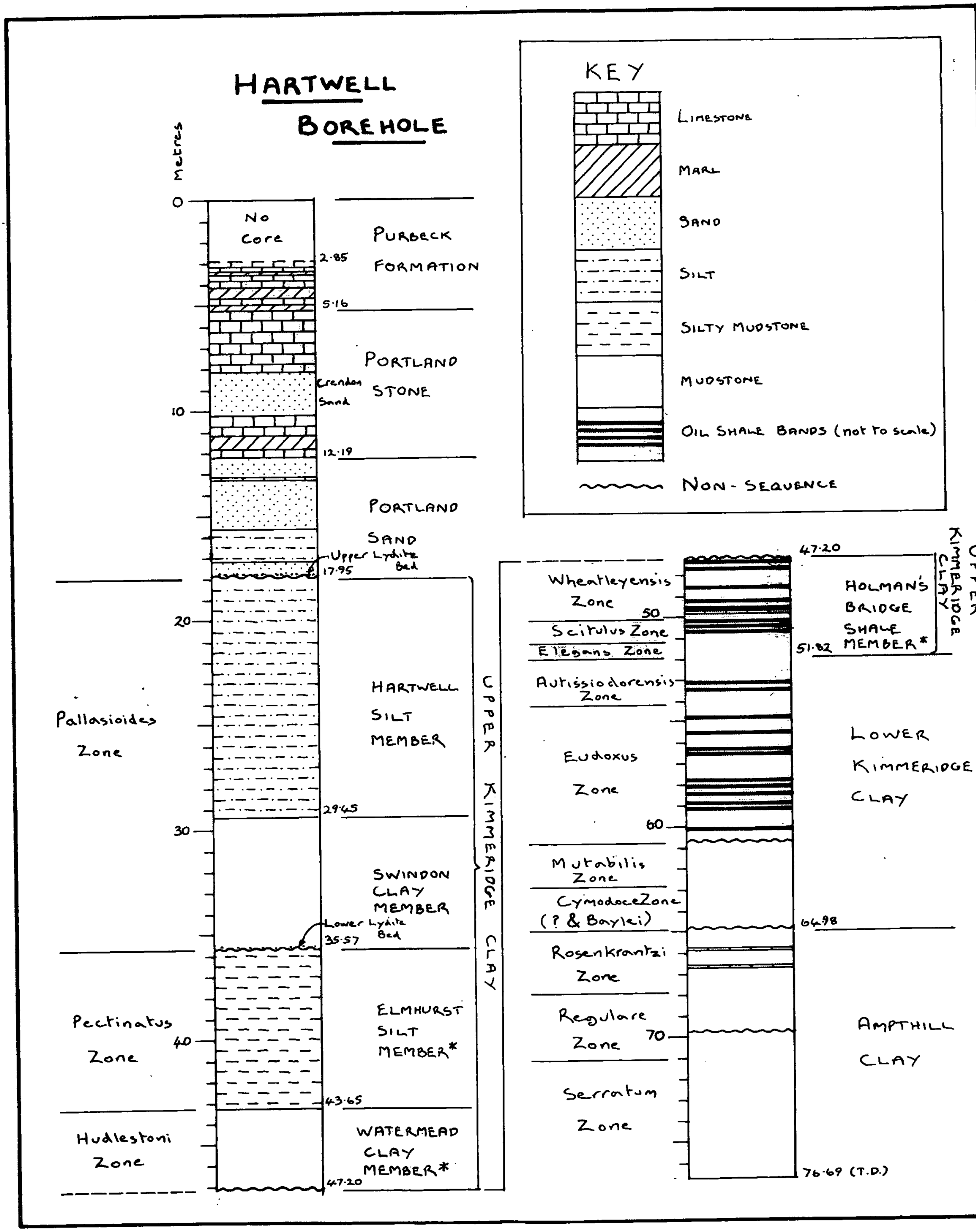

Figure 1. Stratigraphy of the BGS Hartwell Borehole [7926 1223] showing main lithologies, and provisional lithostratigraphic and chronostratigraphic classification based on Cox (1988a; 1988d). See also Appendix 1. Member names marked with an asterisk (*) refer to Oates (in prep.).

part of the Formation) with cementstone (argillaceous limestone) nodule bands. This cyclicity is probably related to water depth (Gallois & Cox, 1977). At outcrop however, the mudstones are weathered, often to a depth of several metres, forming medium to pale grey and fawn clays, commonly containing crystals of selenite (gypsum resulting from the decomposition of pyrite in the presence of calcium carbonate) or specks and tiny nodules of race (secondary calcium carbonate). Cementstones too are generally leached and occur only sporadically in the soil, although some locally form topographic features by which they can be mapped over short distances. The uppermost part of the Formation comprises silts and fine sands, which in part at least, have been mapped separately from the rest of the Kimmeridge Clay.

When fresh, the Kimmeridge Clay yields an abundant aragonitic fauna of ammonites and bivalves, but due to weathering these are generally rare at outcrop, except in some cementstone nodules. Calcitic fossils are more resistant to solution and survive in the soil. These include small thin-shelled oysters and the distinctive striate *Nanogyra virgula* Defrance. The latter appears a few metres above the base of the formation, often in association with *Laevaptychus* (the calcitic jaws or opercula of the ammonite *Aspidoceras*). *Gryphaea* and *Deltoideum* which are common in the Ampthill Clay, seem to be absent from the Kimmeridge Clay.

An abbreviated log of the BGS Hartwell Borehole [7926 1223] is given in Appendix 1 and the sequence is summarised in Figure 1. In the borehole, the basal bed of the Kimmeridge Clay (KC1, at 64.96 to 64.68m depth) consists of grey silty mudstone with angular phosphatic chips including ammonite septate whorl fragments; it rests with a sharp, interburrowed base on the underlying Ampthill Clay. Phosphatic chips at 60.68m mark the base of KC24, which rests non-sequentially on KC18; the "missing" beds KC19-23 were present in the BGS Brill Borehole [6570 1412], c 13 km to the west-north-west (Cox, 1987).

Between 60.25m and 47.20m (KC26-42), numerous thin beds of oil shale are developed, probably at the base of the rhythms or cycles. The upper part of this interval (KC36-42) equates with the Holman's Bridge Shale Member of Oates (in prep.). The base of this member is defined by the base of the Upper Kimmeridge Clay, though this is a biostratigraphic division and no significant lithological change occurs at this level. A shelly cementstone at 49.70m depth probably equates with KC40. It is the only cementstone in the Kimmeridge Clay of the Hartwell Borehole, though several others have been found at outcrop (see below). Overlying beds (47.20 to 43.65m depth) comprise mainly smooth, medium grey mudstones corresponding to the Watermead Clay Member of Oates (in prep.).

Between c 43.65 and 37.48m depth, the sequence includes very silty mudstones and siltstones. This facies is similar to the Hartwell Silt (see below), and is equivalent to the Elmhurst Silt Member of Oates (in prep.). These beds, belonging to the Pectinatus Zone, include sands in the area to the south and west (e.g. the Shotover Grit Sands of the Wheatley-Shotover area).

At 35.57m, a phosphatic pebble bed, including rolled phosphatised bivalve casts, indicates a non-sequence. It equates with the Lower Lydite Bed, which marks the base of the Swindon Clay of Swindon, (Arkell, 1933, p. 456), and the base of the Pallasioides Zone. This bed was found at outcrop on Waddesdon Hill [7535 1594] just beyond the northern margin of the area (Sumbler, 1989). The overlying 6.12m of strata (to 29.45m) of generally smooth mudstones correlate with the Swindon Clay Member of Oates (in prep.).

The topmost 11.5m of the Kimmeridge Clay consists of siltstones or very fine sandstones, with subordinate silty mudstones. This is the Hartwell Silt Member, described in more detail below.

At outcrop, pieces of nodular cementstone have been found at a number of localities. They consist of grey silty 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. A number of different cementstone nodule beds are represented at outcrop; beds probably equivalent to KC 30, 40 and 44 were proved in sections at Aylesbury (Oates, in prep., Cox, 1988c,d). These beds were proved respectively c 7, 15 and 18m above the base of the Kimmeridge Clay in the Hartwell Borehole, although only KC40 (at 49.70m) was developed as a cementstone.

A cementstone nodule bed apparently forms a strong feature on the gravel-capped hill 1km east-north-east of Sheepcote Hill Farm. It contains bivalve fossils including *N. virgula* [from 7796 1494]. A number of *Laevaptychus* were found on the outcrop of the underlying mudstones [7814 1486; 7748 1486], and this association suggests that the cementstone correlates with KC30. Pieces of shelly cementstone dug from ditches in the area to the south east [7810 1431; 7853 1394] are lithologically similar, and though they apparently lack *N. virgula* they again probably represent KC30. Similar material dug for a gas-pipeline near Haydon Mill Farm [7925 1409] is probably higher in the sequence; perhaps KC40.

Pieces of septarian, silty shelly cementstone with *N. virgula* found in the soil respectively 850m and 1km south-west of Sheepcote Hill Farm [7622 1428; 7616 1391] are again identified with KC30 (by Cox, 1989), the presence of common *N. virgula* being considered diagnostic. However, they lie only 15 or 20m below the projected base of the Portland Formation, whereas in the Hartwell Borehole KC30 is some 40m below the base of the Portland. Similarly, another shelly cementstone (without *N. virgula*) probably representative of KC40, dug from the ditch alongside Eythrope Lane [7713 1303], is only 10 or 15m below the projected base of the Portland Formation (compared with 32m in the Hartwell Borehole). The anomalous presence of KC30 (and/or KC40) at these localities may imply local thinning of the Kimmeridge Clay or unrecognised structural complications, though a more plausible explanation invokes valley bulging (see Structure).

Pieces of silty shelly cementstone with a single fragment of *N.virgula*, found 550m east of Eythrope Park Farm [7569 1453] are probably representative of KC40. A little higher in the sequence, silty septarian shelly cementstone with honey-coloured calcite veining were collected from higher in the sequence 750m north-west of Beachendon Hill Farm [7528 1405]. It is lithologically similar to a bed identified with KC44 in a section at Watermead, Aylesbury [829 155] (Oates, in prep.).

Hartwell Silt Member

The upper part of the Kimmeridge Clay Formation of the region has long been known as Hartwell Clay after the now obscured Hartwell (=Lockes) Brickpit [804 125], on the south side of the road from Stone to Aylesbury (SP 81 SW; Sumbler, in prep.a). The beds comprise silty or finely sandy clays, and because of this lithology, are here renamed the Hartwell Silt Member.

The Hartwell Silt was worked for brick-making at Hartwell, Aylesbury [842 142] and apparently at Bierton [839 157] and Whitchurch [807 205]. It was once famous for its abundant, well-preserved and varied fauna, which has been described in numerous publications (see Oates, 1974, for a review and faunal list). Dr John Lee (1783-1866), owner of Hartwell Brickpit, kept a large collection of fossils at his home, Hartwell House [796 124] (now a hotel). His collection is now dispersed, though part at least is held at the Buckinghamshire County Museum in Aylesbury.

Despite the attention received by the Hartwell Silt, there has been considerable dispute over its age and correlation. Blake (1875) placed it in the Lower Kimmeridge, though he later agreed with Hudleston (1880) in placing it in the Upper Kimmeridge. Woodward (1895) included it with the Portland. Neaverson (1924; 1925) illustrated some of its ammonite fauna, and used the Hartwell Silt (of Hartwell Brickpit) in the definition of the Pallasioides Zone. The stratigraphic position of this zone relative to other Upper Kimmeridgian ammonite zones has been the subject of debate, but following Casey (1967), it is now placed above the Pectinatus Zone and below the Rotunda Zone (Cope, 1978). In recent years, the Hartwell Silt has been treated as the lateral equivalent of the Swindon Clay of Wiltshire, representing all of the Pallasioides Zone, and marked at the base by the Lower Lydite Bed (see Cope et al. 1980, fig. 14). However, work by Oates (in prep.) on Aylesbury sections, and by Cox (1988d) in correlating these sections with the Hartwell Borehole, shows that sands and silts (Hartwell Silt) occupy only the upper part of the Pallasioides Zone, and are underlain by clays of more normal aspect, for which, down to the Lower Lydite Bed, the name Swindon Clay is appropriate (Fig. 1).

Silts and fine sands have been mapped at the top of the Kimmeridge Clay throughout most of the district. They are typically dull brownish grey when fresh, but weather to a mottled pale grey and ochreous yellow colour. West of St. John's Hospital, they yielded abundant iridescent fragments of the thick-shelled bivalve *Isognomon bouchardi* (Oppel). Though thickness estimates are difficult at this level because of cambering of the Portland Beds, the mapped sand/silt beds are estimated to be up to 7m in thickness; in the Hartwell Borehole the Hartwell Silt was 11.5m thick. Though this discrepancy may indicate real thickness variations, it seems likely that the mapped beds correspond with only the upper (?more sandy) part of the Hartwell Silt.

PORTLAND FORMATION

The Portland Formation (with overlying beds) caps the higher ground of the area. The main outcrop on the south side of the Thame valley, extends from Dinton, through Stone to Upper Hartwell, and there are small outliers to the north. Outcrops on the north-western margins of the map are part of the Portland ridge which extends south-westwards to Long Crendon [70 09].

The Formation is very poorly exposed, being largely used for pastureland, and the beds are strongly affected by cambering, making thickness estimates uncertain. However, the Portland Stone was formerly quarried at many sites for building and road stone and for lime burning, and because of this, the Portland Formation has received a great deal of attention in the literature. Though all the quarries are now obscured, a number were recorded and these sections are reproduced (with additions and amendments) in Appendix 2. Additionally, the BGS Hartwell Borehole proved the complete Portland sequence, 12.79 m thick, which is probably near the maximum for the area (Figure 1; Appendix 1).

The Formation is made up of a variety of marine limestones and calcareous sands often containing a rich fauna of bivalves (notably large *Protocardia* and *Trigonia*) and ammonites, the latter are commonly extremely large (0.5m or more in diameter) Ammonites are used for zonation of the Portland beds, but are notoriously difficult to study because of their great size and weight, and also because in adult specimens, the internal whorls are rarely accessible. The "zonal" scheme of Buckman (1909-1930) is greatly over-complicated; the currently accepted scheme was developed by Wimbledon & Cope (1978).

The literature on the Portland rocks of the area is considerable in volume, though often lacking in detail. The principal works of interest are Fitton (1836), Blake (1875), Hudleston (1880; 1887), Woodward (1895), Davies & Emary (1897), Davies (1899; 1912), Arkell (1933; 1947), Ballance (1960;1963); Bristow (1963; 1968), and Wimbledon (1974). The complete sequence of beds in the Stone/Aylesbury area was established by the time that Woodward wrote, and the nomenclature was formalised by Buckman (1922-26) and Arkell (1933). In their terminology (used unchanged by Cope et al, 1980), the Formation is divisible into five units. These can be recognised in sections and boreholes, but when mapping poorly exposed ground, the Portland Formation is naturally divisible into only two parts, the Portland Sand Member and the overlying Portland Stone Member. Together with thicknesses proved (see Appendices) the sequence in the area is as follows;

	Hartwell Borehole	Bugle Pit	Aylesbury (Sumbler, in prep.a)
Portland Stone Member:			
Creamy Limestones	2.91m	3.22	>2.2
Crendon Sand	2.28m	1.52	1.52
Aylesbury (Rubbly) Limestone	1.84m	>1.06	1.67 to 2.44
Portland Sand Member:			
Glauconitic Beds	5.64m		}3.05
Upper Lydite Bed	0.12m		}

The Portland Sand corresponds with the "Lower Portland Beds" of Ballance (1960; 1963), though these are alleged to comprise the [Upper] Lydite Bed, Glauconitic Beds, Rubbly Limestone and Crendon Sand, (Ballance, 1960, p.403). This contention appears to be based largely on his preferred classification of a temporary exposure at Westlington [7630 1039], in which he considers that all the Portland beds up to the top of the Crendon Sand amount to only 1.32m (see Appendix 2). This implies a considerable thinning of this part of the sequence when compared with that in the Hartwell

Borehole (see above), and concomitant thickening of the Creamy Limestone; such thickness changes are not borne out by mapping.

Portland Sand Member

The Portland Sand is estimated (from outcrop) to be 4 to 6m in thickness. It comprises the Upper Lydite Bed and Glauconitic Beds, though locally (principally in the north-west part of the area) the overlying Aylesbury (Rubbly) Limestone and Crendon Sand may be included; the latter is lithologically indistinguishable from parts of the Glauconitic Beds (Sumbler, 1989, p.15).

No exposures of Portland Sand were seen during the survey of the Stone area, but the sequence was proved in the Hartwell Borehole. It comprised 5.76m of greenish-grey and brown fine-grained weak calcareous sandstones and siltstones, generally containing a scattering of coarser glauconite grains. Though more calcareous and glauconitic, the lithologies are somewhat similar to the underlying Hartwell Silt. The base (= that of the Upper Lydite Bed) is irregular with burrows and possible dessication cracks. It marks a significant non-sequence; several ammonite zones are "missing" between the Lydite Bed and the Hartwell Silt (Cope et al, 1980, figs 14, 15).

At outcrop, the Portland Sand forms a brown medium-grained marly sand soil. When somewhat fresher, as in auger samples, the sands are commonly of a distinctive mustard-yellow tinge, generally with abundant black to olive-green grains of glauconite. The outcrop of the sands is commonly marked by animal burrows, and the base by a seepage line. In addition, the Upper Lydite Bed forms a useful marker at the base, though it is highly lenticular. It is apparently absent at some localities (e.g. south-east of Dinton [767 102 area]) and was very thin (0.12m) in the Hartwell Borehole, while elsewhere (e.g. west of Stone Hospital [774 120 area]) it is several metres thick. The soil on the Upper Lydite Bed outcrop is characterised by scattered rounded pebbles of black chert (lydites sensu stricto), white or yellowish quartz and quartzite and rarer black phosphate, typically from 5 to 10mm diameter. Locally, where less decalcified than usual, lumps of grey to brown, coarse-grained sandy limestone, and rarely creamy micritic limestone, with abundant glauconite grains and scattered "lydites" occur.

These limestones commonly contain bivalve (mainly modiolid) and ammonite moulds. The latter (e.g. those collected north-west of Sheepcote Hill Farm [7636 1493]) include the zonal fossil *Glaucolithites*.

Higher in the Portland Sand sequence, sandy limestones occur locally; commonly these contain abundant white serpulid tubes and (less commonly) *Nanogyra* cf. *virgula* (e.g. near Springhill Farm [760 117]). Limestone of this type (0.17m thick) occurred c 1m below the top of the Portland Sand in the Hartwell Borehole at 13.20 m depth.

Portland Stone Member

The Portland Stone comprises the Aylesbury (Rubbly) Limestone, Crendon Sand and Creamy Limestones. It equates with the "Upper Portland Limestone" of Ballance (1960; 1963) though this was said to comprise the Creamy Limestones only (see above). The Member was 7.03m in thickness in the Hartwell Borehole; this may well be near the maximum for the area, as estimates from outcrop seldom exceed 5m. Due south of Stone [784 801], the member is locally absent beneath the basal Cretaceous unconformity.

The Portland Stone forms a minor scarp feature rising above the Portland Sand outcrop, which makes it possible to trace the boundary between the two members through pastureland. Though formerly worked in many places, the beds are now exposed only in temporary sections (Appendix 2) and as brash in arable fields. Cambering and repetition of beds (see Structure) make it difficult to establish the vertical sequence of rock types in detail, but a generalized sequence can be recognised.

The Aylesbury Limestone and the lower part of the Creamy Limestones are lithologically similar, and these divisions would be impossible to distinguish but for the presence of of the Crendon Sand. They are dominated by pale grey, rubbly, sandy limestones, often packed with bivalve moulds, generally including large myids and *Protocardia*. Near the top of the Aylesbury Limestone and/or base of the Creamy Limestones, brownish rubbly limestone packed with serpulids and oysters occurs at many localities. Mostly higher in the Creamy Limestones, other typical rock types include white to yellow, strongly burrowed micrite and peloidal micrite with large bivalves (*Protocardia*, trigoniids) and giant ammonites (probably *Titanites*). Lithologies typical of the topmost part of the sequence include hard pale grey or brownish-weathering fine-grained recrystallised rather flaggy limestone, and peloidal micrites and recrystallised calcarenites with large, flat oysters.

The Crendon Sand was 2.28m thick in the Hartwell Borehole, and somewhat thinner elsewhere (see table above, and Appendices). It consists of sands and silts indistinguishable at outcrop from those of the Portland Sand, though in the borehole, the Crendon Sand was less richly glauconitic, and perhaps contained a higher proportion of shell debris. Though said by Ballance (1960; 1963) and Bristow (1963; 1968) to be a readily mappable horizon, it seems likely that (locally at least) they confused it with the Glauconitic Beds of the Portland Sand. Certainly the bed does not seem to be continuously traceable in the Stone area, though it has been located by augering in a few places. In a drainage trench south of Hartwell House [7963 1215], 1m of dull brown to mustard-yellow marly silt was exposed. In a silage pit at Stonethorpe Farm [7840 1205], about 900m west-south-west of the Hartwell Borehole, the full thickness of the bed was 1.1m (see Appendix 2). Mustard-coloured silt and grey marly silt with moulds of bivalves preserved in glauconitic siltstone, and with rare lydites, dug from a ditch near Chilboro Hill Farm [7935 1052] is probably the Crendon Sand, though because of nearby structural complications, it is just possible that the material may represent the Portland Sand Member.

PURBECK FORMATION

The Purbeck Formation forms an extensive outcrop around Dinton and Gibraltar in the south-west of the area, and south-east of Stone and at Bishopstone. Additionally, a small outlier occurs at Eythrope Park Farm [753 145] in the north-eastern part of the area. Due south of Stone [785 100], it is cut out by the basal Cretaceous unconformity, and also in places by that beneath the Whitchurch Sand. The Purbeck Formation was formerly extensively quarried, often in conjunction with the underlying Portland beds. Sections recorded in the literature (principally by Fitton, 1836) are reproduced in

Appendix 2. Currently, the only exposure in the area is at the Bugle Pit, where part of a formerly extensive quarry is preserved as a Nature Conservancy Council Site of Special Scientific interest [7932 1205].

The Hartwell Borehole (Appendix 1) is sited on the Purbeck outcrop. The Formation was bottomed at 5.16m depth (though only 2.3m of core was recovered), and the total thickness hereabouts is probably 6m or more, though 4 to 5m is probably a more usual figure. In the nearby Bugle Pit, up to 3.5m of Purbeck was formerly exposed; the current section (Appendix 2) amounts to just over 3m; the base of the Formation is no longer exposed. Sections at Dinton [7590 1140], Stone [7876 1212], and Bishopstone [7973 1099] (Appendix 2) exposed 3 to 4m of Purbeck beds, but none of these sections showed the top of the Formation.

The Purbeck Formation consists of "lagoonal" limestones and marls, deposited in near-shore, shallow waters under conditions of low or fluctuating salinity, suffering periodic emergence. As might be expected, 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 (Jones, 1885; Chapman, 1897 and p.58 in Davies, 1899; Merrett, 1924; Barker, 1966).

The base of the Purbeck is marked by a distinctive bed traditionally known as the "Pendle", which seems to be a quarryman's term commonly applied to flaggy rocks. The Pendle is present in all recorded sections, and has been traced at outcrop in the fields between Stone and Bishopstone and sporadically elsewhere, and it probably occurs throughout the region. It is a flaggy limestone consisting of thin (5 to 10mm) alternating layers of grey, slightly sandy shell fragmental, ostracod-rich limestone, and cream, pure micrite. This bed was 0.55m thick in the Hartwell Borehole, but generally seems to be somewhat thinner than this.

The overlying beds are dominated by white and brown mottled micrites, which in arable fields, form an angular brash in a dark brown clay soil. These micrites are commonly recrystallised and intensely hard and splintery. They commonly exhibit borings, suggesting penecontemporaneous cementation ("hardgrounds") and shrinkage cracks, "birdseyes" and (near the Bugle Pit [7914 1210]) possible salt pseudomorphs, suggesting subaerial emergence. Locally, impressive algal laminae and stromatolites occur; these are also taken to be indications of regular emergence, modern examples being restricted to the intertidal zone. They can be seen in the Bugle Pit, and probable algal laminae were present in the Hartwell Borehole. Impressive stromatolites occur in the fields at Whaddon Hill [787 133] and north-east of Bishopstone [809 110]. A yellow-brown, ferruginous, cavernous limestone in the Bugle Pit is evidently the result of weathering, possibly dating from shortly after the time of deposition, as the bed is overlain by relatively unaltered beds. Similar ferruginous micrite occurs within the Purbeck sequence south and west of Dinton Stonepits [751 113 to 759 113]. Most of the sections through the Purbeck beds include thin layers of marl, clay and muddy silt and sand. These are rarely evident as discrete beds in the fields, but presumably contribute to the dark clay soil which characterises the Purbeck outcrop.

WHITCHURCH SAND FORMATION

Ferruginous sands overly the Portland/Purbeck beds at a number of places in the Stone area. All these outcrops (together with other such outliers in the region) are classified as Lower Greensand [Cretaceous] on the Old Series Geological Survey maps. However, even before these maps were published, it was realized (e.g. Fitton 1836) that while true Lower Greensand (marine Aptian) occurs in the region, some of these sands are non-marine, yielding fossils such as *Viviparus* and *Unio* (notably at Shotover Hill near Oxford [567 063]). These non-marine Shotover Sands (or Ironsands) have traditionally been ascribed to the early Cretaceous (pre-Aptian) Wealden (Pocock, 1908; Arkell, 1947). They have been equated with the Hastings Beds by Taylor (1959) and the Weald Clay by Ballance (1963).

At Quainton Hill [748 221] and Whitchurch [802 207], Casey & Bristow (1964) found that similar sands contained contained a brackish-water fauna including *Protocardia purbeckensis* (de Loriol), *Laevitrigonia gibbosa* (J. Sowerby), other bivalves, gastropods and serpulids. They introduced the name Whitchurch Sand for these beds and correlated them with the basal Cretaceous

Cinder Bed of Dorset, regarding them as distinct from and older than the Shotover Sands. Morter (1984, pp230, 231) however, reassessed the faunal evidence and concluded that both the Whitchurch Sands and the Shotover Ironsands are of late Portlandian i.e. youngest Jurassic age. Lithologically, there is no significant difference between beds hitherto separated as either Whitchurch Sands or Shotover Sands; all are included in the Whitchurch Sand Formation of the present account. They are, however, lithologically distinct from the beds here described under the heading "Lower Greensand" (see below).

The stratigraphic significance of the bivalve-dominated faunas of the Whitchurch Sand Formation can be questioned. To a large extent they may be determined by sedimentary environment rather than age, and because of the lack of reference sections of similar facies elsewhere, the precise age of the various sand deposits is still open to debate. With this in mind, it is interesting to note the striking lithological resemblance of the local Whitchurch Sands to the lower part of the Woburn Sands ("Brown Sands") of the Leighton Buzzard area. The latter, though largely unfossiliferous, yield Upper Aptian (*nutfieldensis* Zone) fossils from phosphatic nodules in the basal few metres (Casey, 1961).

The outcrop of the Whitchurch Sand is largely concealed by grassland and the built-up area of Stone. There are now few exposures, although the beds were formerly exploited in many pits at Stone (Appendix 2). Up to c 9m of beds are present, with the thickest development being in the vicinity of the Eythrope Road Sand Pit, Stone [779 126]. The thickness of beds (c 7.3m) recorded here by Ballance (1960, p. 162) suggests some channelling of the base of the formation. Possible erosive behavior is also suggested by the fact that, while the formation generally rests on Purbeck limestones, locally (north of the sand pit [778127] and on Beachendon Hill [755 133]) it rests on Portland beds.

In arable fields the Formation is characterised by reddish brown sandy loam soils, 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. Former sections (Appendix 2) showed white, yellow orange and brown varicoloured sands with seams of ironstone and clay. Though totally non-calcareous, large, curiously-shaped siliceous concretions ("bowel stones") occurred in some pits. The sands are generally uniform fine to medium-grained (Taylor, 1959, p.242 suggests a typical mean grain size of about 0.125mm), in contrast to the uniformly coarse grained beds here classified as Lower Greensand. Locally, and invariably at the top of the local sequences, debris of brown and black, limonite- cemented poorly sorted gritty sandstone with tiny quartz pebbles ("carstone") occurs (at Haddenham Low [751 104], Dinton Castle [762 113] and in Stone Farm Sand Pit [7863 1242] (Appendix 2)), and probably in much of the built-up area of Stone (see Lower Greensand, below). This material is mapped with the Whitchurch Sand, but may possibly be Lower Greensand, which is texturally similar though generally uncemented and better sorted.

Beds of clay are occur commonly thoughout the Whitchurch Sand. They are typically pale grey to almost white in colour, commonly with ochreous yellow mottles, and contain limonitic concretions and sand and silt seams. Taylor (1959) describes them as typical fireclays, and despite the "fuller's earth"-like appearance of some samples, they are apparently not montmorillonitic. A lenticular bed, perhaps up to 1m thick, mapped near Dinton Castle [765 115] lies c 2m above the base of the formation, but generally the thicker (and mappable) beds occur at the base. Basal clays form extensive outcrops near Bishopstone [800 110 and eastwards] and at Haddenham Low [754 103]. These are shown as Gault on Old Series Sheets 45 and 46, but their true identity was realised by Davies (1899, p. 55). At the latter locality, the clay was formerly worked for brick-making [7525 1018](see Economic Geology); the pit is now flooded and without exposures. The clay here is probably up to 5m thick.

White sands within the Whitchurch Sand at Stone were formerly used for glass manufacture (see Economic Geology). Ballance (1963, pp.406, 407 and fig.4) claims that these pure sands are unique, being restricted to an east-west river channel cut through "ordinary" Whitchurch Sands (=Wealden Beds of Ballance). This is not borne out by current mapping; white sands are commonplace in the Whitchurch Sand, and conversely, varicoloured ferruginous sands are common in the Stone outlier (see Appendix 2): also, the south-western margin of the outcrop, regarded as the channel margin by

Ballance, appears in fact to be a fault. The reason for the exceptional number of workings at Stone is probably because of the greater thickness of the deposits here than elsewhere, enabling economic quantities of pure sand to be extracted from an otherwise unremarkable sequence.

As discussed above, fossils are rare in the Whitchurch Sand Formation. Within the Stone area, Davies (1899, p.50) found a loose block of sandstone with gastropod casts ("*Paludina*?") at Castle's Pit, Stone [7815 1240], and Bristow & Kirkaldy (1962, p.459) record a "paludinoid gastropod" from the Eythrope Road sand pit [779 126]. Ballance (1963, p. 408) found casts of ?*Viviparus* in ironstone just beyond the margin of the map at Haddenham Low [7512 0924]. Morris (1867, p.458) describes "masses of ferruginous sandstone with *Unio* and *Paludina*" near the base of the sequence near Stone Hospital [probably 780 122 area], and "many specimens of *Endogenites erosa*" near Stone Church [784 123], also near the base of the sequence (probably in one of the pits, see Appendix 2). He also records blocks of brown sandstone "not *in situ*" with casts of "*Unio, Cyrena, Paludina* and traces of plants" at the base of the Lower Greensand at Peverel Court [796 118](see below). These have always been assumed to be derived blocks of Whitchurch Sand.

CRETACEOUS

LOWER GREENSAND

The problems in separating the freshwater/brackish Whitchurch Sands from the marine Lower Greensand have been discussed above. As recognised by Davies (1899) and subsequent workers, without fossils it is impossible to be certain to which formation any particular deposit belongs. Fortunately, Morris (1867) discovered marine fossils in distinctive gritty sands at Peverel Court [796 118] south-east of Stone, and beds of this lithology are separated as Lower Greensand on this and adjoining maps. This usage (at least within the Stone area) accords exactly with that of Taylor (1959) and Ballance (1960, 1963). Davies (1899) likewise attempted to separate the marine from the freshwater beds in the Thame valley region, but perversely grouped all of the sand deposits of the Stone area under the one heading of "Bishopstone Beds" (=Lower Greensand).

Three small outcrops of Lower Greensand have been mapped; outliers at Peverel Court (now a private school)[796 118] and Curzeley Hill [800 111], and a hitherto undiscovered inlier beneath Gault south-west of Chilborough Hill Farm [783 101]. The beds comprise reddish brown ("foxy red") poorly to moderately well sorted grits. The deposit is uniformly coarse, with very few fines; grain size typically averages around 0.5 to 2 mm, and it commonly contains small, (about 5mm) well rounded and polished pebbles of yellow and white quartz and quartzite (cf. those in the basal Portland Upper Lydite Bed). From field brash, it seems to be mainly unconsolidated, though rare pieces of black, limonite cemented pebbly gritstone ("carstone") have been found at Peverel Court and Curzeley Hill.

Smyth (1864, p. 41) states that "near the windmill at Stone, about Peverel Court below, and then further south near Bishopstone, the uppermost capping of the higher ground consists of red friable sands, with bands of indurated ferruginous grits, forming the lower part of the green-sand series", and (plate 2) shows a large outcrop of "Green Sand" resting on "Hastings Sand" (=Whitchurch Sand) north and west of Stone Church [780 124 area] and a smaller outlier at Round Hill [788 123]. Much or all of this material may belong to the Whitchurch Sand (see above), but it is quite possible that there may be true Lower Greensand at Stone in ground now built over. A large, ancient trough carved out of a single block of pebbly carstone in Stone Churchyard [7841 1222] probably weighs nearly 2 tonnes, suggesting a very local source; the Peverel Court pits are over a mile away.

In each outcrop, field relationships suggest that the base of the Greensand is strongly erosive. At Chilborough Hill, the Greensand infills a channel in Portland Sand, while only a short distance away, Portland Stone and Purbeck limestone crop out from beneath the Gault, suggesting channelling of the Greensand through these formations. At Curzeley Hill, the Greensand transgresses from Whitchurch Sand (of clay facies here) onto the underlying Purbeck Limestones. Ballance (1960, p.303) proved up to c 4.6m of Lower Greensand by augering here. The grits have been worked from two small pits [7993 1109; 7995 1102].

The most striking discordance can be seen at Peverel Court where the Greensand outlier, of c 3 hectares extent, constitutes a slight knoll on the Purbeck limestone outcrop. An extensive degraded sandpit on the southern side of the outcrop [7955 1176] extends down to c 2m below the level of the surrounding limestones. Augering by Ballance (1960, pp 196, 197) proved 2.1m of gritty sand beneath the floor of the pit, which suggests downcutting of 4m or more, probably onto Portland beds, and shows that the Greensand infills a basin-like depression cut into the underlying beds. At this pit ("the red sand pit not far from the Bugle Inn"), Morris (1867) records "about six feet [1.8m] of the sands overlying a partly irregular surface of one of the Portland beds" He describes the sand as coarse, highly ferruginous, with ochreous concretions and many quartz pebbles and larger pebbles of quartzite, "lydian stone" and blocks of fossiliferous sandstone as described above. He states that "the sands themselves contain impressions of shells" including *"Exogyra sinuata"* (=*E. latissima* (Lamarck); Casey, 1961, p.563) as well as many other bivalves, brachiopods foraminifera, corals, bryozoa and large pieces of coniferous wood. These fossils are now apparently lost (Ballance, 1963, p.410).

BGS Palaeontological Collection Register F (p.141) lists casts of bivalves and brachiopods "from gritty and ferruginous beds between Hartwell and Bishopstone" in the Hartwell House collection of Dr Lee (see also Woodward, 1891). These may now be in the Buckinghamshire County Museum in Aylesbury. Ballance (1963, p. 410) suggested that they may have come from Curzely Hill, but it seems more likely that they were from the Peverel Court pit which belonged to Lee (Appendix 2). None of the fossils listed is closely age-diagnostic, but the beds here are almost certainly late Aptian or early Albian (Rawson et al 1978). Lithologically, they bear a strong resemblance to the uppermost Woburn Sands ("Red Sands") of the Leighton Buzzard area, which are overlain by "Junction Beds" of the basal Albian *tardefurcata* Zone.

GAULT

Gault clay crops out on the southern margin of the map south of Chilboro Hill Farm [787 101]; probably the basal 4m of the formation are represented; the full thickness hereabouts is about 70m. The outcrop is almost entirely obscured by pasture, but extensive augering around the margins of the outcrop (i.e. in the very basal beds) proves ochreous silty clay with quartz sand and grit (presumably derived from the Lower Greensand). Higher in the sequence, the beds consist of pale to dark grey slightly silty clay with reddish brown streaks or laminae of silt.

The base of the Gault is unconformable and transgressive, resting variously on Lower Greensand, Purbeck limestone, Portland Stone and Portland Sand within a distance of a few hundred metres, implying downcutting of at least 10m. The Gault forms ground of low relief topographically below the adjoining Portland and Purbeck outcrops to the north-east. This appears to be the combined result of channelling and tectonics as discussed below (see Structure).

The basal Gault hereabouts is probably Lower Gault of Middle Albian age (Rawson et al 1978; Sumbler in prep.c).

STRUCTURE

Tectonic Structures

Overall, the regional dip of the Upper Jurassic beds is calculated at roughly 0.6 degrees (10m/km) to the south-east, but there are many superimposed local deviations. Detailed analysis of these is nearly impossible because tectonic structures (folding and faulting) are confused by the almost ubiquitous presence of non-diastrophic superficial structures (see below). Without exposures, superficial effects may locally have been misinterpreted as of tectonic origin and *vice versa*, but nevertheless, it is possible to unravel the main structural elements; these are shown in Figure 2.

The main structures fall into two groups, trending north-east and

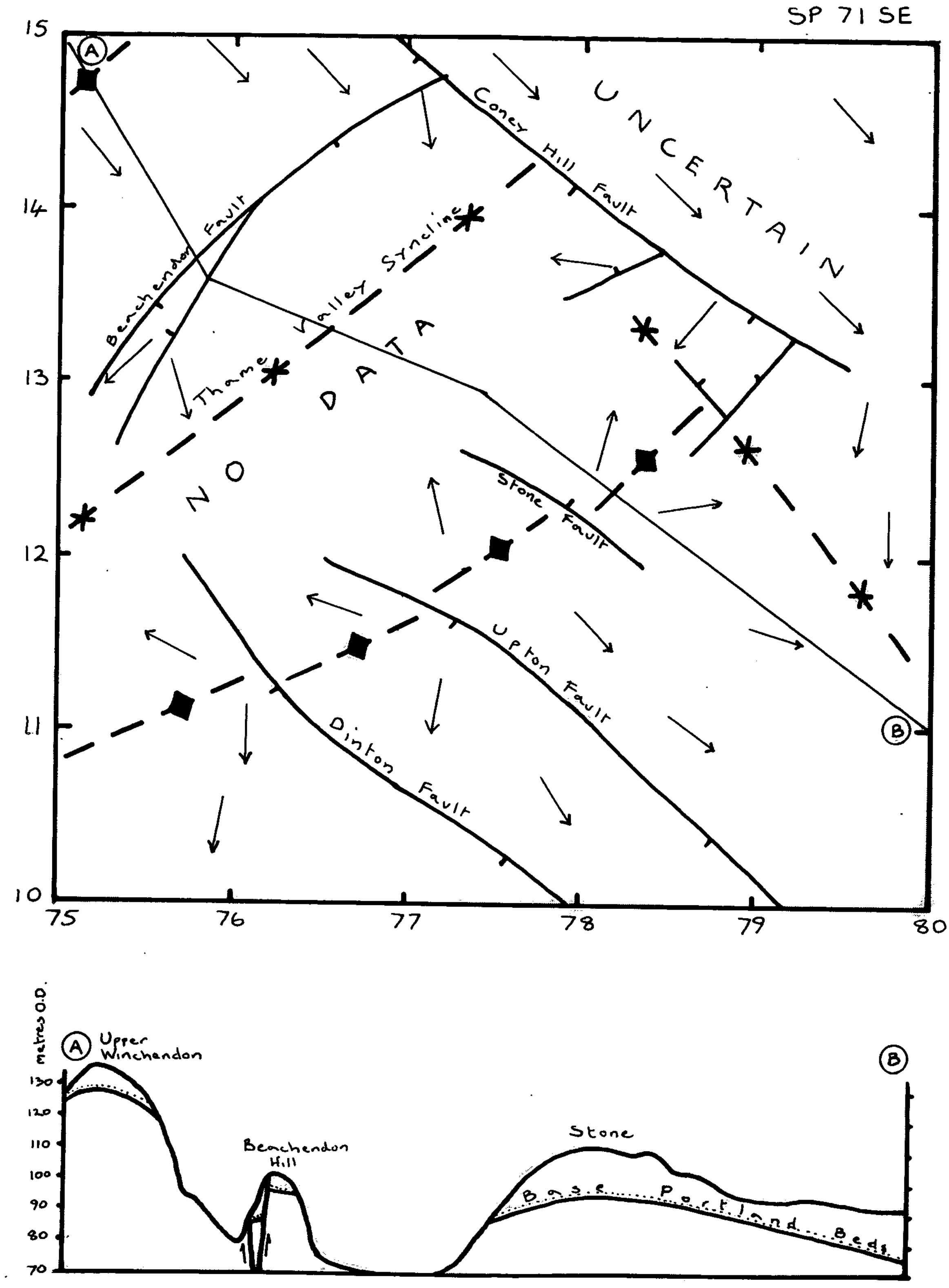

Figure 2. SP 71 SE (Stone): Structure.
showing the main structural elements; anticlines, synclines, direction of dip and faults (crossmark indicates downthrow side). Sketch cross-section A-B shows the inferred position of the base of the Portland Formation. Length of section A-B 6.8km; vertical exaggeration X25.

north-west respectively. Of the first group, the most obvious is a gentle Thame Valley Syncline, manifested by the Portland outliers at Beachendon Hill [756 133], Eythrope Park [765 140] and the spur at Sheepcote Hill [767 147]. At these localities, the base of the Portland is some 20 to 25m lower than would be expected from the neighbouring outcrops at Upper Winchendon [751 147] and Stone [775 127]. Southwestwards, this synclinal structure extends as least as far as Chearsley [c 705 105] where it was described as a faulted monocline by Barron (1988). To the south-east, a complementary gentle anticline runs through Stone and Dinton, following the Stone-Haddenham Portland ridge, and to the north-west, a similar structure appears to follow the Upper Winchendon-Chearsley ridge, though because of the extent of cambering of the Portland outcrop here, this is hard to confirm. The Thame Valley syncline is affected by the north-east trending Beachendon Fault and, on the opposite limb of the fold, a fault at Littleworth Farm [782 136]. An additional fault on the same trend accounts for a small low-level outlier of Portland Sand at Lower Hartwell Farm [792 132].

All of the other main structures trend north-west. The axis of a slight syncline runs close to the Hartwell Borehole [7926 1223] in which the base of the Portland Formation is depressed relative to its outcrop nearby by perhaps as much as 10m. All of the major faults of the area have this trend; they are typically several kilometres in length but of generally slight throw, principally to the south-west. The shorter Stone Fault throws up to perhaps 6m to the north-east. It forms the south-western boundary of the large Whitchurch Sand outcrop [777 123] and was mis-interpreted as a channel margin by Ballance (1960; 1963).

The Coney Hill Fault is well authenticated in the Fleet Marston area to the north (SP 71 NE), where it throws 10 to 15m to the south-west. Its continuation into the Stone area is inferred from the close proximity of Portland beds at Littleworth Farm and Whaddon Hill [787 133] to beds low in the Kimmeridge Clay to the north-east (see Kimmeridge Clay). Its throw may be in excess of 20m here, and it appears to terminate the north-east trending fold structures including the Thame Valley Syncline. The fault

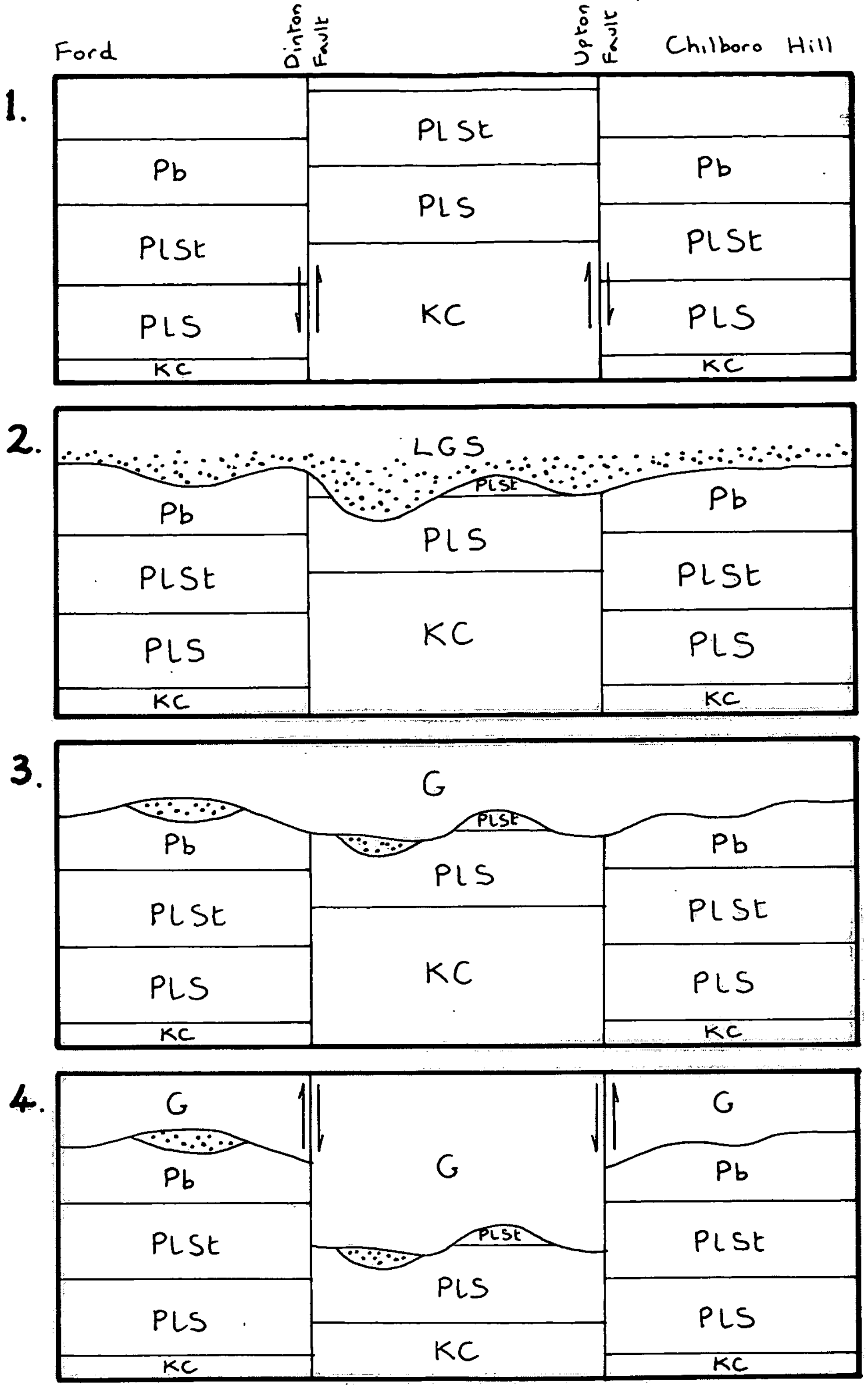

Figure 3. Sketch Section illustrating development of the Dinton and Upton Faults between Ford [778 094] and Chilboro Hill [790 105].
1. Post-Purbeck, pre-Lower Greensand.
2. Lower Greensand deposition.
3. Gault deposition.
4. Post-Lower Greensand.
G=Gault; LGS=Lower Greensand; Pb=Purbeck beds; PlSt=Portland Stone; PlS=Portland Sand; KC=Kimmeridge Clay

cannot be confirmed by ordinary mapping techniques, because of the general lack of marker bands in the Kimmeridge Clay. For this reason, is possible that faults other than those shown on the map may exist.

The Upton and Dinton Faults each have south-westerly throws of a few metres in the Portland/Purbeck and Whitchurch Sand outcrops, but different apparent throws where the base of the Gault is affected. South of Chilboro Hill Farm, the Upton Fault apparently offsets the base of the Gault some 500m or so (beneath alluvium). On the north-east (upthrow) side of the fault, the Gault rests upon Purbeck beds [SP 70 NE]; on the south-west (downthrow) side, it rests variously on Lower Greensand, Portland Sand and Portland Stone. These relationships suggest a post-Purbeck, pre-Lower Greensand north-easterly downthrow of c 10m, followed by a somewhat larger post-Gault south-westerly downthrow, giving the net south-westerly downthrow we see today. Similar relations occur on the Dinton Fault at Ford [780 096], a few hundred metres south of the margin of the map. These relations (Figure 3) are easily understood by considering the block between the faults; pre-Lower Greensand it formed a horst; now it forms a graben.

It could be argued that part (or all) of the apparent displacement of the Gault could be due to preferential channelling into the Portland Sand rather than the more resistant Purbeck Limestones, i.e. that all the fault movements were of pre-Gault age. However the large displacement associated with the Upton Fault suggests that here, at least, post-Gault faulting is almost certain.

This reversal of sense of displacement is known as structural inversion, and seems to be fairly widespread during the Purbeck-Gault interval. Relations near Oxford described by Arkell (1947) can be interpreted as implying post-lower Greensand, pre-Gault inversion as well as continued post-Gault movement. In the Stone area, this cannot be demonstrated, as neither fault cuts Lower Greensand. The date of the post-Gault movements is generally assumed to be Tertiary (Alpine).

Near Dinton Stonepits [763 113], much of the mapping is somewhat uncertain. With this proviso, it appears that the south-westward throw of the Dinton Fault is greater in the Purbeck Limestones than in the overlying Whitchurch Sands, suggesting pre-Whitchurch Sand faulting of the Purbeck beds, as well as subsequent movement, but no inversion.

Superficial Structures

Superficial (i.e. non-diastrophic) structures are common around the margins of the Portland outcrop, especially along the Thame Valley where slopes are steep, as near Upper Winchendon [753 145] and Sheepcote Hill [767 147]. Probably developed mainly during the cold stages of the Quaternary epoch, they result from fracturing, squeezing and wastage of the Kimmeridge Clay, and collapse of the overlying beds, which extend downslope well below their original level, as a "camber" of disjointed blocks.

In Eythrope Park, the apparent presence of beds low in the Kimmeridge Clay in localities where higher beds would be expected (see Kimmeridge Clay) is probably the result of valley bulging. This occurs typically in valley bottoms where mudstones are squeezed upwards by the weight of the strata forming the valley sides.

QUATERNARY

GLACIOFLUVIAL SAND AND GRAVEL

A deposit of poorly sorted clayey sand and gravel caps the interfluve ridge on the western side of the Thame valley north-east of Eythrope Park [778 147]. It forms a of brown loam soil with abundant pebbles, mainly of subangular flint, but with a few rounded Bunter quartz and quartzite pebbles, typically from 10 to 100mm diameter. The deposit is probably only 1 to 2m thick. It is assumed to be genetically related to the chalky till (with a similar pebble content) which occurs at approximately the same altitude a few hundred metres to the north beyond the margin of the map [779 153] (Sumbler, 1989).

The gravel outcrop forms a plateau (at around 82m O.D.) which slopes very gently to the south, towards the Thame valley; for this reason, but for its poorly sorted nature, the deposit might alternatively be classified as an early terrace deposit of the River Thame. It is probably a proximal representative of the Third Terrace deposits described below.

On the eastern side of the Thame valley, the hilltop in the Rabans Lane area of Aylesbury [796 145] forms a similar plateau at approximately the same topographic height. Though formed of Kimmeridge Clay, the presence of scattered flints in the soil suggests the former presence of an analogous gravel deposit.

RIVER TERRACE DEPOSITS

Bench-like deposits of sand, gravel and loam occur within the Thame valley. Interpreted as terrace deposits, they have been grouped (first, second and third terrace) according to their relative height above the present river floodplain. This classification relates solely to the Stone area; though correlation with correspondingly indexed deposits in adjoining areas is probable, this is not yet confirmed.

Third Terrace Deposits

Up to 1m of moderately well-sorted, fairly sandy gravel caps two small knolls of Kimmeridge Clay on the southern side of the Thame valley at Starveall Farm [7637 1272; 7626 1244]. Pebbles are predominantly flints, with rare Bunter pebbles, lydites and small phosphatic nodules (the last probably from the local Kimmeridge Clay). The deposits lie at 74 to 75m O.D. i.e. about 5 or 6m above the nearby floodplain. A third knoll to the south [7622 1233], at approximately the same height has a strew of pebbles, but no mappable gravel remains. These deposits may be downstream representatives of the glaciofluvial gravels described above.

Second Terrace Deposits

Two areas of reddish-brown loam and flinty gravel adjoining the Thame floodplain on the western margin of the map have been designated second terrace deposits in accord with the adjoining sheet SP 71 SW (see Barron, 1988). They seem to be similar in all respects to the first terrace deposits described below, and may well be contemporaneous.

First Terrace Deposits.

Extensive low terraces adjoin each side of the Thame floodplain at Eythrope [785 142; 777 138; 770 132]. The deposits consist of reddish brown loam, generally underlain by gritty sand, and dirty gravel containing small flints and rarer Bunter, lydite, ironstone and (where particularly fresh at depth) Portland/Purbeck limestone pebbles. From a maximum of c 1.5m above the adjacent floodplain, the terraces slope gently down towards the river, and the boundary with the alluvium is typically difficult to define. The deposits extend below the level of the floodplain and may be contiguous with gravels present locally in the river bed. If so, the deposits may be over 3m thick in some places, but generally are probably much less.

ALLUVIUM

Alluvial deposits forms floodplains adjoining the River Thame and the lower reaches of its tributaries. Despite drainage improvements, these floodplains are still subject to occasional flooding in many places. At the surface the alluvium forms a poorly drained, dark greyish brown to black, slightly loamy, humic and locally peaty soil. Seen in ditches and auger holes, the underlying material is generally a grey or fawn clay, almost indistinguishable from weathered Kimmeridge or Gault clay, which are major source materials. Augering in the banks of the Thame indicates up to 3m of alluvial clay, though it is rarely more than 1 to 1.5m thick in the tributary valleys. At many places, the river bed consists of small flint/limestone gravel. It is probable that such gravel (probably 1 to 2m thick) underlies much of the floodplain; it may be contemporaneous with the First Terrace deposits (see above). The basal gravel of the tributaries typically consists of more locally derived material (limestones, lydites, phosphatic nodules etc).

South of Stone [782 105], the Ford Brook (which reaches the Thame via the southern side of the Stone-Haddenham ridge) flows across a basin-like inlier of Kimmeridge Clay surrounded by Portland Beds. The floodplain, up to 500m, is made up of black humic clay with lenses and seams of peat. This area probably was a marsh in former times.

HEAD (Colluvium)

Head is commonly regarded as a solifluxion deposit, formed of material which has moved downslope by a process of gradual mass flow during cold stages of the Quaternary era. However, as mapped, Head includes other similar slope deposits (i.e. colluvium), including those transported by rainwash or soilcreep which continues to the present day.

Head is widespread on the lower slopes of the hills of the area, although only the thickest and most extensive deposits have been mapped. These occur most typically in valleys, often upstream of, or bordering alluvium. Augering suggests that they selom exceed 1.5 to 2m in thickness. Head deposits are locally derived, and their lithology varies according to the nature of the source material. In the Stone area, they consist principally of loamy clays, derived from the Kimmeridge Clay, and can be difficult to distinguish from *in situ* weathered mudstone. Possibly then, deposits other than those shown on the map may exist. Usually however, the Head contains a proportion of small pieces of Portland and Purbeck limestones, lydites and a small amount of ironstone from the Whitchurch Sand. In some places, particularly along the Thame valley, the head includes occasional flints, perhaps derived from former glacial or terrace deposits, or from ancient far-travelled head derived from the Chalk outcrop such as occur in the areas to the east and south (Sumbler, in prep., a-c).

ECONOMIC GEOLOGY

Brickclay

The Kimmeridge Clay was formerly worked for brick making at many sites in the region, but all seem to have closed by the early years of this century, probably because of competition from the large-scale operations of the London Brick Company, working Oxford Clay. The Hartwell Silt seems to have been greatly favoured, perhaps because the sand/silt content helps to prevent shrinkage on firing. It was worked at Hartwell (Locke's Brickyard) just beyond the eastern margin of the map [804 125] (Sumbler, in prep.a), and extensive diggings and hummocks at Dinton [773 111] may also mark the site of a brickpit in the same beds.

At Haddenham Low [753 102] a large (c 1 hectare) pond mark the site of a brickpit in basal Whitchurch Sand clays. It was probably working at the time of survey of Old Series Sheet 45 (Green, 1864), but seems to have been abandoned by the turn of the century (Davies, 1899). The clays of the Whitchurch Sand are described petrologically as "fireclays" by Taylor (1959), but debris in the vicinity of the pit suggests that ordinary building bricks were manufactured here.

Building Stone

The Portland Stone and Purbeck beds were formerly worked extensively for building stone, road rubble and were also burnt for lime for both agriculture and the building trade. The outcrop of these beds are dotted with quarries; the largest were Dinton Stonepits [759 114] (c 2.5 hectares) and the Bugle Pit [794 121] (formerly c1.5 to 2 hectares, now mostly infilled). As far as can be judged from the literature, most of the pits were defunct by the beginning of the 20th century. Certainly the Bugle Pit was in work in the 1880's (Hudleston, 1887) but was abandoned and being infilled by 1912 (Davies, 1912). From the position and estimated depth of the pits, it appears that the Creamy Limestones were most favoured for building. Examples can be seen in almost any of the older buildings in the area; in many cases the walls incorporate giant Portland ammonites as decoration; fine examples can be seen in the walls around Hartwell Park [795 121].

Limonitic gritstone ("carstone") from the Lower Greensand (and probably from the Whitchurch Sand too) is a very minor component of some old buildings; isolated blocks can be seen in the structure of Stone Church and a large trough stands in the churchyard opposite the east door. "Bowel-Stones" (siliceous concretions) from the Whitchurch sand are also seen as occasional features in old buildings, notably Hartwell Park wall opposite the Bugle Horn Inn [795 121], and in Dinton Castle [7654 1154], a ruined folly reputed to have been built (in 1769) by Sir John Vanhattem of Dinton Hall to house his fossil collection (Ballance, 1960, p.151).

Sand and Gravel

The coarse sand and fine gravel of the Lower Greensand was formerly worked at Peverel Court and Curseley Hill [796 118; 800 111], but the outcrops are so tiny that it is inconceivable that any commercial reserves remain. The Thame Terrace deposits are generally to thin and impure to be of economic interest. The Whitchurch Sand at Stone were formerly worked from numerous pits (Appendix 2). The white sands were used in glass manufacture, and though undersold by other deposits even in the nineteenth century (Hudleston, 1880), working continued at the large Eythrope Road pit [779 126] until the 1960's. This perhaps testifies to the material's purity; Boswell (1918) quotes 99.8% silica.

Water Supply

Much of the area is underlain by mudstone and therefore has little groundwater potential. An abortive borehole drilled last century at Stone Hospital entered Great Oolite at about 157m below the base of the Portland beds, but failed to yield useful quantities of water (see Concealed Strata). A number of springs and extensive seepage occurs around the margins of the Portland outcrop, and some shallow wells tapped the same source. Most (and perhaps all) of the dwellings in the area are supplied by mains water, but some wells and springs are still utilised for agricultural purposes.

Engineering geology

Ground conditions in most of the area are unlikely to pose any unusual problems to construction. However care should be exercised in planning development on steeper slopes, as these are likely to be unstable, particularly where affected by cambering or landslips or covered by head. Because of the difficulty in recognising these features in the absence of sections, their depiction on the map may not be comprehensive. No landslipping has been observed within the Stone area, though in adjoining areas, slopes of Kimmeridge Clay steeper than c 10 degrees, are commonly affected (A. Forster, pers. comm.). Slopes of this grade occur in a few places, notably in the north west corner of the map.

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APPENDIX 1: SP 71 SE Boreholes.

SP 71 SE/1

HARTWELL BOREHOLE, Hartwell. [7926 1223]. SL c+98. Drilled 1976, for the Institute of Geological Sciences (later BGS)(Gallois, 1979; Gallois & Worssam, 1983). Cored from 2.85m. This summary log is based on the original log of cores by R.W. Gallois, modified and classified following examination of core specimens by B.M. Cox and M.G.Sumbler. See also Figure 1.

	Thickness (m)	Depth (m)
PURBECK FORMATION 0-5.16		
No core	2.85	2.85
Limestone, weathered and rubbly, cream and pale grey, mottled, fine-grained, porcellanous, splintery. Rare gastropods and ostracods. Some silt-filled burrows.	0.55	3.40
Marl, pale green, very silty, ostracods.	0.10	3.50
Limestone, cream to brown burrow-mottled. Rare gastropods and serpulids. Scattered silt grains. Porcellanous algal limestone with ?desiccation cracks in middle part.	0.30	3.80
Siltstone, calcareous, yellow-brown and green-grey. Abundant ostracods. Some ?glauconite grains. Several irregular lumps of laminated porcellanous ?algal limestone.	0.25	4.05
Limestone, porcellanous, faintly laminated.	0.05	4.10
Marl, pale green-grey with yellow-brown staining. Faintly laminated. Much ostracod, fish and plant debris. Small nodules of porcellanous ?algal limestone at 4.24.	0.27	4.37
Sand, fine-grained, with ostracods.	0.03	4.40
Siltstone, pale grey brown, calcareous, finely laminated. Ostracods and bivalve fragments.	0.21	4.61
Pendle:		
Limestone, argillaceous; alternating fine laminae of cream-brown micrite passing up into dark brown-grey silty plant-rich mud. Intensely burrowed. Ostracods.	0.33	4.94
Marl, yellow-brown, laminated, silty, packed with ostracod debris. Interburrowed base.	0.05	4.99
Mudstone, grey, with much shell-debris (mostly ostracods). Intensely burrowed.	0.17	5.16
PORTLAND FORMATION 5.16-17.95		
PORTLAND STONE MEMBER 5.16-12.19		
Creamy Limestones:		
Limestone, blue-grey, weathering cream-brown, micritic, massive, recrystallised, finely shell fragmental. Some burrows. Casts and empty moulds of bivalves.	0.26	5.42
Mudstone, grey, much shell debris.	0.07	5.49
Limestone, grey, micritic, argillaceous, intensely burrowed. Bivalve and ostracod shells and shell debris, serpulids.	0.98	6.47
Mudstone, calcareous, grey to cream, leached bivalves.	0.07	6.54
Limestone, cream-brown weathered, micritic, argillaceous. Intensely burrowed. Silty in middle and at base. Sparsely shelly with bivalves, oysters. serpulids, ostracods.	0.91	7.45
Limestone, blue-and pale-grey mottled; silty and argillaceous. Intensely burrowed. Abundant ostracods and some bivalves and gastropods. Sandy in lower part.	0.62	8.07

Crendon Sand:		
Sand, pale brown and yellow-brown. Intensely burrowed with decalcified bivalves. Passing into grey argillaceous siltstone for 0.2 at base. (1.50 core lost).	2.23	10.30
Mudstone, pale grey, silty, calcareous.	0.05	10.35
Aylesbury (Rubbly) Limestone:		
Limestone, grey, argillaceous, burrowed. Shelly with bivales and peloids at top.	0.77	11.12
Mudstone, very silty and calcareous, shells and shell debris of bivalves, oysters, ostracods and serpulids.	0.70	11.82
Limestone, argillaceous, fine-grained, burrowed. Fine shell debris and recrystallised bivalves and ammonites.	0.37	12.19
PORTLAND SAND MEMBER 12.19-17.95		
Glauconitic Beds:		
Sandstone, brown-yellow and grey, fine to very fine-grained. Glauconitic. Weak calcareous cement. Burrowed. Serpulids and bivalves mainly in lower part.	0.82	13.03
Limestone, silty, grey, shell fragmental. Glauconitic.	0.17	13.20
Sand, green-grey and brown, very fine grained, glauconitic. Burrow-fills of silty clay particularly in lower part. (0.55 core lost).	2.90	16.10
Siltstone, pale brown-grey, with scattered glauconite grains. Intensely burrowed with burrows filled with clay or glauconitic silt. Sparse bivalves and serpulids. Scattered tiny lydite pebbles in lower half.	1.21	17.31
Sandstone, silty, glauconitic. Scattered bivalves.	0.52	17.83
Upper Lydite Bed:		
Siltstone, brown grey intensely burrowed with clay burrow-fills. Bivalve casts; ammonite, belemnite. Black sub-rounded lydite, phosphate and small quartz pebbles, up to 15mm diameter. Irregular base.	0.12	17.95
KIMMERIDGE CLAY FORMATION 17.95-64.98		
"UPPER KIMMERIDGE CLAY" 17.95-51.82		
HARTWELL SILT MEMBER 17.95-29.45		
Siltstone, medium grey, sparsely micaceous. Intensely burrowed with infills of clean silt or darker clay. Moderately abundant bivalves and ammonites.	10.05	28.00
Siltstone and silty mudstone, medium and dark grey, as above, interburrowed with smooth mudstone. Strikingly interburrowed base.	1.45	29.45
SWINDON CLAY MEMBER 29.45-35.57		
Mudstone, pale grey,smooth with silty burrow fills. Scattered ammonites and bivalves, common oysters; pyrite trails and pins.	2.85	32.3
Mudstone, medium to dark grey, shelly.	1.02	33.32
Mudstone, pale grey, smooth, sparsely shelly, burrow-mottled.	0.78	34.10
Mudstone, medium to dark grey very shelly. Phosphatic pebble bed (*Lower Lydite Bed*) at base. (= base Swindon Clay Member)	1.47	35.57

Mudstone, brownish grey smooth, sparsely shelly. Abundant foraminifera; intensely burrowed.	1.91	37.48
Siltstone, grey, intensely burrowed; infills of clay. Moderately shelly. Phosphatic pebbles at base.	0.28	37.76
Mudstone, slightly silty medium grey, with silt-filled burrows. Smooth for 2m at 40.3.	2.84	40.60
Mudstone, brownish-grey, slightly silty, with silt burrowfills. Shelly. Passing to poor oil-shale for 0.10 at base.	0.60	41.20
Mudstone, medium grey, silty. Shelly in lower part.	0.85	42.05
Mudstone, pale grey, smooth, moderately shelly.	0.55	42.60
Mudstone, medium grey, silty, very shelly.	1.05	43.65
Mudstone, medium to dark grey, silty to smooth with many crushed ammonites and oysters.	0.85	44.50
Mudstone, pale and medium grey, smooth, calcareous, with pyrite trails and pins. Moderatly shelly.	2.70	47.20
Mudstone, medium to dark grey, shelly, with beds of oil-shale (0.04 to 0.11) at 47.25, 47.69, 48.54, 49.32.	2.12	49.32
Mudstone, medium and dark grey with oil-shale wisps and burrow-fills, and for 0.05 at base.	0.48	49.70
Cementstone, shelly, burrow-mottled, passing down into pale grey mudstone.	0.26	49.96
Mudstone, dark and medium grey, mostly very shelly., interburrowed and interbedded with oil-shale.	1.86	51.82
"LOWER KIMMERIDGE CLAY" 51.82-64.98		
Mudstone, dark grey, smooth. Very shelly below 52.40.	0.76	52.68
Mudstone, brownish medium grey and dark grey. Common *N. virgula* at top. Beds of shelly oil-shale 0.12 at 53.12 and 0.07 at 53.50. Very shelly below 53.90	1.44	54.12
Mudstone, dark grey, shelly, interbedded and interburrowed with oil-shale in lower part.	0.87	54.99
Mudstone, medium and pale grey, moderately shelly.	0.50	55.49
Mudstone, brownish medium grey, barren, with beds of shelly oil-shale 0.04 at 55.53, and 0.05 at 56.31, and interburrowed with oil-shale at base.	0.98	56.47
Mudstone, pale and medium grey, very shelly; many bivalves including *N. virgula*. Partly cemented for 0.15 at 56.75 and 57.40.	1.29	57.76
Mudstone, pale, medium and dark grey, sparsely to very shelly, with beds of shelly oil-shale (0.03 to 0.08) at 57.83, 58.02, 58.46.	0.99	58.75
Mudstone, extremely shelly, with *N.virgula*.	0.09	58.84
Mudstone, pale grey. shelly. partly cemented, with wisps and burrowfills of oil-shale, and bed for 0.06 at top and 0.03 at 59.09.	1.26	60.10
Mudstone, dark brownish grey very shelly with bivalves and ammonites. Oil-shale for 0.04 at 60.22.	0.15	60.25
Mudstone, pale grey, smooth, shelly.	0.25	60.50
Mudstone, medium grey, very shelly, with *N. virgula*. Intensely burrowed. Scattered black phosphatic grains and non-sequence at base.	0.18	60.68
Mudstone, pale grey, slightly silty, moderately shelly, pyrite pins and trails.	0.42	61.10
Mudstone, medium grey, burrow-mottled, silty, shelly, with *Pentacrinus* debris.	0.13	61.23

Mudstone, pale to medium grey, smooth, shelly.	0.27	61.50
Mudstone, medium to dark grey, smooth, very shelly.	1.25	62.75
Mudstone, medium and pale grey, very shelly, with *N. virgula*.	0.05	62.80
Mudstone, medium and pale grey, with much shell debris.	0.28	63.08
Mudstone, medium and pale grey, very smooth, sparsely shelly. Tiny phosphatic chips in lowest part, and abundant in shelly siltstone for 0.02 at base.	1.90	64.98
AMPTHILL CLAY FORMATION 64.98-76.69 (TD)		
Mudstone, pale grey, calcareous, smooth. Pyrite pins and trails.	0.80	65.78
Cementstone, smooth.	0.12	65.90
Mudstone, pale grey, calcareous, as above.	0.53	66.43
Cementstone, smooth, strongly cemented.	0.17	66.60
Mudstone, pale grey, very calcareous, as above.	0.20	66.80
Mudstone, medium to dark grey, smooth, moderately shelly, with *D. delta*. Black phosphatic chips in burrows at 66.85.	1.10	67.90
Mudstone, interburrowed medium and pale grey, smooth, shelly. Phosphatic pebbles.	1.12	69.02
Mudstone, medium slightly greenish grey. smooth, sparsely shelly with common *D. delta*. Pyrite pins and trails.	0.84	69.86
Mudstone, gritty and shelly with pebbles and angular chips of dark brown phosphate. Non-sequence at base.	0.02	69.88
Mudstone, medium slightly greenish grey, almost barren. Pyrite knots. *D. delta* at base.	1.02	70.90
Mudstone, dark and medium to pale grey, smooth, shelly.	0.10	71.00
Mudstone, medium and dark grey smooth, much plant dust. Some shell plasters.	2.95	73.95
Mudstone, pale grey, smooth, almost barren. Pyrite pins and trails. Some shell plasters in lower part. Seen to terminal depth of borehole.	2.74	76.69

Appendix 2. SP 71 SE (Stone): Sections

BUGLE PIT S.S.S.I., Stone. [7932 1205]. This once extensive pit has for the most part been infilled, but a small section has been preserved by the Nature Conservancy Ccouncil. Access is via the stable yard [7943 1213]; permission should be obtained from the owner Mrs. Herring. The section exposed on 18 October 1988 was as follows:

	Thickness (m)
Topsoil:	
7. Clay, brown, loamy, crumbly. Rare subangular limestone pieces.	0.34
Purbeck Formation:	
6. Marl, pale buff to green-grey mottled, crumbly. Disturbed colour banding and cryoturbated, 0.03m bands of moderately soft, white to pale brown mottled, poorly laminated, micritic limestone with lenticles of quartz sand with shell debris, at 0.15m and 0.30m above base and at top. Green-grey clay for 0.08 at base.	0.52
5. Limestone, micritic, buff, weathering to yellowish brown, some layers packed with decalcified shell debris including tiny gastropods. Uneven beds, up to 0.07m thick, separated by seams of brown and marly clay. At western end of pit, laminated, stromatolitic limestone for up to 0.06m at top. Basal 0.08m is orange, yellow brown, highly ferruginous, and cavernous due to (possibly penecontemporaneous) weathering.	0.37
4b. Marl, pale cream, with irregular diffuse lenticles of soft to hard and splintery limestone as below. Passing to	0.60
4a. Limestone, micritic, pale cream and brown mottled, with some softer marly patches. Beds 4a and 4b are lithologically similar, but differentially cemented)	0.47
3. Limestone, grey, weathering brownish. Finely sandy (quartz). Very hard, recystallised, with a uniform, finely saccharoidal texture. Prominent bed, sharp base.	0.36
2. Marl, pale grey and buff mottled with discontinuous nodular beds of hard splintery pale buff-flesh structureless micritic limestone up to 0.05m thick at 0.15m and 0.25m above base.	0.33
1. Sand and silt (quartz)bound by calcareous mud. Mid brown and grey striped. Well bedded, and poorly indurated in parts. Scattered black chitinous fish or insect and carbonaceous plant debris. Dark grey, soft slightly shaly silt for 0.12m at 0.18m above base	0.40
Obscured	1.50

Bed 3 probably equates with Bed 7 of Merrett's section (see below), suggesting that the base of the Purbeck lies c 0.4m below the base of the present section. A section totalling 2.7m, and apparently corresponding with the upper part of the section recorded above, is given by Ballance (1960, p.257). The following section is given by Merrett (1924); the face of the pit at that time was probably some distance to the north or north-east of the extant section:

10. Soil and stony clay.	0.30
Purbeck Formation:	
9. Limestone.	0.25
8. Unstratified greenish and white marl with race.	1.14
7. Hard white limestone.	0.36
6. Slightly greenish marl with calcareous concretions.	0.48

5. Sand.		0.06
4. Sandy clay with a band of brown clay at the base.		0.19
2. Black marly clay, brown at base.		0.13
1. Pendle.		0.25
Portland Formation:		[no details or thickness given]

The Portland Formation was formerly exposed beneath the Purbeck. Phillips (1870) gives some details of a section "close to Hartwell", almost certainly the Bugle Pit. Below 2.7m of undoubted Purbeck Beds with "Pendle stone" at the base, it apparently showed about 3m of Creamy Limestones, 1.83m of Crendon Sand and 0.51m of the underlying Aylesbury Limestone. His brief record bears comparison with the following section, pieced together from Hudleston (1880, pp 349, 350; 1887, pp169,170) (numbering and classification added by MGS):

Portland Formation; Portland Stone Member:		
Creamy Limestones:		
7. Soft brash with large oysters and ammonites	}	
6. Hard building stone.	}	0.91
5. Brash	}	
4. Creamy limestone, very fossiliferous, burned for lime		1.83
3. Hard, uniform building stone		0.61
Crendon Sand:		
2. Yellowish-buff loose sand		1.37
Aylesbury (Rubbly) Limestone:		
1. Hard, blue, poorly fossiliferous limestone		(top seen)

Woodward (1891, p.3), gives a section of the Bugle Pit which later formed the basis of his figured "Section at Aylesbury" (Woodward, 1895, p.224). The latter is much reproduced with minor modifications in the publications of Davies and by Arkell (1947, p.126). Lower beds in the figured section (Beds 1, 2 and the lower part of 3) seem to be based on various temporary sections in Aylesbury (Sumbler, in prep.a):

12. Rubbly soil and stony clay filling hollows and irregularities in the beds below.	[no thickness given]
Purbeck Formation:	
11. Grey and greenish marls and clays with race and bands of pale earthy limestone, obscurely oolitic in places; dark clay at base.	3.35
Pendle:	
10. Hard fissile and jointed marl with ostracods, "*Mytilus?*", fish remains and insects.	0.23
Portland Formation:	
Portland Stone Member:	
Creamy Limestones:	
9. Brown, calcareous sandy bed with large ammonites and oysters.	0.18
8. Hard limestone "roach" with casts and moulds of *Trigonia*.	0.30
7. Shelly clay with oysters and ostracods.	0.10
6. Creamy blue-hearted marly and shelly limestone with *Natica*, in three or four beds.	2.13
5. Hard greenish-grey gritty limestone.	0.51
Crendon Sand:	
4. Greenish-yellow sands.	1.52
Aylesbury (Rubbly) Limestone:	
3. Tough bluish limestone, unfossiliferous; seen to	1.06

Material from Bugle Pit in BGS collections:

This list (compiled by B.M. Cox) gives details of the material held in the old BGS collections. The specimens themselves have not been examined; faunal and stratigraphic comments rely on miscellaneous entries in the appropriate registers. Listed in Register F138-41 are fossils from the Kimmeridge Clay, Portland, Purbeck and Greensand in the collection at Hartwell House (dated 1885). Additional material from the area is held in the Buckinghamshire County Museum at Aylesbury.

Lithostratigraphy:	Collector/date:	Register:	Specimen nos:	Comments:
"Portlandian- soft stone- *N.ceres* zone"	W H Hudleston; presented 1920	16/94	Y361-2	bivalves
"Portland-top building stone"	"	16/164	Y1340	bivalve
"Portlandian- about middle of Blue Beds"	S S Buckman; presented 1924	16/273	Z3539	-
"Portland - bed b"	W H Hudleston; presented 1920	16/162	Y1280-4	bivalves
"Portland-top building stone"	"	16/162	Y1285	bivalve
"Purbeck"	S W Hester 1944	85/199-201	Zt310-53	-
"Purbeck, soft part of Cementstone"	W H Burrows; presented 1948	42/55	Zk3904	ostracod

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STONETHORPE FARM [7839 1205]. Silage pit south of the old farm buildings:

Portland Formation; Portland Stone Member:
Creamy Limestones:
3. Pale grey, poorly bedded, rubbly, finely sandy limestone. Rare glauconite grains. A few bivalves. 1.2
Crendon Sand:
2. Pale brown to mustard-tinged structureless fine grained sand and silt. 1.1
Aylesbury (Rubbly) Limestone:
1. Pale grey to white, soft to hard, rubbly silty to finely sandy limestone. Abundant bivalve moulds including large myids and Lima. 0.4

WESTLINGTON [7630 1039]. Ballance (1963, p.401) gives the following section of a temporary exposure:

4. Fossiliferous, chalky white limestone 0.61
3. Fine-grained orange sand, very calcareous in patches, containing *Trigonia* and *Protocardia* near base 1.07
2. Hard, blue hearted sandy fossiliferous limestone 0.25
1. Black calcareous clayey silt, the uppermost foot [=0.3m] oxidised to orange colour

According to Ballance, Bed 4 is the Creamy Limestone, Bed 3 Crendon Sand, Bed 2 "Glauconitic and Rubbly Beds", and Bed 1 Kimmeridge Clay. This implies dramatic thinning of the lower part of the Portland Formation compared with the Bugle and Hartwell Borehole sections, and does not accord with mapping (by MGS) which puts the locality close to the top of the Portland Sand Member. Probably Bed 4 is the Portland Stone/Aylesbury (Rubbly) Limestone; Bed 1 may be Kimmeridge Clay, but seems equally likely to be part of the Portland Sand.

DINTON STONE PITS (Fitton, 1836, p.285). The site is described as "south-west of the cross-road from Dinton to Cuddington", and is probably the extensive ancient pit near Spring Hill [7590 1140], as also concluded by Davies (1899, p.33). Bed numbering (from the top downwards) follows Fitton; paraphrased and classified by MGS.

1,2.	Soil and sandy loam.	0.76
Purbeck Formation:		
3.	Greenish grey clay.	0.23
4,5.	Brown and grey clay with a 0.05 to 0.10m bed of dark brown ferruginous clay with bivalves and shell fragments at the base. Irregular base [probably due to channelling or solution].	0.43 to 1.02
6.	Grey clay and soft freshwater limestone, containing irregular masses of stone, in places with minute tubular cavities [presumably borings]. Gastropods and bivalves.	0.91
7.	Thin, tough dark ?ferruginous clay with iridescent *Isognomon*.	[no thickness given]
8a.	Soft fissile marl in about six beds.	0.91 to 1.22
8b.	Hard, uniform calcareous sandstone [probably a recrystallized sandy limestone].	0.30
9.	Greenish fissile sandy clay with stony concretions.	0.30
10.	Fissile sandy "matter" and grey sandy clay.	0.46
11.	Tough, yellowish fissile sandy marly clay with ostracods and bivalves.	[no thickness given]
Portland Formation; Portland Stone Member; *Creamy Limestones*:		
12a.	Shelly limestone roach.	0.23
12b.	Solid stone.	[no thickness given]
12c.	Soft bluish stone full of shells including ammonites and oysters.	[no thickness given]

CHURCH FURLONG PIT, Bishopstone [7973 1099] (Fitton, 1836,p.287). The pit is named and sited in Smyth (1864, p.46; plates 2,4). Ballance (1960, p.191) wrongly sited this pit is in a field 1km to the east [8075 1090], but there is no sign of a pit at this locality. He seems to have been unaware of Smyth's publication; I am grateful to M.J. Oates for drawing it to my attention. Bed numbering (from the top downwards) follows Fitton; paraphrased and classified by MGS.

1.	Soil	
Purbeck Formation:		
2.	Greenish and brown "fuller's earth".	0.02 to 0.30
3.	Decomposed rubble of white freshwater limestone with ostracods and gastropods.	1.22
4a.	Light olive greenish "fuller's earth".	0.10

4b. Soft limestone.	0.15
4c. "fuller's earth" as 4a.	0.05
4d. Soft limestone as 4b.	0.08
4e. "fuller's earth".	0.05
5. Firm grey and whitish granular calcareous grit. 0.15 to	0.23
6a. Sandy ochreous clay.	0.05
6b. Dark greenish "fuller's earth".	0.05
6c. Greenish grey marly sand with fish scales.	0.17
Pendle:	
7. Fissile clay and marl passing into stone, with ostracods, bivalves and fish scales.	0.45
8. Dark grey fissile clayey limestone, with ostracods, bivalves and gastropods.	0.15
Portland Formation; Portland Stone Member; *Creamy Limestones*:	
9. Dark blue shelly limestone.	[no thickness given]

ST.JOHN'S LODGE QUARRY. [7876 1212] (Smyth, 1864, Plate 3). St.John's Lodge (now Stone House) was, from 1851, W.H. Smyth's home. The following detailed section of the quarry was probably the work of his son, the geologist C.P. Smyth. The quarry is now built over. Bed numbers and classification added by MGS:

Purbeck Formation:	
12. Finely laminated, waved grey clay.	0.91
11. White marly limestone.	1.83
10. Rubbly white marl.	0.38
9. Soft reddish sandstone with fish, gastropods and bivalves.	0.02
8. Pale blue finely laminated clay.	0.28
7. Soft brown sandstone.	0.15
6. Pale blue clay.	0.10
Pendle:	
5. Smooth white slaty limestone.	0.05
Portland Formation; Portland Stone Member; *Creamy Limestones*:	
4. Hard brown oolite limestone.	0.13
3. Hard grey limestone.	0.76
2. Soft shell marl.	0.08
1. White earthy limestone.	1.07

STONE SAND PIT. (Fitton, 1836, p.285). Exact location uncertain. Numbering (from the top downwards) follows Fitton.

Vegetation and soil. 0.30 to	0.91
Whitchurch Sand Formation:	
1. Greenish clay "like fuller's earth". 0.15 to	0.23
2. Grey sandy clay. 0.23 to	0.38
3. Rust-coloured sand, becoming grey downwards; the lower boundary irregular and gradational. 0.46 to	0.61
4. Whitish uniform sand with irregular sub-horizontal layers of grey, yellow brown and nearly black.	2.44

STONE SAND PIT. (Morris 1867, p.458, footnote). Morris' text is ambiguous; the pit is probably the Windmill Pit [780 123] (see below) or one nearby, but it could be the "white sand-pit" [789 124] (see below). Bed numbers added by MGS:

Whitchurch Sand Formation (? and Lower Greensand):		
6.	Coarse sand and pebbles.	1.22
5.	Ferruginous sandstone and rock.	0.15
4.	Imperfectly stratified Clay ("fuller's earth?")	0.10
3.	Ferruginous sand.	0.30
2.	Grey sandy clay.	0.30
1.	White and grey sand, wavy and irregular with carstone and ironstone.	2.44

WINDMILL SAND PIT, Stone [7804 1231] Davies 1899 p.49. Now degraded and incorporated into private gardens.

Whitchurch Sand Formation:		
6.	Sandy clay	1.01
5.	Sand and ironstone.	0.23
4.	Sandy clay.	0.08
3.	Sand and ironstone.	0.43
2.	Cross bedded white and grey sand. with pebbles. 1.68 to	2.36
1.	Bedded firm grey sand.	1.07

Jukes Brown (1887; Bucks 33 field-map, BGS archive) gives the following section of this or a nearby pit:

Whitchurch Sand Formation:		
6.	Clay and soil.	0.91
5.	Alternating sand and clay.	1.52
4.	False bedded white sand	3.58
3.	Clay.	[no thickness given]
2.	Yellow sand.	[no thickness given]
1.	Clay.	[no thickness given]

CASTLE'S PIT, Eythrope Road, Stone [7802 1263] (Davies 1899 p.49). Now filled.

Whitchurch Sand Formation:		
6,5.	Sandy soil and bluish white plastic clay.	1.52
4.	Bright orange sand.	0.30
3.	Whitish sand.	0.15
2.	Black loam.	0.61
1.	Partly cross-bedded white sand with a few seams of black loam, few pebbles.	3.66

Jukes Brown (1887; Bucks 33 field-map, BGS archive) gives the following section of "Twividale Sand Pit", which is almost certainly this same pit:

Whitchurch Sand Formation:

5.	Sandy soil.	0.91
4.	Grey clay.	0.30
3.	Bright yellow sand.	0.30
2.	Grey rather clayey [sand?]	0.91
1.	White sand	2.13

The more recent workings here [779 126], which extended to nearly 5 hectares, were examined by Ballance (1960, p.162). Though he gives no detailed sections, the general sequence appears to have been:

Whitchurch Sand Formation:

2.	Grey, white, ochre-coloured and orange clays with seams of limonitic ironstone and ferruginous sand.	3.65
1.	Fine-grained pure white cross-bedded sand with seams of black peaty material up to 0.15 thick, and occasional seams and pockets of grey silt, abundant clay galls, and seams of pebbles and pebbly sand. Iron-staining and box-ironstone developed in patches.	3.65

CASTLE'S PIT, south of Stone Villas [7815 1240] (Davies 1899 p.49). Now filled.

6.	Soil and drift.	0.76
Whitchurch Sand Formation:		
5.	Clayey sand.	0.10
4.	Clay.	0.23
3.	Cross-bedded sand with pebbles and ironstone.	1.91
2.	Lenticular "Fuller's Earth".	0.23
1.	Cross-bedded sand "etc."	3.05

STONE FARM SAND PIT. (Davies 1899 p.49). Stone Farm (now demolished) lay on the site of Manor Farm Close [7845 1230]. The pit [7863 1242] is now degraded and incorporated into private paddocks and gardens.

5.	Soil.	0:46
Whitchurch Sand Formation:		
4.	Clay.	0.15
3.	Clayey sand.	0.20
2.	Clay.	0.30
1.	Light coloured sand.	2.74

Davies states that in an old face, the beds are capped by a band of hard, ferruginous, small-pebble conglomerate (?Lower Greensand). This is the "white sand pit" of Morris (1867). Morris states that the white sand from the pit (?bed 1, about 20ft=6.1m thick) yields hard siliceous concretions or "Bowel Stones". These are incorporated into the walls around Hartwell House, where they were once known as "the Doctor's Bowels", after the owner, Dr Lee, a keen amateur geologist and the close friend of Smyth. Jukes Brown (1887; Bucks 33 field-map, BGS archive) gives the following section of "Stone pit, opposite Stone Farm", which is almost certainly this same pit, as the thicknesses correspond closely:

6. Soil.	0.30
Whitchurch Sand Formation:	
5. Clay.	[?]0.51
4. Yellow sand.	0.30
3. Grey clay.	0.30
2. Yellow loam.	0.61
1. White sand.	2.13

PEVEREL COURT PIT [7955 1176] (Church-field pit of Smyth, 1864, p.46). See also main text. This formerly extensive sandpit in the Lower Greensand is now degraded and ploughed over, but a considerable depression still marks the site. Morris (1867) recorded c 1.8m of coarse ferruginous pebbly sands resting on Portland beds; the total thickness here is probably of the order 4m. He lists fossils, both indigenous and probably derived. Smyth (1864, p. 46) states that the pit yielded "fine red sand" and also yellowish and brownish-red sand. Lower Greensand fossils in the Hartwell House collection (now dispersed) probably came from this pit.

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