Stanton Harcourt Gravel Pit and Magdalen Grove Deer Park

[SP 415 052] and [SP 520 065]

Highlights

These are important sites for interpreting the stratigraphically complex sequence of deposits forming the Summertown-Radley Terrace of the Upper Thames basin. This formation shows evidence of having aggraded during two full climatic cycles, thereby encompassing two major warm episodes, as well as one complete cold episode and parts of two others. Faunal evidence from Stanton Harcourt has been critical in demonstrating that the earlier of these temperate intervals represents an additional, as yet unnamed interglacial in the British Pleistocene — a terrestrial correlative of Oxygen Isotope Stage 7 (*c.* 200,000 years BP) of the deep-sea record. Formerly attributed to the last interglacial (Ipswichian Stage), the Magdalen Grove site now appears to represent further evidence for this newly recognized Stage 7 interglacial.

Introduction

The Summertown-Radley Terrace of the Upper Thames basin is formed by a complex sequence of sediments (the Summertown-Radley Formation) representing periods of both temperate and cold climate. The terrace is widely preserved in the Thames valley downstream from the confluence with the Windrush, but is not well represented in any of the tributaries (Figure 2.1). The deposits forming this terrace have been well exposed in the past, notably at Eynsham, Summertown, Radley, Cassington, Stanton Harcourt and a number of exposures within the urban area of Oxford (Pocock, 1908; Sandford, 1924, 1926; Dines, 1946). Aggraded to 6–10 m above river level in the Oxford area, the Summertown-Radley Terrace was first named by Sandford (1924), although it had previously been described as the '2nd' or '20 ft' Terrace (Prestwich, 1882; Pocock, 1908).

Sandford (1924, 1926) considered that gravels forming the upper part of the Summertown-Radley aggradation contained the remains of interglacial mammals and molluscs, whereas the underlying lower part of the sequence yielded a mammalian fauna of cold-climate character. In recent years the occurrence of an interglacial deposit clearly stratified beneath Sandford's lower, cold-climate Summertown-Radley gravel has been revealed in a pit to the south of Stanton Harcourt, in the main valley of the Thames (Briggs and Gilbertson, 1980; Briggs *et al.,* 1985; Briggs, 1988). This discovery led to the recognition of a tripartite sequence of deposits beneath this terrace, indicative of a succession of climatic episodes, from temperate to cold (periglacial) and returning again to temperate (Figure 2.12). The earlier of these two temperate episodes has been widely attributed to a hitherto unrecognized interglacial between the Hoxnian and Ipswichian Stages (Briggs and Gilbertson, 1980; Shotton, 1983; Briggs et al*,* 1985; Bowen *et al.,* 1989). Reappraisal of the stratigraphy of the Summertown-Radley Formation suggests, however, that the sequence is even more complex, perhaps representing five separate climatic episodes (Table 1.1).

It has generally been assumed that the cold-climate gravels at Stanton Harcourt are equivalent to those described beneath the upper fossiliferous (temperate-climate) Summertown-Radley deposits in early records. Briggs *et al.* (1985) proposed the name Stanton Harcourt Gravel for this unit. However, the upper interglacial sediments have never been observed at Stanton Harcourt, so the full tripartite stratigraphy of the Summertown-Radley aggradation has never been recorded in superposition. Recent new exposures in this terrace have consistently failed to reveal temperate deposits overlying cold-climate gravels, in the relation ship described by Sandford, and none of the sites featuring in the early records have been available for study for some years. Attempts were therefore made as part of the GCR site selection programme to relocate some of the early sections, with the result that the deposits at Magdalen Grove (Figure 2.13), originally described by Sandford (1924, 1926), were re-excavated (Bridgland, 1985a; Briggs *et al.,* 1985). Briggs *et al.* (1985) followed Sandford in attributing the deposits at Magdalen Grove to the (interglacial) upper part of the Summertown-Radley Formation, which they termed the Eynsham Gravel. Detailed consideration of the altitudinal position and fauna from this and other fossiliferous sites in the Summertown-Radley Formation raises serious doubts about this interpretation, suggesting instead that the Magdalen Grove deposits (and certain others formerly attributed to the Eynsham Gravel) were deposited during the earlier (Stage 7) temperate episode.

Description

Lithostratigraphical classification of the Summertown-Radley terrace deposits has already been established in Chapter 1 (Table 1.1), as follows:

(Figure 2.12) Idealized section through the Summertown-Radley Formation.

Formation	Member	Climate
Summertown-Radley	Unnamed upper gravel at Eynsham	Cold
	Eynsham Gravel	Temperate
	Stanton Harcourt Gravel	Cold
	Stanton Harcourt Channel Deposits	Temperate
	Unnamed lower gravel at Summertown	Cold

This sequence has been determined from records of exposures over a lengthy period. At sites revealing only cold-climate gravels, individual members cannot be identified and the term Summertown-Radley Gravel Formation should be applied.

Descriptions of Summertown-Radley Terrace deposits appeared in the literature long before the definition of the terrace by Sandford (1924). Prestwich (1882) and Pocock (1908) both recorded various fossils from this formation, but it was Sandford (1924, 1926) who first noted that the fauna allowed a bipartite division of the aggradation. According to Sandford, bones from the lower part of the sequence (= Stanton Harcourt Gravel) were of cold-climate mammals, dominated by *Mammuthus primigenius,* with *Coelodonta antiquitatis* (Blumenbach) and *Bison priscus* (Bojanus). *Equus ferus* and *Ursus* sp. (cited as *Ursus anglicus*) were added to the faunal list by Sandford (1954).

Stratigraphically above the lower, mammoth-rich gravel, Sandford described deposits, usually finer and less ferruginous, that yielded *Palaeoloxodon antiquus, Dicerorhinus hemitoechus, Hippopotamus amphibius* L., *Bos primigenius, Cervus elaphus, Equus ferus* and other species typical of temperate environments, as well as molluscan faunas that frequently included the southern bivalve species *Corbicula fluminalis* (Müller). If the records of Sandford (1924) and Dines (1946) are combined, this upper temperate-climate deposit has been recorded at ten sites (Briggs *et al.,* 1985), of which the most important were Eynsham (Station Pit, [SP 429 088]), Magdalen College (Magdalen Grove GCR site), Summertown (Webb's Pit, [SP 503 086]) and Radley (Silvester's Pit, precise location uncertain). These were assigned by Briggs *et al.* (1985) to their Eynsham Gravel.

Stanton Harcourt

Erstwhile workings at Stanton Harcourt have been recorded in the various Geological Survey memoirs for the area (Pocock, 1908; Sandford, 1926; Dines, 1946). None of these authors provided any detailed description of the site, although all noted that the gravel here is locally ferruginously cemented into a hard rock. This was used to construct the nearby megaliths, the Devil's Quoits, and appears in the stonework of Stanton Harcourt church. Arkell (1947a) referred to the present pit, to the south of the village. The modern workings, Dix's Pit, exploit an area known as Linch Hill. To avoid confusion with the type locality of the Lynch Hill Terrace of the Middle Thames, it is preferable to refer to this Upper Thames site as Stanton Harcourt.

The Stanton Harcourt site shows two of the five members now recognized within the Summertown-Radley Formation: the Stanton Harcourt Channel Deposits and the Stanton Harcourt Gravel. Although the overlying Eynsham Gravel is absent throughout the large workings here, its type locality, at Station Pit, Eynsham (Briggs *et al.,* 1985), is only 4 km downstream (Sandford, 1924, 1926; (Figure 2.1)).

The importance of the Stanton Harcourt site lies in the occurrence there of interglacial sediments underlying the cold-climate Stanton Harcourt Gravel (Briggs and Gilbertson, 1980; Briggs *et al.,* 1985). This temperate-climate deposit appears, from its restricted distribution, to fill a 'single thread' channel cut into the Oxford Clay, which floors the pit (see (Figure 2.12)). It is composed of gravels, sands, silts and organic sediments and is highly fossiliferous, yielding mammals, molluscs and beetles, together with wood and plant remains (Figure 2.14). The rich molluscan fauna, comprising at, least 34 aquatic and terrestrial species of warm-climate aspect, includes the important bivalve *Corbicula fluminalis* (Briggs *et al.,* 1985). The mammals include *Mammuthus primi genius, Equus ferus* and *Panthera leo* (L.) The first two of these species were also found *in situ* near the base of the overlying Stanton Harcourt Gravel, in company with a small horn core and skull fragment from a bovid, probably *Bison* sp. (Seddon and Holyoak, 1985).

The exposures of Stanton Harcourt Gravel at the type locality (Dix's Pit) have been described in varying detail on a number of occasions (Briggs, 1973, 1976a; Goudie and Hart, 1975; Gilbertson, 1976; Briggs and Gilbertson, 1980; Bryant, 1983; Briggs *et al.,* 1985; Seddon and Holyoak, 1985). Two divisions have been recognized at Stanton Harcourt (Figure 2.15) within this cold-climate member (Stanton Harcourt Gravel). The lower is coarser and has a maximum thickness of 1.5 m. The higher, finer-grained division is separated from the lower by a well-developed zone of cryoturbation. Capping the sequence is a deposit that has been described as 'coverloam' and which is thought to postdate the formation of the Summertown-Radley Terrace (Briggs *et al.,* 1985). Both divisions of the Stanton Harcourt Gravel contain thin, intermittent sand and silt beds from which molluscan remains have been obtained (Briggs *et al.,* 1985; Seddon and Holyoak, 1985). In addition to the important interglacial channel deposits already described, the Stanton Harcourt Gravel is locally underlain by a basal sand/silt unit, often with ripple drift or parallel lamination, that contains plant remains and occasional Mollusca (Figure 2.15). Pollen and other plant remains were also obtained from within a single silt-filled channel structure, at a height of *c.* 1 m above the Oxford Clay (Seddon and Holyoak, 1985). These various molluscan assemblages, from minor beds within the Stanton Harcourt Gravel, are in keeping with other evidence, from periglacial structures, implying deposition of this member under cold conditions.

Zones of cryoturbation occur at the top of both divisions of the Stanton Harcourt Gravel (Figure 2.15). Ice-wedge casts occur at many different levels within the member (Seddon and Holyoak, 1985; (Figure 2.16)).

Magdalen Grove

A small pit in Magdalen College Grove (now a deer park) was described by Sandford (1924). He noted that the site had a low elevation within the Summertown-Radley aggradation, but that it nevertheless showed both parts of the bipartite sequence he had established, with a later warm-climate gravel channelled into an earlier deposit containing mammoth remains (Figure 2.13). He regarded this as 'probably the most instructive section as yet opened' (1924, p. 142), an opinion that was supported by Arkell (1947a).

A section at the Magdalen Grove GCR site, re-excavated in 1984, appeared similar to that illustrated by Sandford, revealing silty sands and gravels channelled into an earlier sequence of gravels, silts and sands (Figure 2.13). However, whereas in Sandford's section the earlier deposit, below the channel feature, was identified as the cold-climate (Stanton Harcourt Gravel) aggradation (on the basis of its fauna, which comprised abundant *Mammuthus primigenius*), the beds in the same stratigraphical position in the 1984 section yielded temperate-climate pollen and faunal remains (Figure 2.13). These deposits contained molluscs and pollen, as well as a humerus of lion (*Panthera leo*). The molluscan fauna (27 species), comprising land snails, freshwater snails and bivalves (Briggs *et al.,* 1985), included *Corbicula fluminalis* in abundance (see below). The pollen assemblage was dominated by arboreal and herb taxa, with a high incidence of broad-leaved trees; it provided confirmation of an interglacial origin for the silts and sands. These temperate-climate deposits have been attributed to the Eynsham Gravel Member (Briggs *et al.,* 1985), but reevaluation of the stratigraphy of the Summertown-Radley Formation suggests that this may be incorrect (see below).

Interpretation

The combination of the geological evidence from sites such as Stanton Harcourt and Magdalen Grove, in conjunction with mapping of the distribution of the Summertown-Radley deposits and observations of their stratigraphy throughout their outcrop, has allowed a tripartite sequence to be established (Briggs *et al.,* 1985; (Figure 2.12)), as follows:

3. Eynsham Gravel (temperate)

2. Stanton Harcourt Gravel (cold)

1. Stanton Harcourt Channel (temperate) Deposits

Before assessing this sequence, it is necessary to examine the bipartite division of the Summertown-Radley Terrace deposits, proposed by Sandford (1924, 1926), in which only members 2 and 3 (above) were recognized. It is important to establish that the cold-climate gravel that underlies the Eynsham Gravel is the same deposit that overlies the more recently discovered interglacial channel-fill at Stanton Harcourt. This stratigraphical relationship is fundamental to the interpretation of the Stanton Harcourt Channel Deposits as the product of a post-Hoxnian but pre-Ipswichian temperate episode.

Sandford's (1924) distinction of a lower, cold-climate aggradation (the Stanton Harcourt Gravel of Briggs *et al.,* 1985) was further underlined by the discovery, at the base of Summertown-Radley Terrace deposits at Dorchester [SU 569 948], of an organic layer that yielded fossil plants indicative of a cold climate (Duigan, 1955).

One of the more significant advances stemming from recent research in the Upper Thames is the realization that the various gravels have predominantly accumulated under periglacial conditions. Earlier models tended to regard cold intervals as periods of erosion and to attribute the bulk of the deposits to interglacials, a view backed up in this region by the relatively frequent occurrence of warm-climate faunas in the gravels. A significant move away from this view was promoted by Briggs and Gilbertson (1973), who demonstrated that the gravels underlying the Hanborough Terrace were laid down under cold conditions and concluded that the warm-climate mammalian fossils they contained were reworked (see above, Long Hanborough). Following this work, it was suggested by Goudie and Hart (1975) that a large part of the Summertown-Radley Formation was deposited under a 'fluvio-periglacial regime'. This view was based on observations at Standlake and at the present Stanton Harcourt site, which showed that at least the upper 3.5 m of the gravel is of similar character to the Hanborough Formation, suggesting a braided river origin, and that intraformational ice-wedge casts are common. Briggs (1976a) noted that the large complex ice-wedge casts that characterize the gravel at Stanton Harcourt (see Seddon and Holyoak, 1985; (Figure 2.16)) are associated with festooning and that, when observed on cleared horizontal surfaces, they form a polygonal 'patterned-ground' effect. Briggs also noted that the ferruginous cementation of the gravels (see above) is typically localized within these ice-wedge cast/festoon features. The braided river origin of the gravels at Stanton Harcourt was confirmed in a sedimentological study by Bryant (1983).

Further support for the interpretation of this gravel as the product of a periglacial environment is provided by a molluscan fauna obtained from an extensive silt band near the base of the succession. This fauna was dominated by the land snail *Oxyloma pfeifferi,* with significant numbers of *Pupilla muscorum* (Gilbertson, 1976; Briggs and Gilbertson, 1980). None of the species present is indicative of particularly cold conditions, but *P. muscorum* requires an exposed, open habitat. This, and the absence of woodland species, leads to the conclusion that this silt accumulated under a climatic regime significantly cooler than that of the present. Seddon and Holyoak (1985) found similar faunas in several silty beds within the Stanton Harcourt Gravel and noted that, although the species present are not good climatic indicators, the low diversity of the assemblages strongly suggests a cold climate. These authors also described pollen and plant assemblages dominated by herb species, mostly of arctic–alpine affinities.

It has become apparent in recent years that the cold-climate Stanton Harcourt Gravel Member very much dominates the Summertown-Radley Formation, certainly in the areas of recent exposure. However, Sandford (1924) considered the upper deposit (the Eynsham Gravel) to be dominant, believing that erosion had removed much of the lower, cold-climate gravel (Stanton Harcourt Member) before the warm-climate deposit was laid down. He noted, however, that the upper deposit was frequently superimposed upon the lower with little sign of any break in the sequence, although occasionally there was evidence of channelling at its base. He illustrated channelling on a large scale at the Magdalen College site (see (Figure 2.13)).

A critical reappraisal of the altitudinal relations and faunal content of the various deposits attributed to the uppermost (temperate) Summertown-Radley gravel raises a number of problems that have hitherto largely escaped attention. It appears that many attributions to this member have been erroneous. The original descriptions of the sites (Sandford, 1924, 1926; Dines, 1946) were made long before it was suspected that a further, older interglacial might be represented within the Summertown-Radley Formation (that subsequently identified in the channel deposits at Stanton Harcourt). Faunal records from the various sites in this terrace were merely combined to produce lengthy lists (for example, Kennard and Woodward, 1924) and recent authors have tended to assume, on the basis of the convincing stratigraphical descriptions by Sandford, that these assemblages were entirely derived from the upper deposit, the Eynsham Gravel of Briggs *et al.* (1985).

Eynsham Station Pit is no longer available for study, although degraded faces remain. Excavations here by the GCR Unit in 1984 failed to recover faunal remains (Bridgland, 1985a). Sandford (1924, p. 140) recorded *c.* 3 m of gravel, which was 'noteworthy for the very common occurrence of *Hippopotamus'.* He also noted that teeth of mammoth occurred at the base of the sequence, implying that his 'lower Summertown-Radley gravel' (Stanton Harcourt Gravel) was also represented at the site, making it 'one of the most important in the district' (1924, p. 141). There was faunal evidence for a cold-climate deposit beneath the hippopotamus-bearing levels at Radley and Iffley, as well as at Eynsham. Sandford (1924) also recorded a higher unit at Eynsham, separated from the Eynsham Gravel by an erosional contact, comprising *c.* 1 m of fine pebbly cross-bedded sand. This unit, devoid of fossils, may represent a post-interglacial aggradation (phase 2 of the terrace model — Chapter 1), superimposed upon the Eynsham Gravel during the early Devensian Stage (Table 1.1).

Hippopotamus amphibius is a most important species in the Late Pleistocene of Britain. It is regarded as an indicator for the Ipswichian Stage (*sensu* Trafalgar Square) since, despite the recognition of additional climatic cycles in recent years (Chapter 1), it is thought not to have lived in Britain between the Cromerian and the Ipswichian (Sutcliffe, 1960, 1964; Stuart, 1974, 1982a, 1982b; Gascoyne *et al.,* 1981). This species has been recorded from six sites in the Summertown-Radley Terrace: Eynsham, Wytham, Iffley, Radley, Abingdon and Dorchester (Sandford, 1924, 1965; Briggs *et al.,* 1985).

Many of the sites in the Summertown-Radley Formation, previously ascribed to the Eynsham Gravel Member, have yielded another species of possible stratigraphical significance, the bivalve *Corbicula fluminalis.* It has long been recognized that this mollusc has not lived in Britain during the Holocene, but it is now suggested that it was also absent during the Ipswichian Stage (*sensu* Trafalgar Square), although it has been recorded from many sites formerly regarded as Ipswichian but now considered to be older (Keen, 1990). The principal basis for this view is that there is no reliable record of *C. fluminalis* and hippopotamus occurring together in the same deposit. The Eynsham Gravel would appear to be an exception, but close scrutiny of the records reveals that, of the six sites listed above that have yielded hippopotamus, C *fluminalis* is recorded only from Radley, where its presence was based on a single abraded fragment (Sandford, 1924; Kennard and Woodward, 1924). It seems highly likely that this was reworked. At other sites, such as Summertown, the species was found in abundance (Prestwich, 1882; Sandford, 1924), as it is at both the Magdalen Grove and Stanton Harcourt GCR sites. None of these sites has yielded hippopotamus, although numerous other mammalian remains were found. The occurrence of abundant *C. fluminalis* and the absence of hippopotamus from these sites suggests that they represent the earlier of the two temperate intervals recognized from the Summertown-Radley aggradation, that which was first identified from the Stanton Harcourt channel. The true Eynsham Gravel yields hippopotamus but not *Corbicula* (except for derived specimens, as at Radley, reworked from the earlier interglacial member) and is therefore attributable to the Ipswichian Stage (*sensu* Trafalgar Square). It has been recognized unequivocally only at the six sites, listed above, from which hippopotamus is recorded.

Sandford (1924) recognized a lower cold-climate gravel beneath the interglacial beds with *Corbicula* at Summertown and Magdalen College. In both cases this interpretation was based on the occurrence below the *Corbicula* levels of *Mammuthus primigenius,* which is also the most common vertebrate fossil in the Stanton Harcourt Channel Deposits. At Summertown the mammoth was accompanied by horse and ox, which are also present in the Stanton Harcourt Channel Deposits, but neither site yielded woolly rhinoceros *Coelodonta antiquitatis,* the only species that appears, within the Summertown-Radley Formation, to be exclusive to the cold-climate Stanton Harcourt Gravel Member. The elevation of the Summertown site was not recorded, but that at Magdalen Grove (58.8 m O.D.) is at a low level within the altitudinal range of the formation, again suggestive of the lower, rather than the higher, interglacial member. The recorded location of the Summertown pit (see above), in the western edge of the gravel outcrop, suggests that the section there was also relatively low within the formation. These facts seemingly lead to the conclusion that the sites yielding *C. fluminalis* but not hippopotamus represent the earlier of the two Summertown-Radley interglacials and are older than both the Stanton Harcourt and Eynsham Gravels. They also suggest that faunal records from the Summertown-Radley Formation require detailed scrutiny, to determine whether cited upper or lower stratigraphical levels are correct.

The Stanton Harcourt Channel Deposits

The Stanton Harcourt Channel Deposits are of major importance in the British Pleistocene, as they have been repeatedly cited in recent years as providing critical evidence for the recognition of an additional post-Hoxnian/pre-Ipswichian interglacial (Shotton, 1983; Briggs *et al.,* 1985; Bowen *et al.,* 1989; Bridgland *et al.,* 1989). With comparable deposits at Aveley (see Chapter 4), Marsworth (Buckinghamshire) and Stoke Goldington (Buckinghamshire), they have been attributed to a temperate interval at about 180,000 years BP, which has been correlated with Oxygen Isotope Stage 7 (Chapter 1; Shotton, 1983; Bowen *et al.,* 1989).

All these sites have yielded mammalian faunas with mammoth and horse, but lacking hippopotamus, and have insect faunas dominated by the beetle *Anotylus gibbulus* (Shotton, 1983). The sediments at Aveley, Stoke Goldington and Stanton Harcourt have yielded molluscan assemblages that include *Corbicula fluminalis.* A site in the catchment of the Warwickshire–Worcestershire Avon, at Ailstone near Stratford-upon-Avon, has recently been added to this list (Bridgland *et al.,* 1989).

There has not been total agreement with the interpretation of the Stanton Harcourt Channel Deposits as being of pre-Ipswichian age, however. Gibbard (1985) did not accept that they occupy a lower stratigraphical position within the Summertown-Radley Formation. He suggested instead, following Goudie and Hart (1975), that the thick periglacial gravel at Dix's Pit post-dates the interglacial beds recognized by Sandford in the upper part of the formation. The principal reasoning behind this interpretation is that Gibbard, closely adhering to the chronology outlined by Mitchell *et al.* (1973), considered both the Stanton Harcourt Channel Deposits and the Eynsham Gravel to represent the Ipswichian Stage. He claimed support for this conclusion from thermoluminescence dating of silts within the gravel at Stanton Harcourt, which suggested an early Devensian age. This would require the gravel at Stanton Harcourt to be younger than the Eynsham Gravel. Details of two dates obtained by this method, of 91,000 (± 8000) and 93,000 (± 9000) years BP, were provided by Seddon and Holyoak (1985). These authors also cited a radiocarbon date from a similar stratigraphical level, however, that suggested a mid-Devensian age, in the region of 35,000 years BP. This alternative interpretation of the Summertown-Radley sequence raises doubts about the validity of the tripartite sequence established by Briggs and Gilbertson (1980). In support of the view that the Stanton Harcourt Channel Deposits are pre-Ipswichian, in addition to the biostratigraphical arguments already presented, are amino acid ratios recently obtained from specimens of *Corbicula* and *Valvata.* These are comparable to ratios from other sites ascribed to Oxygen Isotope Stage 7 (Bowen et al,1989).

It is ironical that, whereas the reality of extra climatic cycles within this part of the Pleistocene is now accepted by most workers, the interpretation of the Stanton Harcourt site remains controversial.

The Magdalen Grove deposits

The sediments at Magdalen Grove have provided a wealth of palaeontological information, both from the early collections and from the 1984 re-excavation. The latter provided new information from palynological studies, which have rarely been applied to deposits in the Upper Thames basin. The abundance of broad-leaved trees in the pollen assemblage (see above) argues for a temperate climate, with the occurrence of *Carpinus* and virtual absence of *Betula* suggesting the late-temperate zone (biozone III) of an interglacial (Hunt, 1985). According to Hunt, the absence of *Abies* and the presence of *Picea, Acer* and abundant *Carpinus* are features of the Magdalen Grove assemblage that resemble pollen biozone IpIII of the Ipswichian Stage. However, many sites that were once considered Ipswichian, but which are now widely attributed to older, post-Hoxnian but pre-Ipswichian temperate intervals, share these features. As was outlined above, the abundance of *C. fluminalis,* the absence of hippopotamus and the elevation of the deposits at Magdalen Grove suggest that they belong to the earlier of the two interglacials represented within the Summertown-Radley

Formation, that correlated with Oxygen Isotope Stage 7.

If this reinterpretation can be corroborated, perhaps by the application of geochronological dating techniques (such as the analysis of the amino acid content of shells — see Chapter 1), Magdalen Grove would be the best reference site for the lower temperate-climate member (the Stanton Harcourt Channel Deposits), since at Stanton Harcourt these are buried beneath several metres of gravel and are therefore inaccessible.

Palaeolithic artefacts from Stanton Harcourt

Palaeolithic implements have been discovered in some numbers in the Summertown-Radley Terrace deposits and offer a possible insight into the approximate age of the aggradation. Sporadic finds of Acheulian hand-axes in these deposits were recorded in the early literature (Evans, 1897; Manning and Leeds, 1921; Almaine, 1922; Smith, 1922; Sandford, 1924). It later became clear that, by Upper Thames standards, a considerable wealth of artefacts occurred throughout the formation, although with the highest concentrations in the cold-climate Stanton Harcourt Gravel (Sandford, 1932, 1939, 1954; Arkell, 1945, 1947a; Wymer, 1968; MacRae, 1991). Both Sandford and Arkell originally considered this to be the earliest appearance of Acheulian implements in the Upper Thames sequence; both thought the prolific Wolvercote Channel to be later than the lower part, if not the whole, of the Summertown-Radley Formation, despite its association with the higher Wolvercote Terrace (see above, Wolvercote). However, one or two hand-axes were later recorded from the Hanborough Gravel (Arkell, 1947c; Wymer, 1968), which is therefore the oldest source of artefacts in the area. Arkell (1945) believed that the numerous worn Acheulian hand-axes found in the Summertown-Radley Terrace deposits were manufactured during a warm period prior to deposition of the cold-climate gravels identified by Sandford. Since no earlier interglacial terrace with such an abundance of artefacts had been identified in the region, he suggested that there might be a third, hitherto undiscovered, earlier division of the Summertown-Radley sequence, of interglacial origin. This suggestion by Arkell preempted by more than 30 years the discovery of the lower interglacial channel at Stanton Harcourt and the recognition of the tripartite climatic sequence.

According to Wymer (1968, p. 85) a hand-axe, the largest at that time from west of Oxford, was found in 1962 in the vicinity of the Stanton Harcourt GCR site. This was one of only two discoveries at the locality prior to 1982 (MacRae, 1987). Recent exposures, at Dix's Pit and other nearby workings, have been repeatedly visited by the local archaeologist R.J. MacRae, who has built up a collection of artefacts that includes nearly 50 hand-axes, including (by 1989) 13 made from quartzite (MacRae, 1988, 1989, 1991; MacRae and Moloney, 1988). In the Upper Thames, only the Wolvercote Channel and pits at Berinsfield have yielded larger numbers; those from the latter locality include finds from both the Summertown-Radley and the Northmoor Formations (MacRae, 1982).

The pits at Stanton Harcourt are therefore the most important source of palaeoliths from the Summertown-Radley Terrace. In 1986 a very large hand-axe was discovered there, which, at 26.9 cm long, surpasses the 1962 discovery by 5 cm and is claimed as the third-largest from Britain (MacRae, 1987; (Figure 2.17)). Forty-two hand-axes were found at the site between 1984 and the end of 1987, but in the following two years the number retrieved greatly diminished (R J. MacRae, pers. comm.). According to MacRae, the rate of discovery of mammoth teeth and tusks, which was high from 1984 to 1987, has declined since then in parallel with the artefacts. He reports that this change has occurred as the working faces migrated away from the area of the Stanton Harcourt Channel. This fact, as well as the association of palaeoliths with mammoth remains (the most abundant vertebrate fossil in the channel deposits), suggests that the incidence of artefacts might be related in some way to the channel. Until recently, all the finds from Dix's Pit were from the Stanton Harcourt Gravel (MacRae, 1985, 1988; MacRae and Moloney, 1988), but a few hand-axes have now been found in the channel deposits (MacRae, 1991). The reinterpretation of the stratigraphy of the Summertown-Radley aggradation, presented above, implies that sediments accumulated during the earlier temperate interval to considerable thicknesses, such as was recorded at Summertown. Subsequently there must have been considerable erosion of these deposits in those areas where the Summertown-Radley Formation is now represented only by later sediments. At Stanton Harcourt, deposits representing the early temperate interval are preserved only as channel deposits incised into the Oxford Clay; these are truncated by the Stanton Harcourt Gravel (Figure 2.15). The erosive nature of this contact suggests that there may have been considerable reworking of material from the channel deposits into the gravel, perhaps including mammoth remains and artefacts. This might explain a concentration of both in the Stanton Harcourt Gravel in the vicinity of the channel.

Correlation

Attempts at correlating the Upper Thames sequence with the British Pleistocene chronology were, until the new framework based on the deep-sea oxygen isotope record was established (Chapter 1), impeded by the fact that only two interglacials were recognized between the Anglian and Devensian Stages (Mitchell *et al.,* 1973), whereas post-Cromerian interglacial faunas are recorded at four stratigraphical levels within the Upper Thames terraces: The similarity of the upper Summertown-Radley and Wolvercote Channel interglacial assemblages was stressed by two of the leading authorities on the Upper Thames, Sandford (1924, 1932) and Arkell (1947a). Both authors concluded that these deposits were of comparable ages, despite the fact that they occurred in association with different terraces (see above, Wolvercote). Both also considered the lower cold-climate Summertown-Radley aggradation (Stanton Harcourt Gravel) to pre-date the Wolvercote Channel. Sandford (1924) was impressed with the similarity of the fauna in the upper Summertown-Radley sediments with that from Crayford, implying a correlation with the Tap-low Terrace (see Chapter 4, Lion Pit). Sandford (1932) later changed his opinion, correlating Crayford with the Wolvercote Channel Deposits. In this later view, which was supported by Arkell (1945, 1947a), he favoured a correlation of the Eynsham Gravel with the Boyn Hill Terrace at Swanscombe, implying a Hoxnian age. Both Sandford and Arkell were strongly influenced by the first appearance of palaeoliths in the Upper Thames at this level (see above). However, Breuil (Appendix to Sandford, 1932) attributed the upper Summertown-Radley (hippopotamus-bearing) sediments to the 'Riss–Würm interglacial' (= Ipswichian Stage), again proposing a correlation with Crayford. With the recognition, in more recent years, that *Hippopotamus amphibius* was absent from Britain during the Hoxnian, most subsequent writers placed the upper Summertown-Radley deposits in the Ipswichian (for instance, Bishop, 1958; Tomlinson, 1963). Bishop (1958) regarded the Wolvercote Channel as Hoxnian and therefore considerably older. This model was adopted by Wymer (1968), who was then able to claim the Wolvercote Channel as a possible source for the Summertown-Radley implements.

4.	Upper Summertown-Radley Formation	(Eynsham Gravel)
3.	Lower Summertown-Radley Formation	(Stanton Harcourt Channel Deposits)
2.	Wolvercote Channel Deposits	
1.	Hanborough Gravel	(derived fauna)

Two recently suggested correlations are worthy of note, being based on attempts to trace the terraces from the Oxford area to the lower reaches of the river. In the first, Evans (1971) linked the Summertown-Radley Terrace with the Upper Floodplain Terrace of the Middle and Lower Thames, claiming support from the occurrence of *Hippopotamus amphibius* in the former; this species occurs beneath the Upper Floodplain Terrace (Kempton Park Formation) at Trafalgar Square (Table 1.1). Gibbard (1985) considered that the Summertown-Radley deposits equated with a variety of deposits downstream of the Goring Gap, ranging in age from late Saalian to Early Devensian. He correlated the terrace not with the Upper Floodplain (Kempton Park Gravel) aggradation, but with his Early Devensian Reading Town Gravel. It is argued in Chapters 1 and 3 that the latter is, in fact, based on a misidentification by Gibbard of the Taplow Gravel in the Reading area. Therefore Gibbard's conclusions actually imply correlation between the Summertown-Radley and Taplow Formations.

The Summertown-Radley sequence provides critical evidence in support of the correlation schemes presented in this volume (Chapter 1) for relating the sequence in the Upper Thames to that elsewhere in the basin and to the deep-sea oxygen isotope record (Figure 2.18). In these schemes the Stanton Harcourt Channel Deposits are taken as an important stratigraphical marker for Oxygen Isotope Stage 7 and the Eynsham Gravel is assigned to the Ipswichian (*sensu* Trafalgar Square — Substage 5e). Correlation between the Upper and Middle Thames, based on the reconstruction of terrace long-profiles (Figure 1.3), indicates that the Summertown-Radley Formation is the upstream equivalent of the Taplow Gravel. The latter unit also incorporates temperate-climate sediments attributed to Stage 7, particularly in its Lower Thames equivalent, the Mucking Gravel (see Chapters 1 and 4). As stated above, the Trafalgar Square Ipswichian sediments are found beneath a later aggradation, the Kempton Park Gravel (Figure 2.18)b, that is ascribed to the Devensian Stage (Gibbard, 1985). The Kempton Park Gravel, which gives rise to the 'Upper Floodplain Terrace' of Dewey and Bromehead (1921), cannot be traced further upstream than Marlow (Gibbard, 1985; Chapter 3; (Figure 1.3)). This suggests that the rejuvenation event that separated the aggradation of the Kempton Park and Taplow Gravels was restricted to that part of the valley downstream from Reading ((Figure 2.18)b). It is interesting to note that Sandford (1965) claimed that the Goring Gap was the site of a major 'nick point', which is the situation now envisaged during the deposition of the Kempton Park Gravel.

This interpretation explains the unusual incidence, in the Summertown-Radley Formation, of two full climatic cycles represented within a single aggradational sequence. The uppermost, unfossiliferous gravel at Eynsham, recorded by Sandford (1924; see above) may represent aggradation at the beginning of the cold half-cycle that followed the Ipswichian (*sensu* Trafalgar Square). The lower gravel at Summertown, underlying deposits containing *Corbicula,* may also represent a cold-climate deposit, presumably representing Oxygen Isotope Stage 8. In terms of the model for terrace formation outlined in Chapter 1, the full Summertown-Radley sequence would therefore be as shown in (Table 2.3) (see also (Figure 2.18)a).

Rejuvenation to the Northmoor Gravel level occurred during the mid-Devensian (see above, Introduction), perhaps as part of the incision that led to the separation of the Kempton Park and Shepperton Formations in lower reaches of the Thames catchment (Table 1.1). Information regarding the timing of this rejuvenation in the Upper Thames may be obtained in the near future from a recently discovered site in the Northmoor Gravel, at Cassington. Preliminary investigations suggest that organic and shelly channel-fills from the lower part of the sequence here may represent one or more of the inter-stadial episodes of the early/middle Devensian (D. Maddy, pers. comm.). This may prove difficult to reconcile with the Middle Thames sequence, in which these temperate episodes are represented within the Kempton Park Formation. It appears that rejuvenations may have occurred at different times in the Upper Thames and Middle Thames valleys.

(Table 2.3) Stratigraphical subdivisions of the Summertown-Radley Formation.

Lithostratigraphical unit	Terrace model (Chapter 1)	Oxygen Isotope Stage
Uppermost gravel at Eynsham	Phase 4	5d–2?
Eynsham Gravel Member	Phase 3	5e
Stanton Harcourt Gravel Member	Phases 2 and 4	6
Stanton Harcourt Channel Deposits	Phase 3	7
Gravel underlying interglacial deposits at sites with *Corbicula*	Phase 2	8

Summary

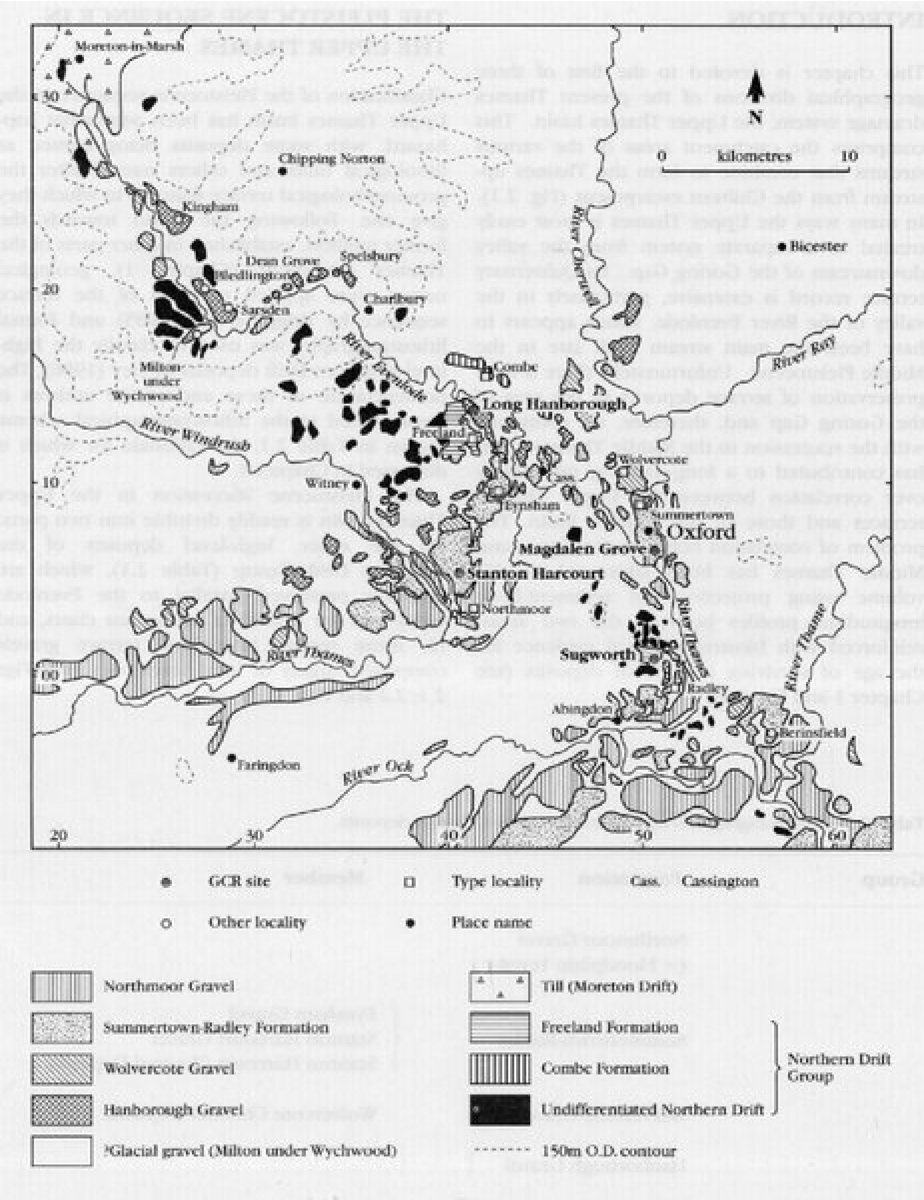
The GCR sites at Stanton Harcourt and Magdalen Grove combine to provide coverage of the complex of deposits that underlies the Summertown-Radley Terrace of the Upper Thames. Considerable controversy surrounds the interpretation of this sequence, to the extent that there is disagreement on the subdivision of the deposits and the number of climatic cycles represented. The resolution of these problems is fundamental to an improved understanding of the Upper Thames sequence, which is clearly of considerable importance, given its position between the London Basin and the Midlands. Further research is required to address these difficulties. In particular, additional attempts to date the various sediments would be of value; the cold-climate Mollusca from the Stanton Harcourt Gravel could be suitable for geochronological dating by amino acid analysis. Similar analyses of shells from Magdalen Grove might give support (or otherwise) to the view that the deposits here are of the same age as those from the Stanton Harcourt channel-fill.

Conclusions

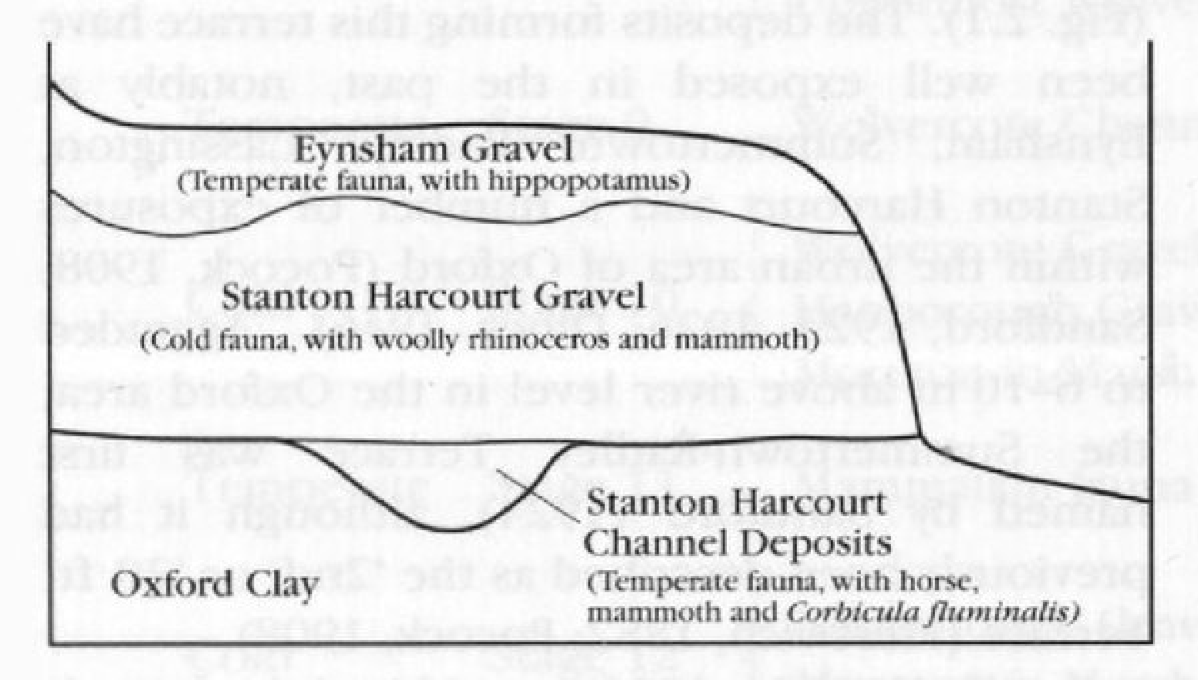
The Stanton Harcourt and Magdalen Grove sites provide an insight into a complex sequence of deposits forming a major terrace in the Upper Thames basin (the Summertown-Radley Terrace). The gravels that form the bulk of this sequence were laid down under intensely cold (periglacial) conditions, as is demonstrated at Stanton Harcourt both by structures such as ice-wedge casts and by the shells of cold-climate snails, which occur in silt bands interbedded with the gravels. It has long been recognized, from a number of sites in the region, that parts of the sequence yield interglacial faunas. Early records suggested that they were generally from the upper part of the gravel. They have been widely attributed to the last (Ipswichian) interglacial (around 125,000 years BP), largely on the basis of the occurrence of hippopotamus, which is highly characteristic of that interval.

The more recent discovery of a fossiliferous channel-fill beneath the gravel at Stanton Harcourt has provided critical evidence to show that two separate interglacials are represented within the Summertown-Radley Terrace sequence. This has also been a key site in establishing that the earlier of these interglacials is additional to the sequence of climatic events recognized hitherto in Britain and for its correlation with the oceanic record of Oxygen Isotope Stages, in which it is believed to represent Stage 7 (*c.* 200,000 years BP). The Magdalen Grove deposit has been widely regarded as an example of the upper, last interglacial element of the Summertown-Radley sequence. However, a reconsideration here of the evidence from this and other associated sites now suggests that it is also of Stage 7 age. It is further concluded that five different climate episodes are represented within the Summertown-Radley sequence, respectively cold, warm, cold, warm and cold.

[References](#)



(Figure 2.1) The gravels of the Upper Thames catchment.

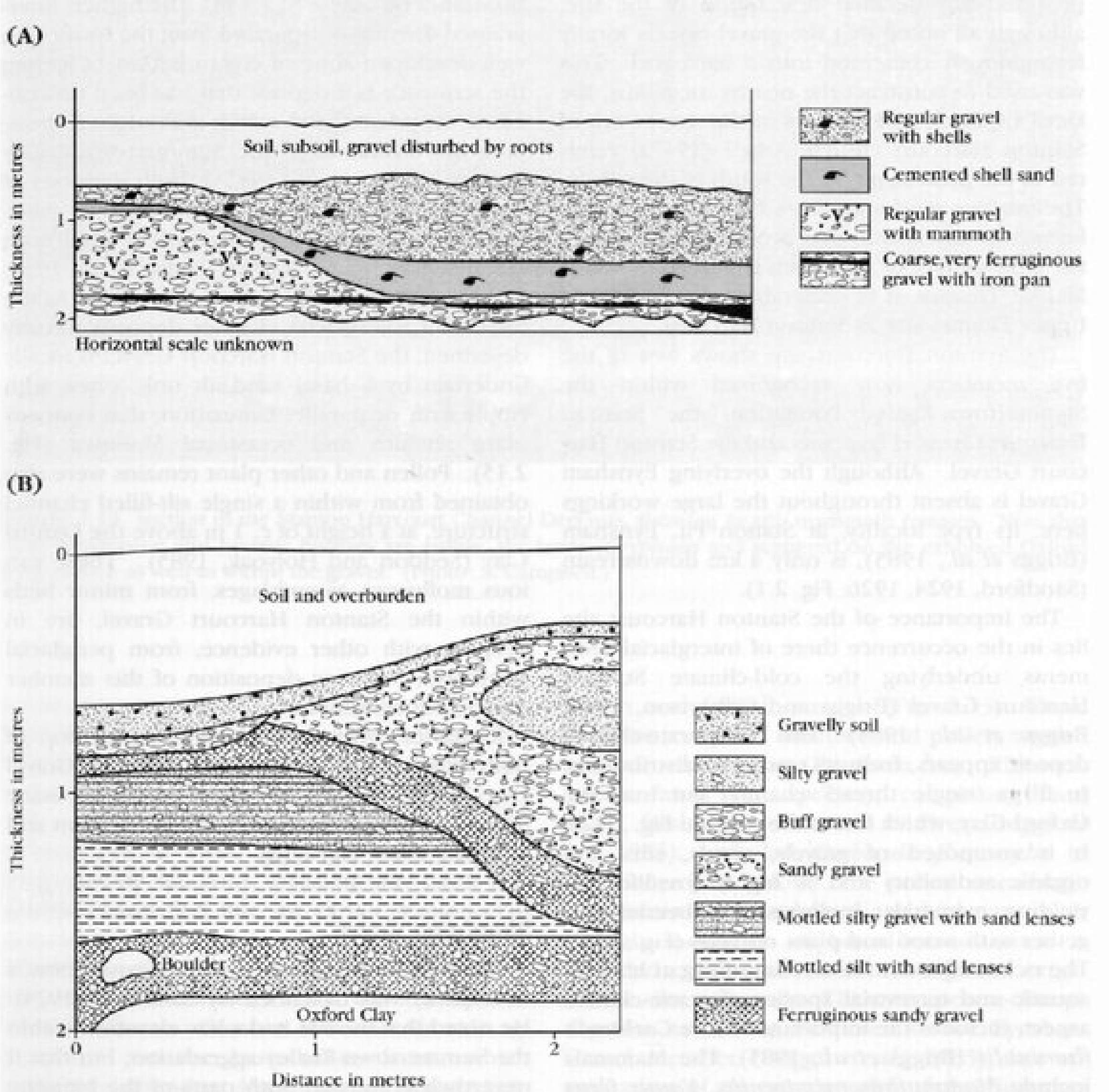


(Figure 2.12) Idealized section through the Summertown-Radley Formation.

Age (in thousands of years)	Upper Thames	Middle Thames	Lower Thames	Essex	Stage	^{18}O
	Recent floodplain and channel deposits: Holocene alluvium of floodplain and coast				Holocene	1
10						
	Northmoor Gravel	Shepperton Gravel	Submerged	Submerged	late Devensian	2-4
	Rejuvenation event					
71						
		Temperate climate deposits at South Kensington (Ismaili centre), Isleworth and Kempton Park	Submerged	Submerged	early/mid Devensian? interstadial(s)	5a &/or 5c?
?						
	Cold climate gravels above Eynsham Gravel	Reading area: U. levels of Taplow Gravel; Slough area: Kempton Park Gravel	East Tilbury Marshes Gravel	Submerged	early-mid Devensian	5d-2
122						
	Eynsham Gravel	Within Taplow Formation; Trafalgar Square and Brentford deposits	Below floodplain	Submerged	Ipswichian (sensu Trafalgar Square)	5e
128						
	Stanton Harcourt Gravel	Taplow Gravel; Basal Kempton Pk Gravel - incl. Spring Gardens Gravel of Gibbard (1985)	Basal East Tilbury Marshes Gravel	Submerged	late Saalian	6
		Rejuvenation event				
		Taplow Gravel	Mucking Gravel			
186						
	Stanton Harcourt Channel Deposits, interglacial Magdalen Grove, Summertown etc.	Interglacial deposits at Redlands Pit, Reading	Interglacial deposits at Aveley, Ilford (Uphall Pit), West Thurrock, Crayford and Northfleet	Submerged	Intra-Saalian temperate episode	7
245						
	Basal Summertown-Radley Formation at some sites?	Basal Taplow Gravel?	Basal Mucking Gravel	Submerged		
	Rejuvenation event				mid-Saalian	8
	Wolvercote Gravel at some sites?	Lynch Hill Gravel	Corbets Tey Gravel	Barling Gravel		
303						
	Wolvercote Channel Deposits		Interglacial deposits at Ilford (Cauliflower Pit), Belhus Park, Purfleet and Grays	Shoeburyness Channel interglacial deposits	Intra-Saalian temperate episode	9
339						
	Basal Wolvercote Gravel	Basal Lynch Hill Gravel?	Basal Corbets Tey Gravel	Shoeburyness Channel - basal gravel		
	Rejuvenation event				early Saalian	10
	? Moreton Drift (Arkell, 1947a)					
	Hanborough Gravel	Boyn Hill Gravel	Orsett Heath Gravel	Southchurch/Asheldham/Mersea Island/Wigborough Gravel		
?						
	Reworked mammalian fauna in Hanborough Gravel		Swanscombe deposits	Southend/Asheldham/Cudmore Grove/Clacton Channel Deposits	Hoxnian (sensu Swanscombe)	11
423						
	Basal Hanborough Gravel?	Basal Boyn Hill Gravel?	Basal Orsett Heath Gravel (incl. Basal Gravel at Swanscombe)	Southend/Asheldham/Cudmore Grove/Clacton Channel - basal gravel		
	Rejuvenation event					
	Freeland Formation	Black Park gravel				
	Moreton Drift?	Anglian glacial deposits	Hornchurch Till	U. St Osyth/U. Holland Gravel	Anglian	12
	Freeland Formation	Winter Hill/Westmill Gravel	Valley did not exist as a Thames course prior to this	St Osyth/Holland Formation		
478						
	Sugworth Channel Deposits	Rassler Gravel?		Wivenhoe/Cooks Green Fm; Ardleigh/St Osyth Formation; Waldringfield Gravel	Cromerian Complex	21-13
?						
	Combe Formation	Gerrards Cross Gravel		Bures Gravel*	Early Pleistocene	pre 21
	Higher divisions of the Northern Drift Group	Beaconsfield Gravel; Satwell Gravel; Gravel at Chorleywood; Westland Green Gravels; Stoke Row Gravel; Nettlebed Gravel; Nettlebed interglacial deposits		Moreton Gravel*; Stebbing Gravel*		

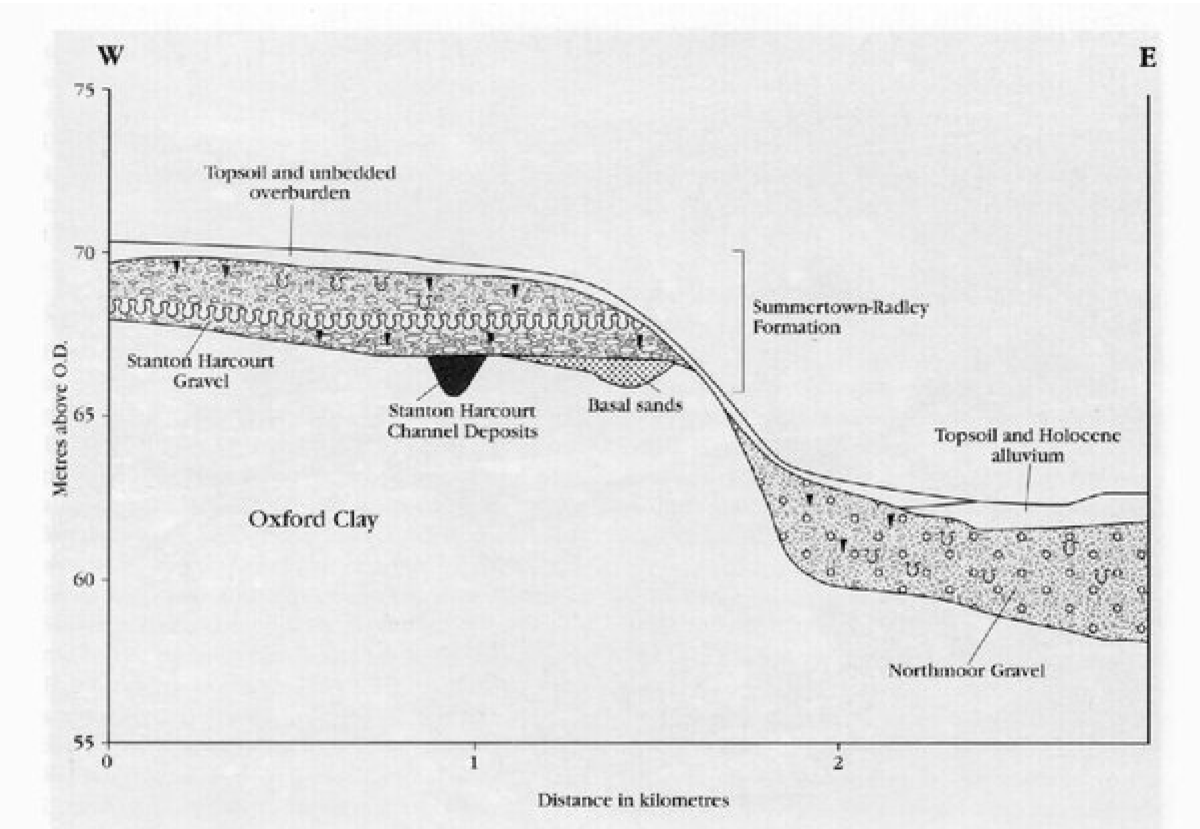
* Nomenclature for High-level Kesgrave Subgroup in Essex follows Whiteman (1990).

(Table 1.1) Correlation of Quaternary deposits within the Thames system. Rejuvenations that have occurred since the Anglian glaciation are indicated.

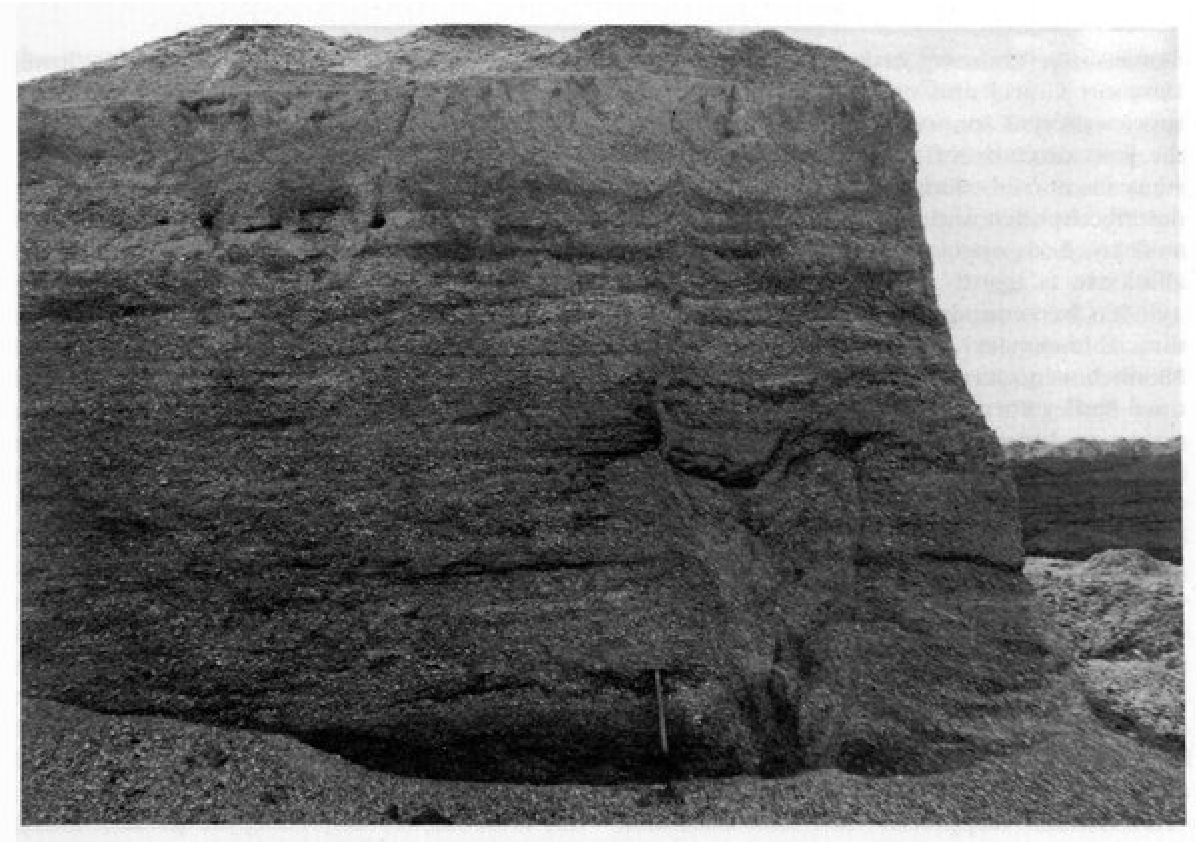


(Figure 2.13) A comparison of sections recorded at Magdalen Grove, by (A) Sandford (1924) and (B) Briggs et al. (1985).

(Figure 2.14) Section in the Stanton Harcourt Channel Deposits, showing in situ mammoth remains. Note that both Pleistocene and Jurassic bivalves are visible, the latter (Gryphaea sp.) scattered on the exhumed Oxford Clay surface as well as within the gravel. (Photo: S. Campbell.)

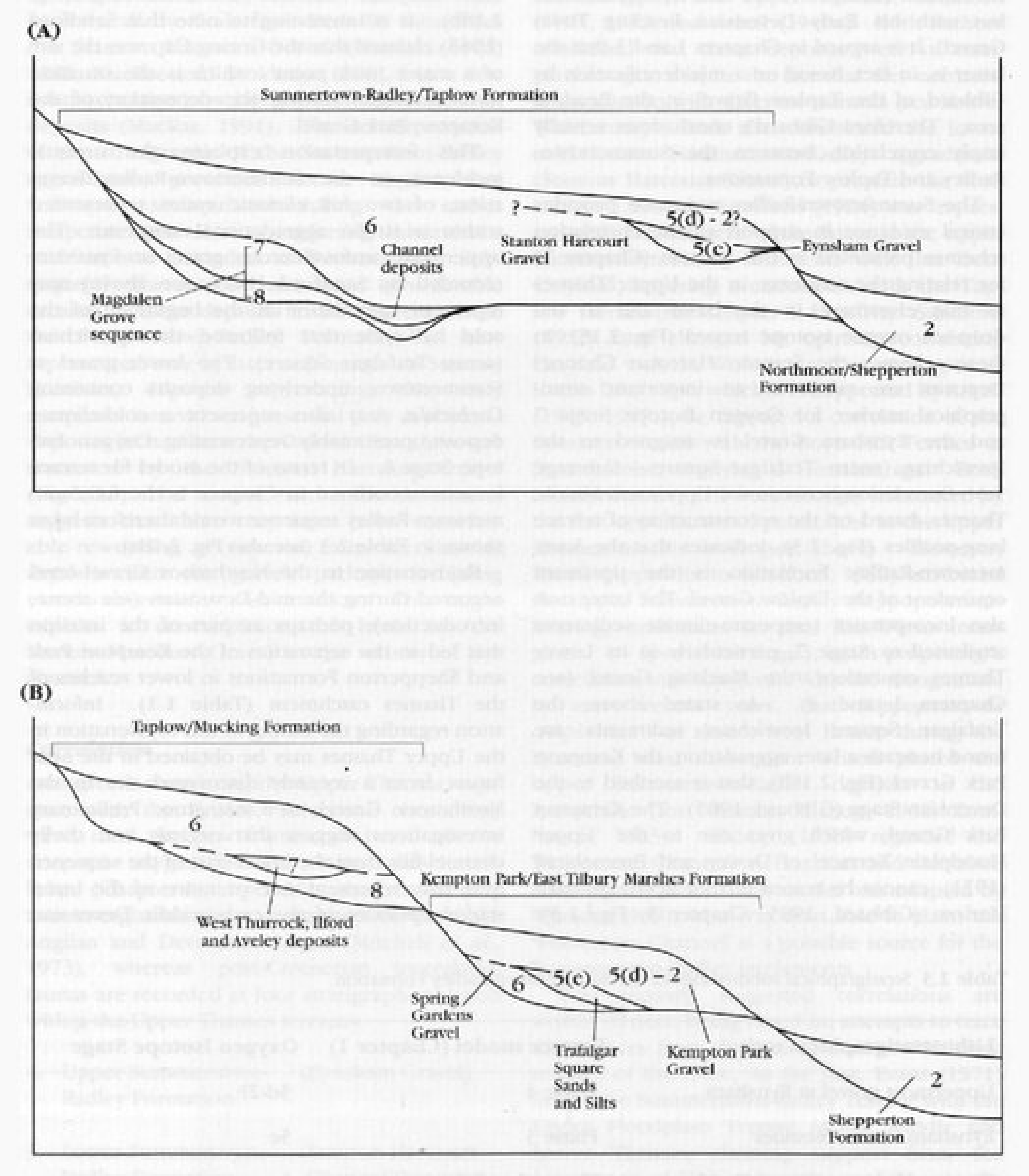


(Figure 2.15) Composite section through the deposits at Stanton Harcourt (after Briggs et al., 1985).

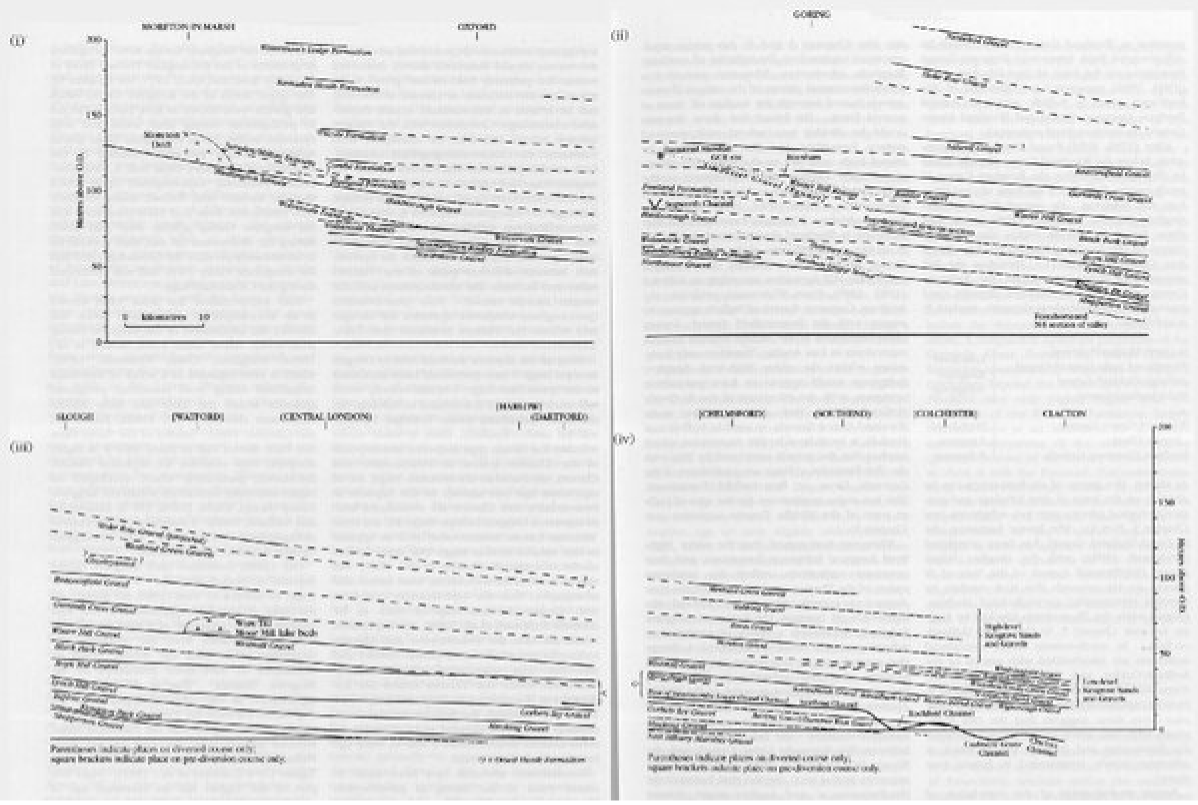


(Figure 2.16) Section at Stanton Harcourt, showing an intraformational ice-wedge structure in the Stanton Harcourt Gravel. The complexity of this feature is typical of such structures at this site (see text). (Photo: D.J. Briggs.)

(Figure 2.17) Hand-axe from Stanton Harcourt, discovered by Mr V. Griffin, the excavator driver. Some 26.9 cm long, this is believed to be the third-largest hand-axe discovered to date in Britain (MacRae, 1987). (Photo: R.J. MacRae.)



(Figure 2.18) Comparison of terrace stratigraphy upstream (A) and downstream (B) from the limit of the Kempton Park Formation. Numbers 2-8 indicate oxygen isotope stages.



(Figure 1.3) Longitudinal profiles of Thames terrace surfaces throughout the area covered by the present volume. The main sources of information used in the compilation of this diagram are as follows: Arkell (1947a, 1947b), Briggs and Gilbertson (1973), Briggs et al. (1985), Evans (1971) and Sandford (1924, 1926) for the Upper Thames; Gibbard (1985) and Sealy and Sealy (1956) for the Middle Thames; Bridgland (1983a, 1988a) and Bridgland et al. (1993) for the Lower Thames and eastern Essex; Whiteman (1990) for central Essex.

Lithostratigraphical unit	Terrace model (Chapter 1)	Oxygen Isotope Stage
Uppermost gravel at Eynsham	Phase 4	5d-2?
Eynsham Gravel Member	Phase 3	5e
Stanton Harcourt Gravel Member	Phases 2 and 4	6
Stanton Harcourt Channel Deposits	Phase 3	7
Gravel underlying interglacial deposits at sites with *Corbicula*	Phase 2	8

(Table 2.3) Stratigraphical subdivisions of the Summertown-Radley Formation.