Long Hanborough Gravel Pit

[SP 418 136]

Highlights

This pit is the type locality for the Hanborough Gravel Formation, the oldest of the limestone terrace gravels of the Upper Thames.

Sedimentary features, periglacial structures and snail faunas in the deposits at Long Hanborough have been fundamental in demonstrating that these and, by comparison, many other Thames terrace gravels are largely the products of fluvial deposition under intensely cold conditions.

Introduction

Long Hanborough Gravel Pit provides sections in the gravel that forms the Hanborough Terrace of the River Evenlode. This deposit, the Hanborough Gravel Formation, is aggraded to *c.* 100 m O.D. in its type area and is the highest of the limestone-dominated terrace gravels of the Oxford region (Sandford, 1924, 1926; Arkell, 1947a, 1947b; Briggs and Gilbertson, 1973, 1974). Higher and older formations, with the exception of the Sugworth Channel sediments, are preserved only as decalcified Northern Drift deposits, dominated by quartz and quartzites (see Introduction to this Chapter and the Sugworth report). The Hanborough Formation is also recognized in the Cherwell and Thames valleys (Figure 2.1).

The largest remnant of Hanborough Terrace deposits is that on which the villages of Church Hanborough and Long Hanborough are built (Figure 2.7). Since the Long Hanborough pit is situated on the 'type outcrop' of the Hanborough Gravel, it may be considered to represent the type section for this formation, there being no other exposures surviving in the area. Although earlier pits have been described (Sandford, 1924; Arkell, 1947a, 1947c), much important recent work on the Hanborough Terrace sediments has been carried out at the GCR site, notably the description of a cold-climate molluscan fauna from silty horizons within the gravel sequence (Briggs and Gilbertson, 1973, 1974). This did much to overturn old ideas that the aggradation of terrace deposits (here and elsewhere) took place during temperate periods. The Hanborough Gravel is now believed to have been laid down under cold (periglacial) conditions, but the identification of the cold episode during which this took place is the subject of controversy, particularly as a result of recent work in the Midlands (Rose, 1987, 1989), to the north-west of the Evenlode catchment (see below and Chapter 1).

Description

Early descriptions of Hanborough Terrace deposits record a variety of different exposures. According to Arkell (1947a, p. 202), 'a dozen large pits at Long Hanborough and Church Hanborough' had existed (or did exist) by 1947. The most famous site was Duke's Pit [SP 415 143], 0.5 km to the north-west of the present site, which was described by Sandford (1924), Richardson (1935) and Arkell (1947a, 1947c). Sandford (1924, 1925) also described a working known as Lay's Pit, Long Hanborough, near the northern edge of the gravel spread, and two pits in the Hanborough Terrace of the Cherwell at Kirtlington. Numerous less important exposures were described in the second Oxford memoir (Sandford, 1926), but the most extensive list of pits in the Hanborough Terrace was provided by Dines (1946) in the Witney memoir. In more recent years attention has been centred on the present site, to the south of Long Hanborough village, as well as on exposures at Dean Grove, *c.* 10 km upstream (Briggs and Gilbertson, 1973, 1974), and at Cassington (Kellaway *et al.,* 1971).

Sandford (1924) established that a number of mammalian species occurred in the gravel of the Hanborough Terrace, namely *Palaeoloxodon antiquus* (Falconer and Cantley), *Mammuthus primigenius* (Blumenbach), *Dicerorhinus* sp. (probably *D. hemitoechus* (Falconer)), *Bos primigenius* (Bojanus), *Equus ferus* (Bodaent) and *Cervus elaphus* (Falconer)

(Sandford, 1924, 1925, 1926). Arkell (1947c) reported the discovery of an Acheulian hand-axe in Duke's Pit, Long Hanborough. This is the only palaeolith that can be attributed with certainty to the Hanborough Terrace gravel (Arkell, 1947c; Wymer, 1968; Roe, 1976; Briggs *et al.,* 1985), although a previous record exists of an early find that probably came from these deposits (Anon., 1908; Manning and Leeds, 1921; Wymer, 1968).

The most recent detailed description of the Long Hanborough GCR site was by Briggs and Gilbertson (1973), who recorded the following sequence at NGR [SP 418 138]:

	Thickness
3. Loam, red-brown, unbedded. Contains scattered non-calcareous pebbles and is typically up to 1 m thick. This deposit fills pipes in the gravel down to a depth of 2.5 m from the surface	up to 1 m
2. Gravel, pale-coloured (pinkish), with cross-bedding and localized channelling; dominantly composed of limestone clasts, with quartz, quartzite and sandstone, plus rare flint and igneous or metamorphic rocks. Occasional seams and thin beds of silt occur, locally containing non-marine Mollusca (see (Figure 2.8)).	1–3 m
1. Oxford Clay	

The recovery by Briggs and Gilbertson of a gastropod assemblage from silts within bed 2, comprising *Pupilla muscorum* (L.), *Oxyloma pfeifferi* (Rossmassler), *Catinella arenaria* (Bouchard-Chantereaux), *Planorbis* spp., *Columella columella* (Martens), *Agriolimax* spp., *Pisidium vencentianum* (Woodward), *P. nitidum* (Jenyns) and *Trichia hispida* (L.) provided important additional evidence for palaeoenvironmental conditions during the aggradation of the Hanborough Terrace deposits. The origin of the 'pipes' filled with red brown loam (bed 3) has been the subject of considerable debate (see below).

Interpretation

The Hanborough Formation has been recognized as a separate, early division of the limestone gravels of the Upper Thames for over a century. In early Geological Survey memoirs both Hull (1859) and Green (1864) noted that the gravel at Long Hanborough and Church Hanborough lay at a greater elevation than the bulk of the terrace deposits in the area. The Hanborough Terrace, which has also been referred to as the '100 ft Terrace', the 'High Terrace' and the 'Fourth Terrace' (Pocock, 1908), is better preserved in the Evenlode valley than in the other branches of the Upper Thames system.

Sandford (1924), in the first of his major papers on the Upper Thames, introduced the term 'Handborough Terrace' (using the old spelling). He interpreted the various remnants of this formation as the product of a temperate-climate environment, on the basis of the mammalian remains found in them (see above). Arkell (1947a, 1947b) interpreted the Hanborough Terrace as an interglacial gravel 'delta', remarking on the evidence in the Upper Thames basin for a single period of major rock-disintegration and terrace formation, represented by the aggradation at Hanborough. This he correlated with the comparable 'Silchester Gravel' of the Kennet valley, assigning both to the 'First Interglacial' (this would now be equated with the Cromerian).

Arkell was the first to claim that the Hanborough Gravel has a gentler downstream gradient than later terrace deposits in the Evenlode valley, including the floodplain sediments. It therefore intersects with the projected profiles of successively more recent formations as it is traced upstream. Upstream from Kingham, where the Hanborough Gravel is only *c.* 10 m above the modem floodplain, Arkell believed it to underlie glacial deposits, the 'Moreton Drift'. These flint-rich glacial sediments are believed to result from the glaciation that deposited the 'Chalky Boulder Clay' ('Chalky Till') of the Midlands, this col in the Cotswolds escarpment representing its furthest encroachment into the modern Thames catchment (Arkell, 1947a, 1947b; Bishop, 1958; Kellaway *et al.,* 1971; Briggs, 1973). To the north, beyond the present Stour–Evenlode watershed, a limestone gravel similar to the Hanborough Formation occurs beneath the Moreton Drift in the area of Great Wolford and Stretton-on-Fosse. Arkell believed that this deposit, which he called Paxford Gravel, was an upstream continuation of the Hanborough Gravel, laid down by a formerly more extensive Evenlode.

This interpretation is of considerable importance: if the Paxford Gravel is correctly identified as an upstream equivalent of the Hanborough Formation, the latter must pre-date the 'Chalky Till' glaciation of the Cotswolds. The same conclusion has also been reached from the analysis of gravel composition. It has been widely reported that the Hanborough Gravel of the Evenlode valley does not contain the typical north-eastern erratic components, fresh flint in particular, that were introduced into the Stour–Evenlode watershed area by the 'Chalky Till' glaciation; it has been claimed instead that such material first appears in the Wolvercote Gravel (Bishop, 1958; Kellaway *et al.,* 1971; Briggs, 1988; see below, Wolvercote). This view has been challenged recently by Maddy *et al.* (1991), who have suggested that there is no significant difference between the gravel contents of these two formations in the Evenlode.

Kellaway *et al.* (1971) and Briggs and Gilbertson (1973) have supported Arkell's reconstruction of the Hanborough Terrace long-profile and its convergence upstream with the valley floor. However, Tomlinson (1929) and Kellaway *et al.* (1971) recorded gravels of Hanborough type from the Wychwood area at levels that are too high to be consistent with this interpretation. If Arkell's correlation of the Paxford and Hanborough Gravels is correct, these higher calcareous deposits may be non-decalcified remnants of the lowest Northern Drift formation(s) or they may be locally derived 'fan gravels'. However, it has been shown in Chapter 1 that miscorrelation may have occurred between the Upper and Lower Evenlode valleys, with the implication that the gravels underlying the Moreton Drift might be older than the Hanborough Formation. Further investigation of the gravel remnants in the Evenlode valley is required in order to assess the relations of the Hanborough Formation to the glacial deposits of the Cotswolds.

More recent studies in the south Midlands have challenged Arkell's conclusion that the Hanborough Gravel dates from the Cromerian. Tomlinson (1963) placed it in the 'Great Interglacial' (Hoxnian) on the grounds of its mammalian fauna and its relation, established by Arkell, to the Cotswolds glaciation, which she attributed to the Saalian. Wymer (1968) pointed out that no elements of the fauna found at Long Hanborough are diagnostic of the Cromerian as opposed to the Hoxnian Stage and that a deposit as old as the Cromerian might be expected to be more decalcified. He also considered substantial accumulations of gravel of the type represented at Long Hanborough to be more typical of cold-climate than of interglacial conditions.

Kellaway *et al.* (1971) thought that the relative abundance of Triassic quartzites and the paucity of flint in the Hanborough Gravel implied formation during the interval between the 'Northern Drift glaciation' and the 'Chalky Till' glaciation. According to Shotton (1973a), this would place the Hanborough aggradation between the Anglian and Saalian (Wolstonian) glaciations. The rejection, in recent years, of the Northern Drift as a glacial deposit renders this view obsolete (see above, Sugworth); it is now clear that the Northern Drift is a complex group of deposits spanning the Lower and lower Middle Pleistocene (Chapter 1). Another problem in assessing the age of the Hanborough Formation is the dispute that has arisen in recent years as to which glacial episode is represented by the 'Chalky Till' of the West Midlands (see below).

An important challenge was made by Briggs and Gilbertson (1973, 1974) to the long-held belief that the Hanborough Terrace deposits were of interglacial origin. This view, based on the occurrence of occasional mammal bones in the gravels (see above), had been questioned by Wymer (1968), but reiterated by Kellaway *et al.* (1971). Briggs and Gilbertson presented new evidence from the Long Hanborough pit, from studies of sedimentology and molluscan faunas, pointing to deposition under cold-climate conditions. The sedimentological analyses, based on samples from temporary exposures at Milton-under-Wychwood and Kingham, as well as the pits at Dean Grove and Long Hanborough, revealed a considerable downstream increase in coarse-grade local material. This would have been incorporated in the gravel as the river flowed through the Evenlode Gorge, suggesting a period of highly active local erosion. In addition to this, the sediment type and the range of sedimentary structures occurring in the deposits suggest deposition by a braided river. The full picture is therefore one of a braided, gravel-bed river in an open environment with sparse vegetation.

Assemblages of non-marine Mollusca obtained by Briggs and Gilbertson (1973) from two silt/fine-sand horizons in the Long Hanborough pit (Figure 2.8) provide further important evidence. The lower of these horizons yielded species indicative of subarctic conditions, with *Pupilla muscorum,* a xerophilous land-snail, dominating an assemblage otherwise typical of marshlands and small streams. In the higher silty horizon *P. muscorum* was replaced by *Oxyloma pfeifferi,* a snail found in marshland or damp habitats, in a general assemblage hinting at slightly milder conditions than that from the lower horizon. Briggs and Gilbertson likened the assemblages from both horizons to those from the various Devensian interstadials. They concluded that the Hanborough Gravel accumulated under cold (periglacial) conditions and that the interglacial mammalian remains previously recorded, which appear to have been concentrated near the base of the aggradation, were probably reworked from earlier deposits and/or land surfaces. They suggested an early Wolstonian (Saalian) age as the most probable, taking into account (1) the occurrence of the derived temperate-climate mammalian fauna, which they considered likely to be of Hoxnian age, and (2) the apparent link with the pre-Moreton Drift ('Chalky Till') Paxford Gravel of the Stour–Evenlode watershed area, first suggested by Arkell (1947a, 1947b). At that time the Saalian age of the Moreton Drift, now in doubt, was unchallenged. If this glaciation is of Anglian age, as suggested by more recent authors (see above), and the correlation of the Hanborough and Paxford Gravels is correct, the latest possible age for the Hanborough Gravel would be Anglian. The implication of this would be a return to the interpretation of the derived mammalian fauna as being of Cromerian age, a view that has no support from biostratigraphy and is contrary to evidence from terrace stratigraphy in the Thames basin as a whole (see below).

Biostratigraphical evidence for the age of the Hanborough Terrace is rather sparse. The Mollusca obtained by Briggs and Gilbertson (1973) are of considerable palaeoenvironmental significance, but yield no information of significance to relative dating (although amino acid ratios from these shells might prove informative at some future time). Many of the teeth of *Palaeoloxodon antiquus* from the Hanborough Terrace deposits were described as having primitive or archaic affinities (Sandford, 1925), but recent reassessment of the material has not confirmed this potential indication of antiquity (Lister, 1989). These derived mammalian remains are of potential significance, however. Both mammoth and straight-tusked elephant appear for the first time in the Pleistocene of north-west Europe in the Elsterian (Anglian) Stage and have not been recorded from pre-Elsterian interglacials (Lister, 1989). Unless this fauna represents an intra-Anglian interstadial, it would not be expected beneath Anglian glacial deposits. All the mammalian species recorded from the Hanborough Gravel have, in contrast, been recognized from deposits ascribed to the Hoxnian Stage (*sensu* Swanscombe and *sensu* Hoxne). Therefore this derived (temperate-climate) fauna provides support for the chrono-stratigraphical scheme for the Thames terraces proposed in Chapter 1, in which it was considered to represent Oxygen Isotope Stage 11 (Hoxnian *sensu* Swanscombe), although reworked into a Stage 10 gravel aggradation.

Arkell's correlation of the Paxford and Hanborough Gravels has been questioned by a number of authors. Shotton (1953) correlated the Paxford Gravels with the early Wolstonian (*sensu* Wolston) Baginton-Lillington Gravels of the Leamington area, whereas Richardson and Sandford (1963) described a mammalian assemblage of cold-climate affinities from the Paxford deposits. At this time the Hanborough Formation was confidently attributed to the Hoxnian, on the basis of its mammalian fauna, and regarded as interglacial in origin. Arkell's interpretation was also challenged by Kellaway *et al.* (1971), who noted compositional similarities between the Hanborough and Paxford Gravels, but regarded them as the products of separate river basins. Briggs and Gilbertson (1973, 1974) considered that their new evidence for cold conditions during the aggradation of the Hanborough Terrace eliminated the objections of Shotton (1953) and Richardson and Sandford (1963) and were inclined to accept Arkell's hypothesis. Strong additional evidence for a pre-Cotswolds glaciation age for the Hanborough Gravel was cited by Briggs (1973; Briggs and Gilbertson, 1974). He recognized quartzite-rich gravels (outwash) and a purple clay (Triassic-rich till?) in the upper Evenlode valley and attributed these to an ice sheet moving from the north-west, independent of, and probably slightly earlier than, that which deposited the (flinty) Moreton Drift. According to Briggs, the quartzite-rich outwash overlies the Hanborough Gravel upstream of Kingham, but has a steeper downstream gradient and is incised below the Hanborough Terrace level further downstream. However, Maddy *et al.* (1991b) have recently pointed to descriptions by Gray (1911) and Tomlinson (1929) of significant quantities of flint in deposits at Bledlington and Milton-under-Wychwood that Arkell (1947a, 1947b) included in the Hanborough Terrace. These latter observations suggest that, even if the Hanborough Gravel can be demonstrated to underlie the Moreton Drift, flint from the Cotswolds glaciation was already being fed into the Upper Thames by the time of Hanborough Gravel deposition. As has been discussed in Chapter 1, there is a distinct possibility that the gravels underlying the glacial deposits in the Upper Evenlode, the 'Bledlington Terrace' of Arkell (1947b), might be older than the Hanborough Gravel of the type area, perhaps the equivalent of the Freeland Formation (see (Figure 1.3)).

Solution and periglacial features

The various large-scale post-depositional structures with v-shaped cross-sections that disrupt the deposits at Long Hanborough have attracted considerable interest. Periglacial and solution features have been noted in the Hanborough Terrace deposits by many workers (Sandford, 1924, 1926; Dines, 1946; Arkell, 1947a; Briggs and Gilbertson, 1973, 1974; Briggs, 1976a). According to Sandford (1924, p. 124), '… the top of the (Duke's) pit is marked by a remarkable series of so-called solution-pipes to a depth of 10 ft or more, filled with brown gravelly clay'. Sandford noted root remains in some of these features and suggested that the roots of trees might have been responsible for their formation, pointing out that the Hanborough area was formerly part of Wychwood Forest. He observed similar features in the Hanborough Gravel of the Cherwell valley at Kirtlington. Sandford reported that bedding could be traced through the 'pipes' and that it also sagged into them. Dines (1946), however, noted that the bedding was deformed upwards on either side of these features, which he believed to be infilled with material foreign to the Hanborough Gravel. These observations were confirmed by Arkell (1947a).

The 'pipes' in the gravel at Long Hanborough are striking features, picked out by their dark red-brown, clayey infill, which stands out against the surrounding pale limestone gravels (Figure 2.9). They were described in some detail by Kellaway *et al.* (1971) as part of a study of various Pleistocene structures in the Upper Thames and Cotswold regions. These authors confirmed Arkell's view: 'clearly the "wedges" are long tapering pipes or inverted cones, not wedge shaped masses arranged on a polygonal plan' (Kellaway *et al.,* 1971, p. 12). However, they did not believe the features to be simple solution pipes. They noted that the immediately adjacent calcareous gravel was disturbed and showed no sign of decalcification. Furthermore, they suggested that the dark infill was not the residue of gravel that had been decalcified, but was derived from a formerly continuous superficial deposit that had fallen in from above. They established that the 'pipes' were widely distributed at about 3 m intervals on the flat part of the terrace remnant, but were absent from the peripheral slopes, which they believed to have been cambered. They suggested that the features were the degraded bases of 'frost boils', formed in a periglacial environment. Kellaway *et al.* also noted the occurrence of calcrete and small-scale normal faulting at Long Hanborough, as well as 'gulls' near the edge of the gravel spread at Church Hanborough, where cambering has occurred.

Briggs and Gilbertson (1973, 1974) recognized various ground-ice pseudomorphs (ice-wedge casts and frost-cracks) at several places in association with the solution pipes, as well as small-scale festooning (involutions) within the top metre of sediment. They accumulated evidence that ice-wedge formation had been contemporaneous with gravel deposition (intraformational), claiming this as support for their conclusion that the Hanborough Terrace deposits were laid down under periglacial conditions (Briggs and Gilbertson, 1973). They later reserved judgement on the matter, considering it possible that the observed features might be 'dip and fault structures', related to cambering, rather than ice-wedge casts (Briggs and Gilbertson, 1974). Briggs (1976a, 1988) suggested that the characteristic Hanborough Terrace 'pipes' might have originated as cylindrical growths of ice within the upper part of the gravel, perhaps associated with festooning, followed, under warmer conditions, by solution at points where the gravel fabric was aligned vertically. This two-stage hypothesis of 'pipe' formation explains the fact that the upward deformation of adjacent bedding is confined to the top part of the pipes; these parts were presumably initiated by periglacial processes. The hypothesis also explains why the widest pipes show the least deformation (deformed zones having been removed by solution), the opposite to what might be expected in the best-developed features if they were simple periglacial structures.

Correlation with the sequence in the London Basin

Correlation of the Hanborough Terrace with the Pleistocene sequence in the London Basin has previously proved somewhat problematic (see Chapter 1 and (Figure 1.3)). Previous attempts at correlation between the Upper and Middle Thames have usually associated the Hanborough Gravel with the Boyn Hill (Sandford, 1924, 1926; King and Oakley, 1936) or the Winter Hill Formations (Sandford, 1932; Wooldridge, 1938). Arkell's (1947a) correlation of the Hanborough and Silchester Gravels (see above) would, at the time, have implied parity with the Winter Hill Terrace, but the Silchester (Hampstead Marshall Terrace) Gravel has recently been correlated with the Black Park Gravel of the Thames (Gibbard, 1985; see Chapter 3, Hamstead Marshall). Lower facets within what was recognized as the Winter Hill Terrace when Sandford and King and Oakley were active have subsequently been attributed to the Black Park Formation (see Chapters 1 and 3).

The palaeolith from Duke's Pit (see above) has also been interpreted as evidence for relative antiquity, having been regarded as 'Early Acheulian' or Abbevillian (Arkell, 1947c). This interpretation was not supported by Wymer (1968) or Roe (1976), both of whom advised against drawing conclusions from single finds. In any case, the separate existence of earlier phases of the Acheulian Industry, characterized by less skilfully made implements, is no longer widely accepted (Chapter 1).

Arkell's interpretation has remained a minority view, most authors having correlated the Hanborough and Boyn Hill Gravels, largely on the basis of the similarity of the mammalian faunas at Hanborough and Swanscombe. This view was widely accepted prior to the work of Briggs and Gilbertson (1973, 1974), both aggradations being assigned to the Hoxnian Stage (Mitchell *et al.,* 1973). Briggs and Gilbertson, in showing the Hanborough Formation to have accumulated under periglacial conditions, cast doubt on this correlation. The basis for this doubt has subsequently been negated by the work of Gibbard (1985), who has shown that the Boyn Hill Gravel of the Middle Thames is also largely the result of aggradation under periglacial conditions and that interglacial sediments such as those at Swanscombe are atypical. Gibbard placed the Boyn Hill Gravel in the early 'Wolstonian' (Saalian) Stage and considered the Hanborough Gravel to be its direct upstream equivalent. The remains of interglacial mammals found in these gravels were considered by Gibbard to have been reworked during the destruction of Hoxnian sediments similar to those preserved at Swanscombe.

Recent reappraisal of the glacial stratigraphy of the Midlands (Perrin *et al.,* 1979; Sumbler, 1983a; Rose, 1987, 1989, 1991; Chapter 1) has important implications for this correlation. In East Anglia it has been generally accepted, since the work of Bristow and Cox (1973) and Perrin *et al.* (1973), that the local 'Chalky Till' is entirely of Anglian age, but in the Midlands till of the same general type has been placed in the Saalian (Wolstonian) (Shotton, 1953, 1973a; Kelly, 1964). Recent research has challenged this last view, however, with the implication that the glaciation of the Vale of Moreton may, in fact, be of Anglian age (Sumbler, 1983a; Rose, 1987, 1989). Such an interpretation would seem to support Arkell's (1947a, 1947b) view, in which the Hanborough Terrace was regarded as earlier than the Catuvellaunian (= Anglian) glaciation. However, the scheme for terrace correlation between the Upper and Middle Thames valleys, outlined in Chapter 1 (Figure 1.3), has an important bearing on this discussion. A pre-Anglian glaciation age for the Hanborough Gravel would rule out correlation with the Boyn Hill Gravel of the Middle Thames, which postdates the Anglian glaciation of the Vale of St Albans (Gibbard, 1979, 1985). Correlation with the Black Park Gravel would also prove difficult, since this formation is believed to have been deposited in the Middle Thames valley while Anglian ice sheets occupied parts of the Vale of St Albans (Gibbard, 1977; see Chapter 3).

The conclusion that the Hanborough Gravel may be older than the Anglian glaciation therefore poses major problems for terrace correlation between the Upper and Middle Thames. The Black Park Gravel (formerly the Lower Winter Hill Terrace — see Chapter 3, Highlands Farm Pit) is aggraded to over 90 m O.D. in the district immediately downstream from the Goring Gap (Evans, 1971, fig. 53; Gibbard, 1985, fig. 10), whereas the Hanborough Terrace has already fallen below 80 m O.D. immediately upstream of the gap (Figure 2.3). These facts strongly indicate that the Hanborough Terrace must correlate with a formation lower, and therefore later, than the Black Park Gravel. It must also, therefore, post-date the glaciation of the Vale of St Albans. In fact, altitudinal evidence unequivocally indicates correlation between the Hanborough and Boyn Hill Gravels (Chapter 1 and (Figure 1.3)), as many past authors have claimed (Sandford, 1924, 1926; King and Oakley, 1936; Gibbard, 1985).

The Arkell (1947a, 1947b) interpretation of the Hanborough Gravel underlying the glacial deposits of the Moreton-in-Marsh area is thus of considerable significance. The downstream equivalent of the Hanborough Formation, the Boyn Hill Gravel, is ascribed to the early Saalian (Gibbard, 1985), so a broadly Saalian (post-Swanscombe interglacial) age appears to be implied for the Cotswolds glaciation. It should be noted, however, that the records of flints in deposits ascribed to the Hanborough Formation (Maddy *et al.,* 1991b; see above) may indicate that at least part of the Hanborough aggradation incorporates outwash from the Cotswolds glaciation. Maddy *et al.* (1991b) did not address the question of whether Arkell's interpretation of the stratigraphical relations between the Hanborough Gravel and the glacial deposits is correct. This question, which is discussed above and in Chapter 1, remains of paramount importance and is an issue requiring urgent attention.

In Chapter 1, schemes for correlating the Upper and Middle Thames terraces and for relating these to the oceanic oxygen isotope sequence were described. According to these, and if Arkell's interpretation is correct, the relation of the

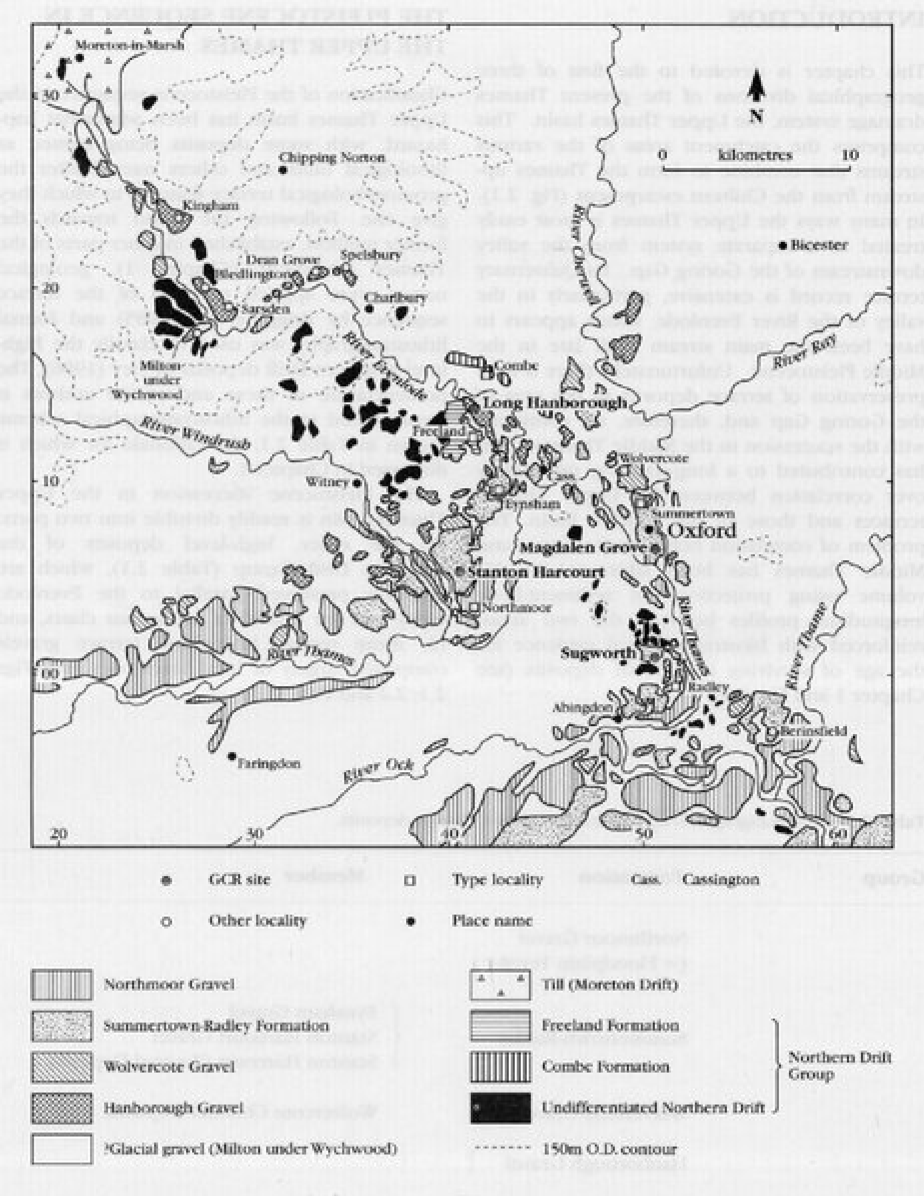
Hanborough Formation to Moreton Drift implies that the Cotswolds glaciation was later than that which diverted the Thames from the Vale of St Albans. If the latter is correctly correlated with Oxygen Isotope Stage 12 (Bowen *et al.,* 1986b), the former may equate with Stage 10 (Chapter 1). If Bowen *et al.* (1989) are correct in correlating the type-Hoxnian with Oxygen Isotope Stage 9, it is possible that the Moreton glaciation is both post-Anglian and pre-Hoxnian (*sensu* Hoxne), although it appears that it might post-date the interglacial sediments at Swanscombe (see Chapter 1).

It remains possible, in the light of the complexity of sedimentary sequences beneath single terrace surfaces implied by the model for terrace formation advocated in Chapter 1, that late Anglian (Oxygen Isotope Stage 12) outwash is included within a range of deposits making up the Hanborough Formation. This would allow the Moreton Drift to be ascribed to the same glacial event as the tills of the London Basin, although there is still the major problem that the glaciation of the Cotswolds appears to occur (or at least persist) after the downcutting to the Hanborough/Boyn Hill terrace level. The flinty gravels described by Gray (1911) and Tomlinson (1929) at Milton and Bledlington (see above) would, according to this view, equate with the gravels underlying the Moreton Drift, but the Hanborough deposits containing the mammalian bones must presumably date from the subsequent cold episode (Stage 10), if the fauna is correctly attributed to Stage 11 (Hoxnian *sensu* Swanscombe). The two sets of gravels would thus represent phases 2 (Stage 12) and 4 (Stage 10) of the model for terrace formation, with phase 3 represented by the *remanie* fauna. Further discussion of the age and stratigraphical relations of the Moreton Drift will he found below, in the Wolvercote report.

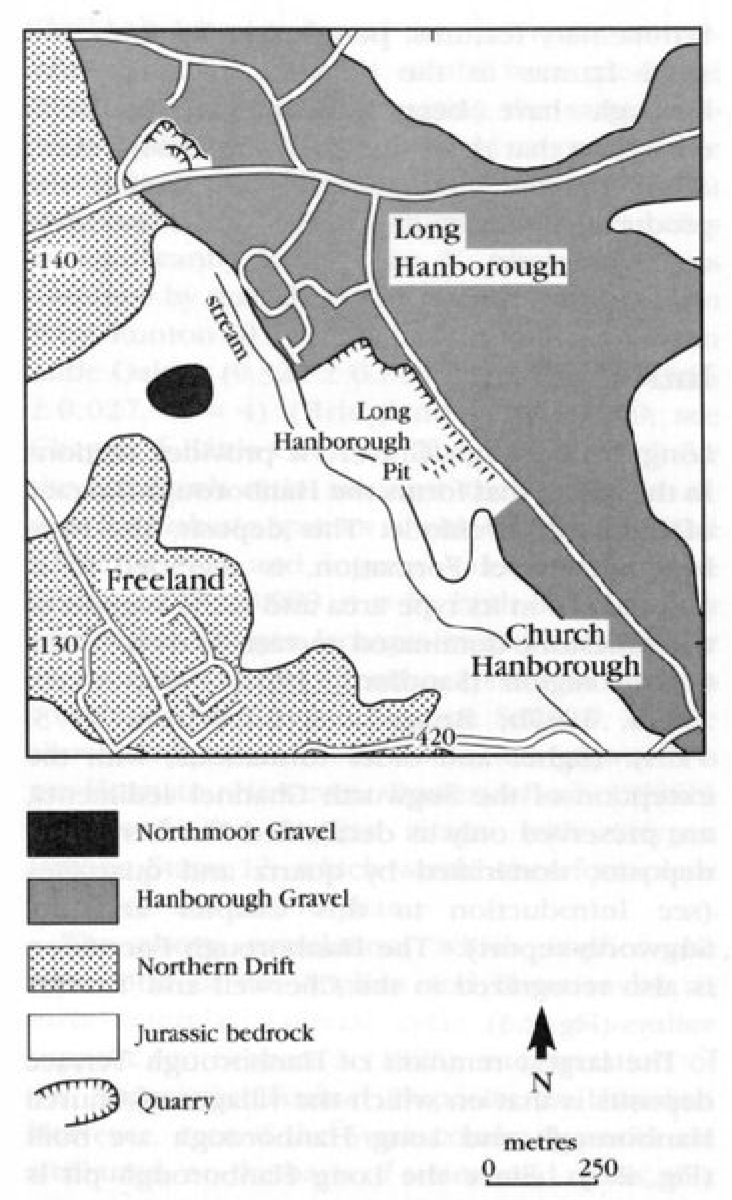
Conclusions

The gravels at Long Hanborough were deposited by a braided, gravel-bed river that flowed across a sparsely vegetated, treeless landscape during one or more of the cold-climate phases of the Pleistocene. Since the gravels at Long Hanborough contain the bones of large mammals, of species that preferred warm climates, the deposits were formerly thought to have accumulated during a temperate (interglacial) phase. The discovery of the remains of cold-tolerant snails within the gravels, however, has shown that the deposits were laid down under harsh, periglacial conditions. It seems likely that the bones of the temperate-climate mammals were derived from older, interglacial sediments. It appears that the gravels at Long Hanborough were laid down by an early River Evenlode, which drained a larger area than the present catchment. The precise age of the deposits is difficult to establish. On the basis of correlations with sequences in the English Midlands and elsewhere in the Thames basin, it is likely that the Long Hanborough gravels date back to around 300,000 to 400,000 years BP, somewhat later than the most intense of the Pleistocene glaciations (the Anglian glaciation). The interest of the site is enhanced by a series of infilled pipe structures that penetrate down into the gravels. These are thought to have formed by a combination of periglacial processes and the solution of carbonate-rich sediments, but their precise origin is uncertain.

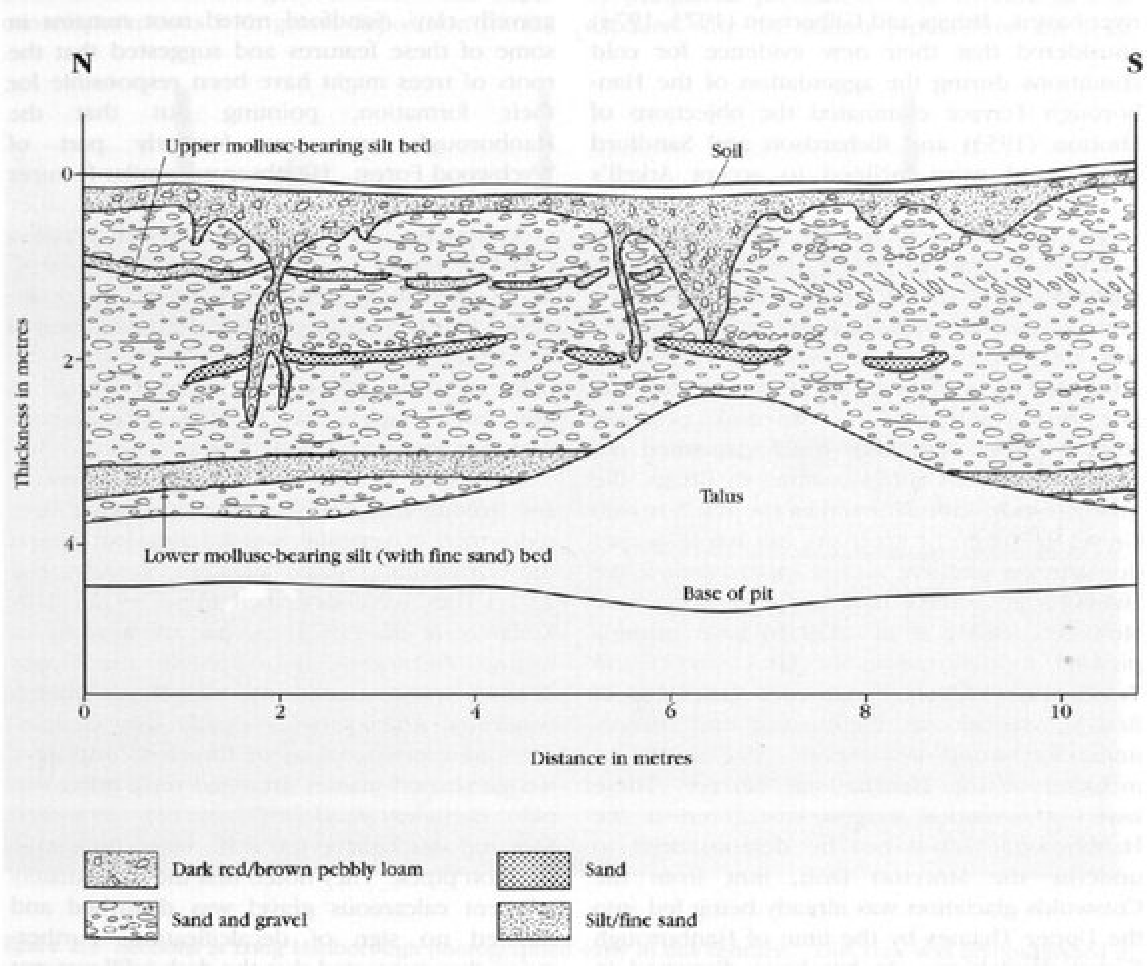
References



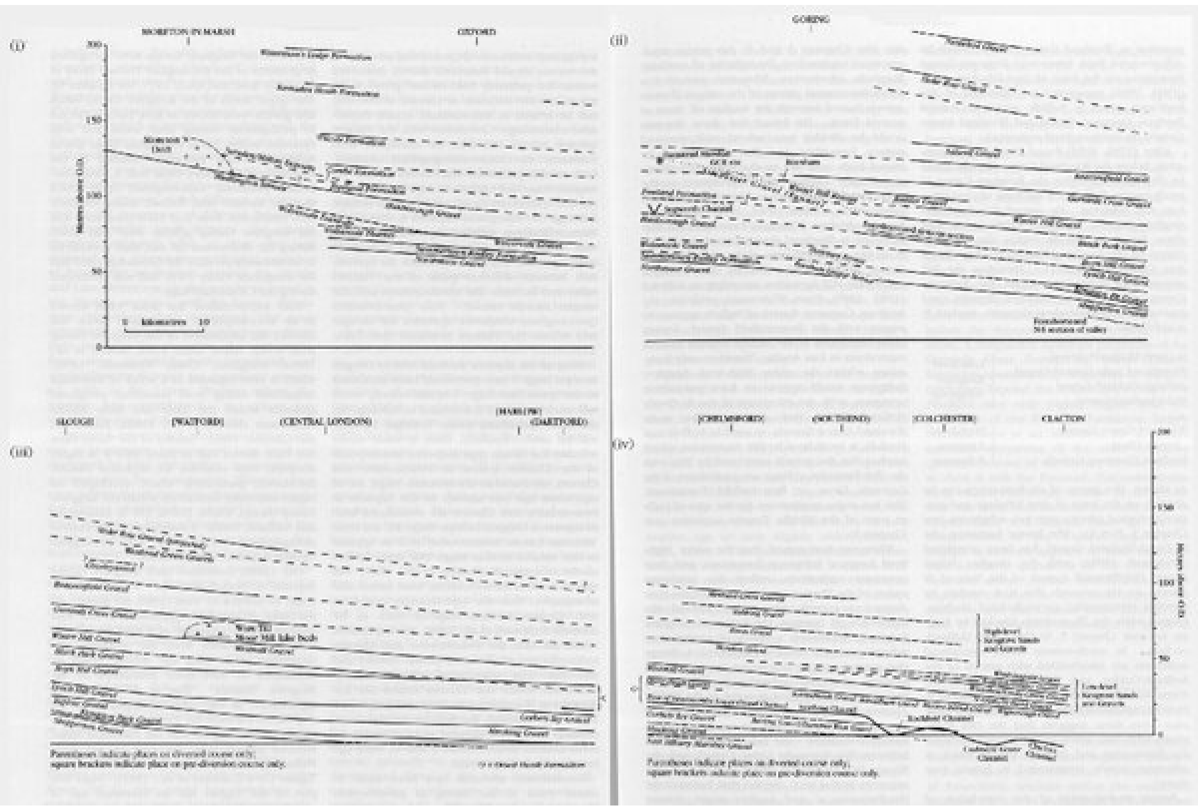
(Figure 2.1) The gravels of the Upper Thames catchment.



(Figure 2.7) Map of the Long Hanborough area, showing the location of the GCR site. The quarry in the top left part of the diagram is Duke's Pit.

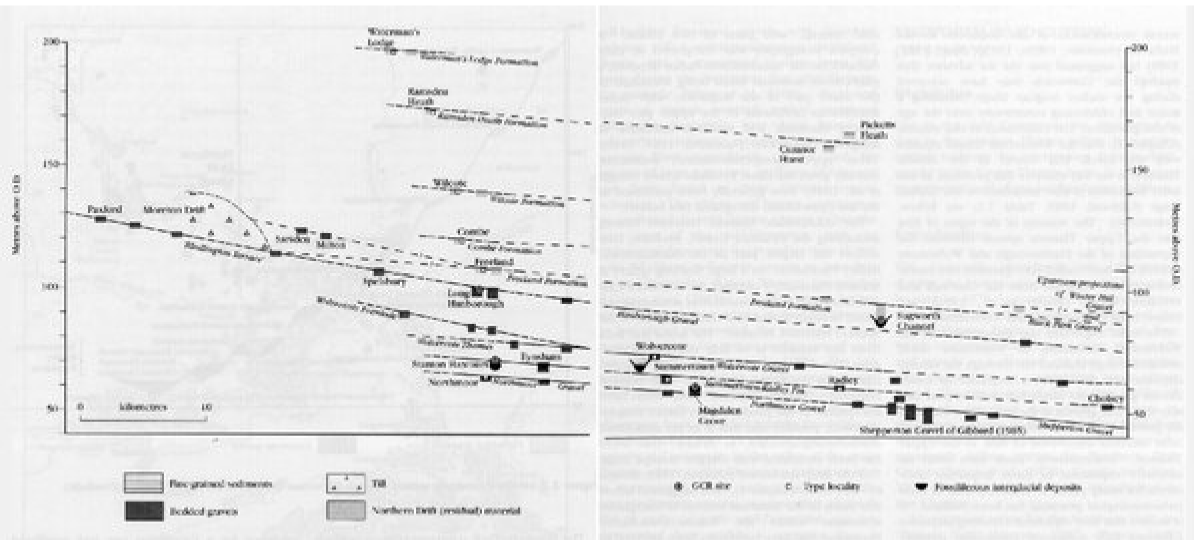


(Figure 2.8) The east face at Long Hanborough Gravel Pit (after Briggs and Gilbertson, 1973). This shows 'frost boils'/decalcification pipes, filled with pebbly loam. Note the effects of frost heaving in the adjacent bedding.



(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.*

(Figure 2.9) Sections at Long Hanborough photographed early in this century. This view was first published in the Witney Geological Survey memoir, where it was attributed to Duke's Pit. Note the prominent 'frost boil'/pipe features, filled with darker material. Upward deformation of the gravel bedding adjacent to the left-hand pipe is clearly shown. Photograph reproduced by courtesy of the British Geological Survey (A3188).



(Figure 2.3) Longitudinal profiles of the Upper Thames terrace deposits. Compiled from the following sources: Arkell (1947a, 1947b); Bishop (1958); Briggs and Gilbertson (1973); Briggs et al. (1985); Evans (1971); Kellaway et al. (1971); Sandford (1924, 1926); Tomlinson (1929).