Part 1 Pliocene/Lower Pleistocene Deposits in the London Basin

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Introduction

High-level deposits, often capping Palaeogene outliers, are sporadically preserved on the Chilterns and North Downs, the Chalk escarpments bordering the London Basin to the north and south. The highest of these deposits have usually been attributed to Late Pliocene/Early Pleistocene marine episodes, although the incidence of corroborative palaeontological evidence is very rare. In addition, many of the hills north of London, both to the north and south of the Vale of St Albans (Figure 3.1), are covered by gravelly deposits composed predominantly of rounded flint pebbles of the type that make up the various Palaeogene pebble beds. This type of deposit is commonly known as Pebble Gravel.

Early studies of Pliocene/Lower Pleistocene deposits were concentrated on the North Downs. Most early descriptions of the fossiliferous Lenham Beds on these hills in Kent attributed them to the Pliocene (Prestwich, 1858a; Lye11, 1865; Geikie and Reid, 1866; Reid, 1890; Newton, 1916; Wooldridge, 1927a; see Little Heath), although they are now considered to be Miocene (Curry *et al.,* 1978). Similar deposits were recognized on the North Downs of Surrey at Netley Heath and Headley Heath (Whitaker, 1862; French, 1888) containing, at the former site, fossil molluscs (Stebbing, 1900; Davies, 1917; Chatwin, 1927; Dines and Edmunds, 1929; John and Fisher, 1984). These are poorly preserved moulds in ferruginously indurated horizons and/or clasts that provide evidence of correlation, not with the Lenham Beds, but with the Red Crag of East Anglia. Although formerly regarded as Pliocene (Reid, 1890; Harmer, 1902), the Red Crag has for much of this century been considered to be basal Pleistocene (Baden-Powell, 1950; Boswell, 1952). Later appraisal suggested that at least part of the Red Crag belongs to the Upper Pliocene Series (Cambridge, 1977; West, 1977). Recent estimates of the age of this formation and its suggested correlation with the Praetiglian and Upper Reuverian Stages of The Netherlands imply that the Red Crag is wholly pre-Pleistocene, dating from between 3.5 and 2 million years BP (Zalasiewicz and Gibbard, 1988).

There are very few deposits south of the main Red Crag outcrop and north of the Thames that contain biostratigraphical evidence for a Pliocene age. However, the various high-level outliers rich in well-rounded flint pebbles, the Pebble Gravel, have been recognized as deposits of considerable antiquity, possibly as old as Pliocene, since the middle of the last century. The rounded nature of the majority of its clasts has led numerous authors to regard the Pebble Gravel as a series of marine or littoral deposits (Hughes, 1868; Wood, 1868; Prestwich, 1881, 1890a, 18906; Whitaker, 1889). In addition to the rounded flints, these deposits also contain small amounts of subangular flint, together with quartz, quartzites and sarsens. The term Pebble Gravel was first used by Whitaker (1864, 1875, 1889), who regarded this type of material as the oldest 'drift' deposit, distinguishing it from the fossiliferous Pliocene beds that occur in comparable situations capping high ground, but which he regarded as part of the 'solid' geology. There has, however, been considerable confusion as to whether certain high-level deposits lacking fauna are unfossiliferous Pliocene marine beds or part of the Pebble Gravel.

In one of the earliest descriptions of the Pebble Gravel, Hughes (1868) referred to it as 'Gravel of the Upper (or Higher) Plain', forming the higher of two dissected gravel-covered plateaux recognized by him in Hertfordshire. According to Hughes: 'there are just enough subangular flints and large partly worn pieces of quartz etc. to show that this gravel derives its pebbly character from the waste of older pebble beds, with which the unworn fragments got mixed, and not that they were all worn together into pebbles along the shingly shore of the Higher-Plain Gravel-sea' (Hughes, 1868, p. 285). Like Hughes, Whitaker (1889) also realized that the rounded nature of the flints in the Pebble Gravel was a feature inherited from the Palaeogene, although both he and Hughes nevertheless favoured a marine origin. Prestwich (1881, 1890b) correlated the Pebble Gravel of the area north of London with his 'Mundesley and Westleton Beds' (later simply Westleton Beds'), which he sought to trace southwards and westwards, at increasing altitudes, from East Anglia. Prestwich interpreted the deposits as evidence for a Late Pliocene/Early Pleistocene marine incursion into the London Basin. He realized that these beds dated from near the Pliocene/Lower Pleistocene boundary and considered them to be 'the base of the Quaternary Series' (Prestwich, 1890a, p. 85).

Salter (1896) attempted to subdivide the Pebble Gravel on the basis of composition, recognizing four types. These were:

1. Barnet Gate type — strongly dominated by flint and occurring widely on the highest land in Hertfordshire.
2. Hampstead type — of more restricted occurrence, characterized by smaller pebbles than (a) and by the presence of Greensand chert.
3. High Barnet type — distinguished from (a) and (b) by a sandier matrix, a considerably greater complexity of pebble composition and with a more widespread distribution.
4. Bell Bar type — differing from the others in that it occupies lower levels and has an even greater complexity of composition than (c), including plentiful quartzites.

Within all these compositional divisions, the elevations of the various outliers generally decline from west to east, a factor that led Salter to reject the marine hypothesis in favour of an interpretation of the deposits as reflecting the onset of 'Glacial' conditions. He believed that the various types of Pebble Gravel were the 'first deposits of the Glacial Series' (Salter, 1896, p. 404), but he later emphasized the role played by rivers in their deposition (Salter, 1898, 1901, 1905). In many ways Salter's work, combining altitude and clast-lithological composition as criteria for classification, was far ahead of its time; in the first half of the twentieth century theoretical geomorphology and denudation-chronology prevailed and there was little progress in the interpretation of the Pliocene/Lower Pleistocene deposits in the London Basin.

White (1906) proposed a possible solution to one of the major puzzles presented by the Pebble Gravel, that of the relatively large proportion of quartz it contains, especially in the finer gravel fractions. This material is foreign to the London Basin, and is generally absent in the Palaeocene and Eocene pebble beds. However, White reported the discovery of a markedly different facies of the Palaeocene Reading Beds, at Lane End in Buckinghamshire. Reading Beds gravel at this locality contains abundant quartz as well as subangular flint and 'lydite'. White suggested that this facies was once widespread to the north-west of the present Chiltern escarpment, prior to the erosional recession of the latter during the Pleistocene. This quartzose facies of the Reading Beds was seen by White as a potential source for the non-flint component of the Pebble Gravel.

There followed several years of controversy over the precise age of these deposits at Lane End. Barrow (1919a) questioned White's assertion that they belonged to the Reading Beds. A major factor in favour of White's interpretation was that the quartzose gravel is overlain by what appears to be basal London Clay. Barrow suggested that this clay could have been redeposited and that the quartzose gravel belonged itself to the Pliocene Pebble Gravel. He cited the deposit at Little Heath (see below, Little Heath) as a typical example of Pebble Gravel with a comparable composition. Barrow suggested a mechanism of 'static washing', whereby the mixture of flint and quartz pebbles surrounded by a clayey matrix was left as a residue capping some of the hills in the area north of London. He regarded this type of residual material as the normal Pebble Gravel, quite distinct from a series of deposits occurring at around 400 ft (120 m) O.D. on the Chilterns dip slope, which he believed to be true marine Pebble Gravel. He interpreted the slightly higher Pebble Gravel of the Stanmore area (Stanmore Pebble Gravel see below, Harrow Weald Common), at up to 500 ft (155 m) O.D., as a beach deposit of equivalent age to the 120 m deposits, regarding the latter as sea-floor sediments, formed near the margins of a Pliocene sea that covered all but the highest parts of the Chalk escarpment.

Some discussion of the age and origin of the Pebble Gravel was undertaken in the various local Geological Survey memoirs published during the following few years (Sherlock, 1922; Sherlock and Noble, 1922; Sherlock and Pocock, 1924; Bromehead, 1925). Sherlock (1924) produced a more detailed argument, in which he proposed that the deposits should be assigned to the Pleistocene rather than the Pliocene and that they were formed by locally nourished glaciers which merely rearranged the local Tertiary materials.

Discussion of the Pliocene/Lower Pleistocene deposits of the London Basin was dominated for the next thirty years by S.W. Wooldridge and his co-workers. Wooldridge and Gill (1925) reinvestigated the quartzose gravels at Lane End and confirmed their Reading Beds age. They noted that a later Pebble Gravel also occurred at the locality, capping the Palaeogene outlier. They suggested that this younger deposit was of Late Pliocene to Early Pleistocene age and reaffirmed White's view that the quartzose component of the Pebble Gravel might, in the main, have been secondarily derived from the quartzose facies of the Reading Beds. Indeed, they went further and suggested that the Greensand chert that occurs locally in the Pebble Gravel might also have been reworked from the Palaeogene.

In a much-quoted sequence of publications, Wooldridge (1927a, 1957, 1960; Wooldridge and Linton, 1939, 1955) redefined the term Pebble Gravel to apply only to the deposits concentrated at around 122 m (400 ft) O.D., Barrow's sea-floor sediments. These deposits, which occupy an area known as the 'South Hertfordshire Plateau' (more or less coincident with Hughes (1868) 'Upper Plain'), have become known as the 'Hertfordshire', 'Lower' or '400 ft Pebble Gravels'. Wooldridge recognized that the higher-level deposits of the Stanmore area contain less non-flint material than the '400 ft' gravels (he regarded the latter as Pebble Gravel *sensu stricto*), thus confirming Salier's observations. Wooldridge ascribed these higher-level gravels to the Late Pliocene marine incursion recognized on the North Downs (at Netley Heath), considering the deposits at Little Heath and Stanmore to be lateral equivalents (see below, Little Heath and Harrow Weald Common). He recognized that chert from the Lower Greensand is locally abundant in the '400 ft Pebble Gravels', reflecting input from Wealden rivers.

Wooldridge (1928) described regional variants of his Pebble Gravel *sensu stricto* in south-west Essex, around Brentwood, Billericay and Laindon. At the last of these, a southern tributary is indicated by the presence of Lower Greensand chert. Wooldridge attributed the fluvial Pebble Gravel (400 ft) to the Late Pliocene or Early Pleistocene. The localization of Greensand chert in north-south trending zones, reflecting south-bank tributaries of an ancestral Thames, led Wooldridge (1927a, 1928) to conclude that the '400 ft Pebble Gravels' were entirely of fluviatile origin. However, he later revised this view and suggested that the chert was distributed along the courses of streams from the Weald across an emergent sea-floor during the Early Pleistocene (Wooldridge, 1957, 1960). Wooldridge was able to delimit, in the area to the north of the modern Lower Lea valley, a confluence area, where, in Pebble Gravel times, a major stream from the south, emanating from the area of the present Mole catchment (Figure 3.4), met with another from the west, presumably the ancestral Thames.

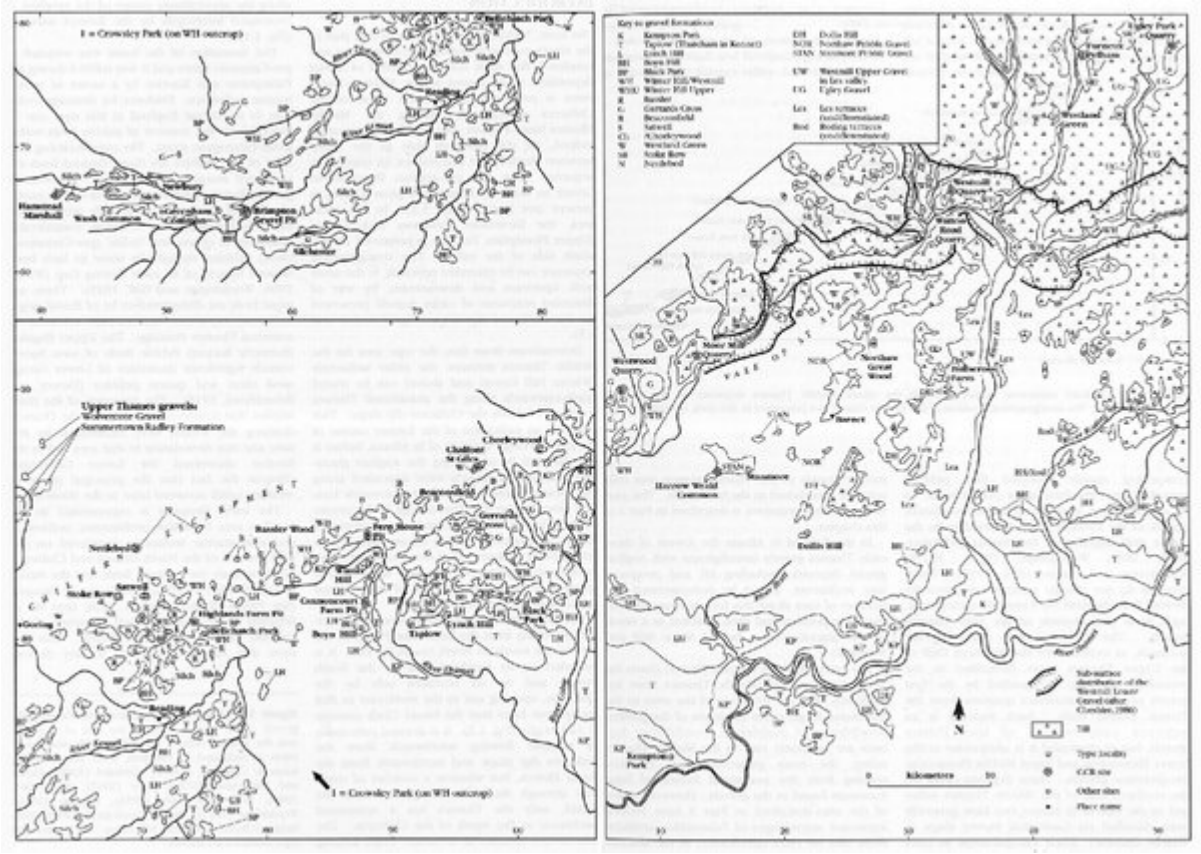
In recent years parts of the Pebble Gravel (*sensu lato*) have been lithostratigraphically redefined. The first work of this type was by Hey (1965), who found that subdivision was possible in much the way that Salter (1896) had suggested. In particular, Hey recognized in Salter's fourth and lowest category, his 'Bell Bar Group', a compositionally distinctive gravel that could be traced from the Goring Gap to Hertfordshire. This deposit, named the Westland Green Gravels by Hey (1965), was regarded at that time as the highest within the Middle Thames sequence to contain material from the Midlands. It was therefore interpreted by Hey as the first true Thames gravel (see Part 2 of this Chapter). Hey *et al.* (1971) conducted a study of the surface textures of sand grains from all the various types of Pebble Gravel, using scanning electron microscopy. They found a progressive decrease in grain-surface features indicative of a marine or beach environment between the higher-level Pebble Gravel (the Stanmore type — see below, Harrow Weald Common) and the Westland Green Gravels. They concluded from this evidence that the high-level deposits were true littoral gravels, deposited following the maximum Early Pleistocene transgression as 'a single series of regressional marine beaches' (Hey *et al.,* 1971, p. 381). These results confirmed the Westland Green Gravels as fluvial deposits, but the '400 ft Pebble Gravels' appeared to yield conflicting grain-surface evidence, with some support for a partly marine hypothesis, though with most indicators suggesting a dominantly fluvial origin.

Gibbard (1983, 1985) further subdivided the Pebble Gravel, recognizing two divisions higher and older than the Westland Green Gravels, also attributable to the Thames. He applied the names Nettlebed Gravel and Stoke Row Gravel to these (see (Figure 3.2) and below, Nettlebed). It is apparent from a comparison of the clast composition of these two formations that a connection was first made between the headwaters of the Upper Thames system and the Midlands in the interval between the deposition of the Nettlebed and Stoke Row Gravels, although there is some suggestion that material from the Midlands may be present in the Nettlebed Gravel (see below, Nettlebed). Sites associated with deposits laid down after this connection was made are described in Part 2 of this chapter. Descriptions of sites at Little Heath, Harrow Weald Common and Nettlebed appear below. These provide sections in sediments that have all at some time been loosely termed Pebble Gravel. The Nettlebed site is part of the type outcrop of the Nettlebed Gravel, but is of enhanced significance in that a Lower Pleistocene interglacial deposit is also preserved there.

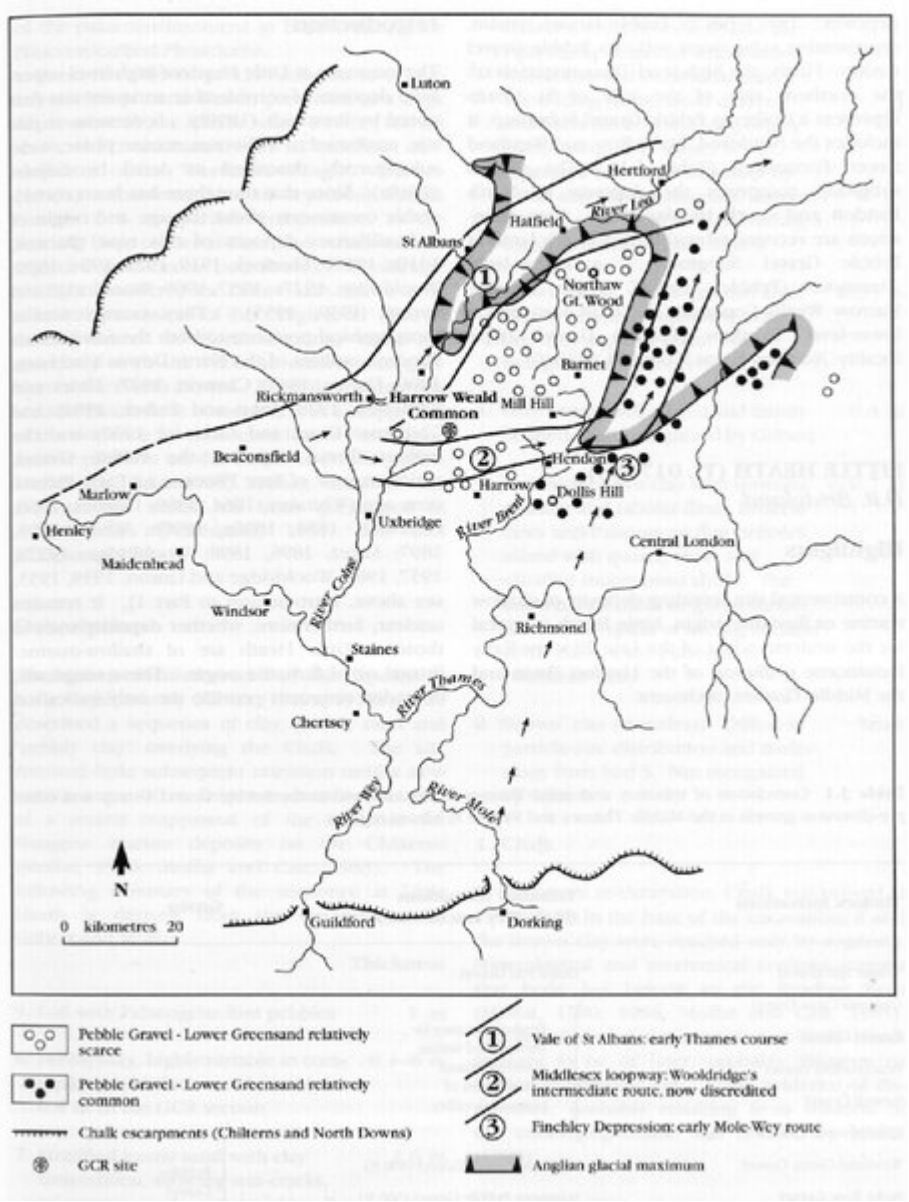
Recent studies have shown that the term Pebble Gravel has been applied to different types of deposit whose only connection is that they contain a high proportion of rounded flint reworked from the Palaeogene. Three main categories can be recognized: (1) high-level gravels on the Chilterns, of possible marine origin, as at Little Heath; (2) high-level remnants north of the Vale of St Albans, of early Thames origin, such as at Nettlebed (these form the highest elements of the terrace 'staircase' that is preserved on the dip slope of the Chilterns) and (3) hill-capping gravels in North London and

south Hertfordshire, of fluvial origin, but laid down by south-bank tributaries of the Thames. Only deposits of the third category occur in the type area of the Pebble Gravel, where they were described and classified by Barrow (1919a) and Wooldridge (1927a), although both of these authors suggested correlations with remnants on the Chilterns. The marine gravels, if correctly interpreted, are essentially unrelated to the evolution of the fluvial system, so they should be distinguished from the Pebble Gravel and the latter term restricted to the early fluvial deposits. Two types of Pebble Gravel remain, representing sub-groups within a Pebble Gravel Group. Firstly, the high-level Thames gravels on the northern side of the Vale of St Albans represent a Chilterns Pebble Gravel Subgroup; it includes the Nettlebed, Stoke Row and Westland Green Formations (Table 3.1). The second subgroup comprises the deposits in North London and south Hertfordshire. Two formations are recognized within this North London Pebble Gravel Subgroup — a higher-level 'Stanmore (Pebble) Gravel' (type locality: Harrow Weald Common, the GCR site) and a lower-level 'Northaw (Pebble) Gravel' (type locality: Northaw Great Wood, [TL 281 040]).

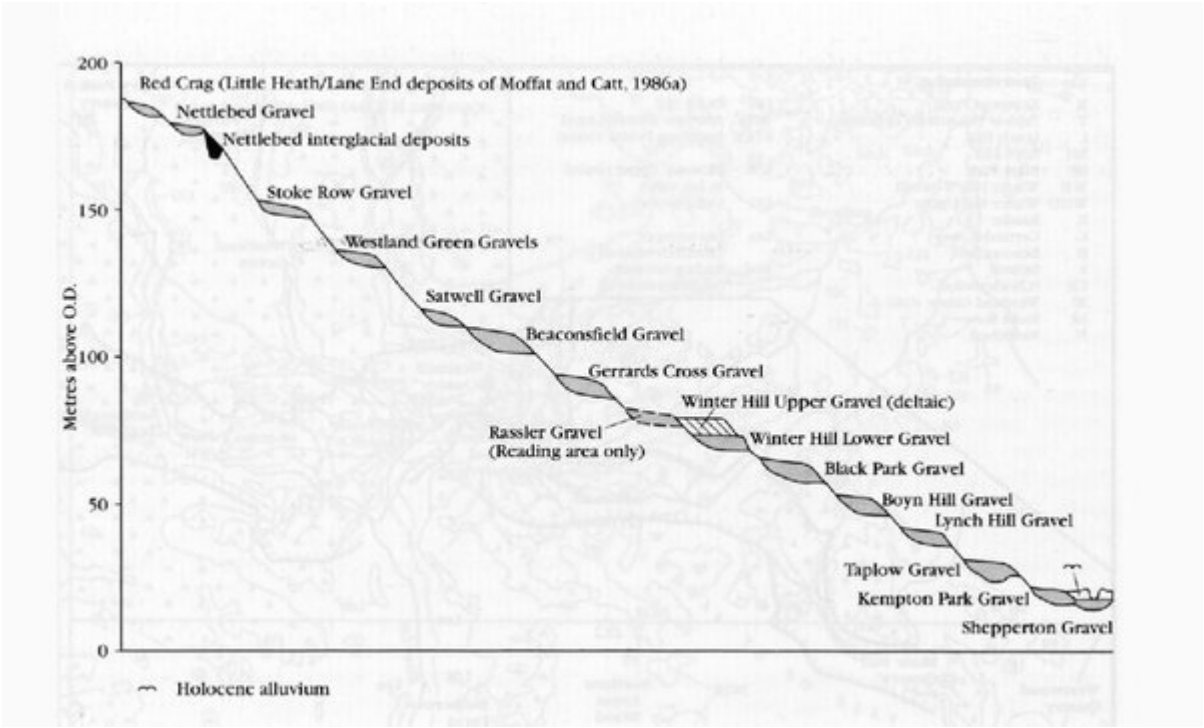
References



(Figure 3.1) (Following two pages) Map showing the gravels of the Middle Thames, the Vale of St Albans and the Kennet valley. Compiled, with reinterpretation as indicated in the text, from the following sources: Cheshire (1986a), Gibbard (1985), Green and McGregor (1978a), Hare (1947), Hey (1965, 1980), Sealy and Sealy (1956), Thomas (1961), Wooldridge (1927a) and the Geological Survey's New Series 1:50,000 and 1:63,360 maps. GCR sites and type localities are shown.



(Figure 3.4) Map showing Wooldridge's reconstructed courses of the Thames and its tributary, the Mole–Wey. The distribution of Pebble Gravel remnants is also shown; those remnants in which Greensancl chert is scarce are distinguished from those in which it is relatively common.



(Figure 3.2) Idealized transverse section through the classic Middle Thames sequence of the Slough-Beaconsfield area. The stratigraphical position of the Rassler Gravel, not preserved in this area, is shown.

Thames formations	Tributary formations (Mole-Wey catchment?)	Group
Winter Hill Gravel	Dollis Hill Gravel	
Gerrards Cross Gravel	Equivalents may be represented within undifferentiated gravels west of Lower Lea valley	
Rassler Gravel		
Beaconsfield Gravel		
Satwell Gravel		
Chorleywood Gravel		
Westland Green Gravel	Northaw Pebble Gravel (400 ft)	Pebble Gravel
Stoke Row Gravel	Stanmore Pebble Gravel (500 ft)	
Nettlebed Gravel		

(Table 3.1) Correlation of tributary and main Thames formations within the Pebble Gravel Group and other pre-diversion gravels in the Middle Thames and Vale of St Albans regions.