CHAPTER 2
PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.1. Location of study area

The study area incorporates part of north Hertfordshire, south and mid-Bedfordshire as well as the southwest corner of Cambridgeshire and lies approximately 40 km north of London (Figure 1.1). Coverage of the area by British Geological Survey (BGS) 1:50,000 map sheets is shown in Figure 2.1.

2.2. Bedrock geology

The strikes of the solid geological formations are approximately northeast-southwest across the study area (Figure 2.2). The solid geological succession is shown in Table 2.1.

To the northwest of the Chiltern Hills the Gault Clay forms a rich agricultural landscape, representing a continuation of the Vale of Aylesbury. Beyond this, running approximately from Bow Brickhill (SP915343) to Gamlingay (TL234525) is a discontinuous ridge formed by the Woburn Sands Formation, part of the Lower Greensand. This prominent 'Greensand Ridge', rising to 170 m O.D. at Bow Brickhill, separates the Cretaceous clays from the Jurassic Oxford and Ampthill Clays to the northwest.

The oldest formation is recorded in a borehole (TL23NE1) at Ashwell (TL286390), where Devonian strata were reached at a depth of 186.54 m, i.e. 93 m below O.D. (Smith, 1992). Lying just beyond the northern boundary of the present study area, north of the River Ouse, a borehole (TL15NE2) at Wyboston (TL175572) penetrated Ordovician rocks of Tremadoc age at a depth of approximately 230 m (Moorlock *et al.*, 2003). The Oxford Clay of the Upper Jurassic represents the oldest formation outcropping within the study area.

Both Jurassic and Cretaceous rocks outcrop within the study area and are described as follows:

Sheet 187	Huntingdon	(S & D)	1975
Sheet 203	Bedford	(B & Sup)	Due 2008
Sheet 204	Biggleswade	(S & D)	2001
Sheet 220	Leighton Buzzard	(S & D)	1992
Sheet 221	Hitchin	(S & D)	1995

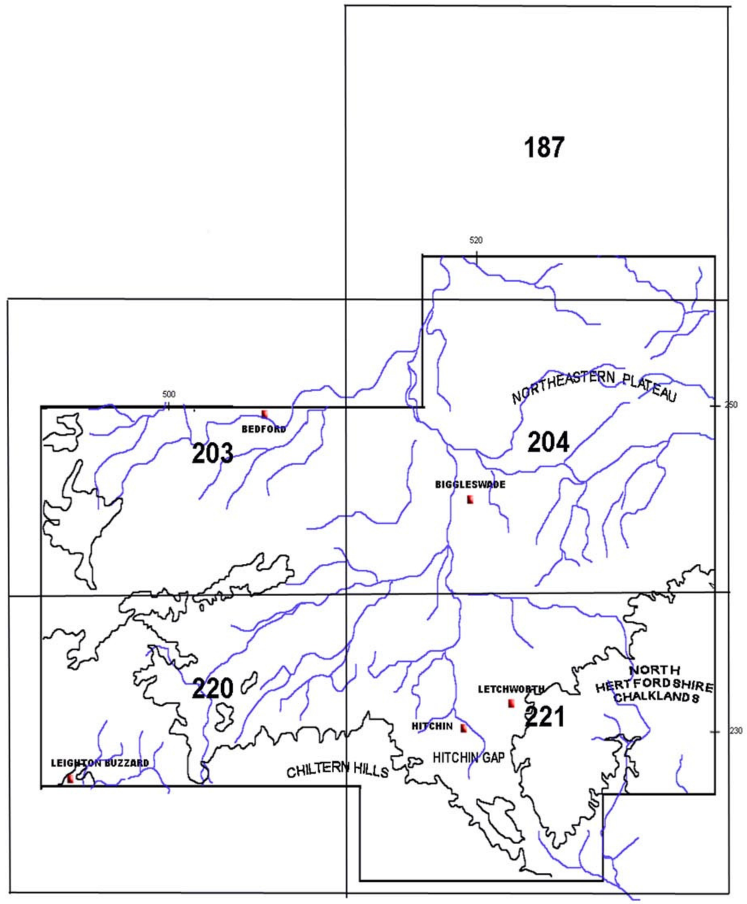

Figure 2.1. Coverage by 1:50,000 BGS geological map sheets.

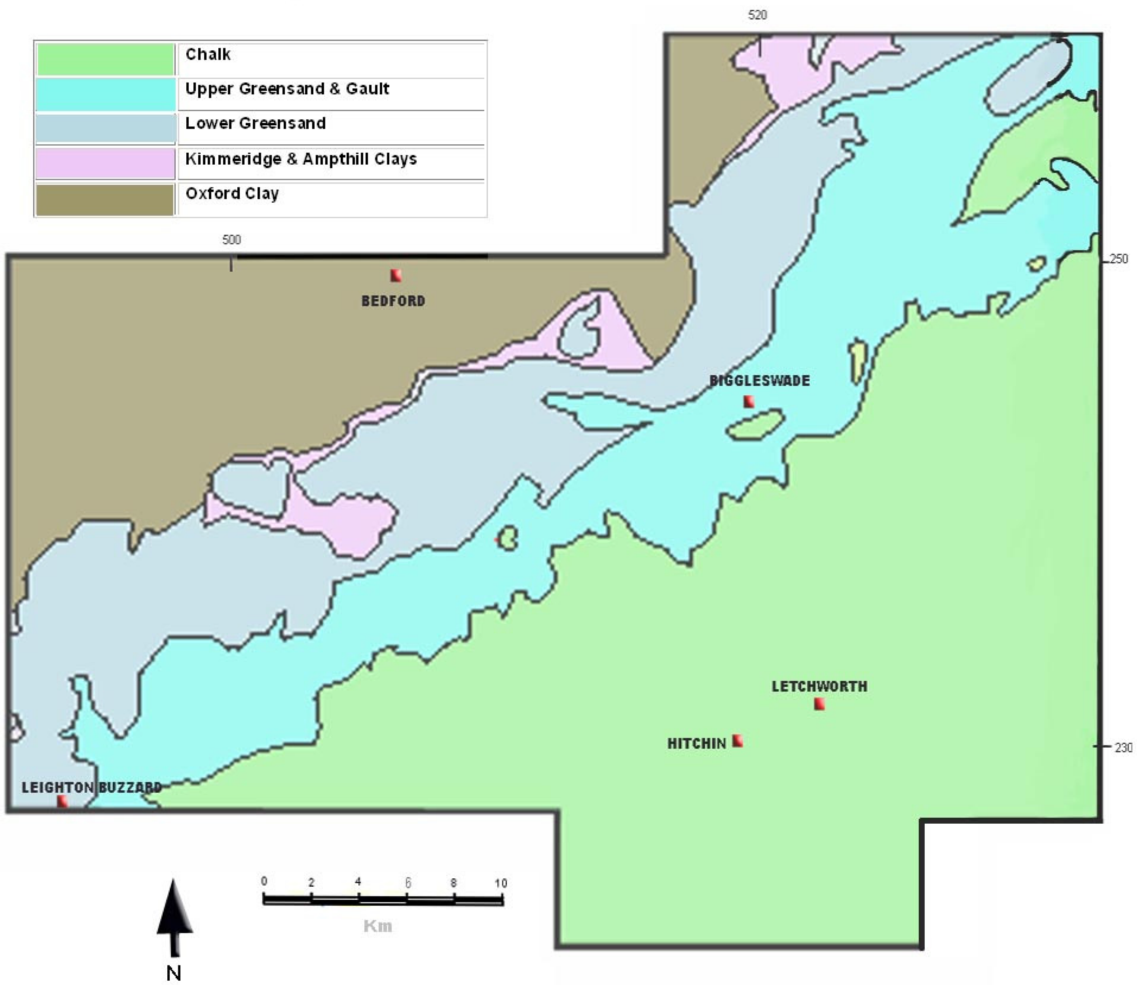

Figure 2.2. Bedrock geology
Based on BGS 1:625,000 Geological map of the United Kingdom : south [solid], 3rd edition (1979).

		GROUP		FORMATION	PREVIOUS CLASSIFICATION
Cretaceous	Upper	Chalk Group	White Chalk Subgroup	Lewes Nodular Chalk	(Upper Chalk)
				New Pit Chalk	(Middle Chalk)
				Holywell Nodular Chalk	
			Grey Chalk Subgroup	Zig Zag Chalk	(Lower Chalk)
				West Melbury Marly Chalk	
	Lower			Upper Greensand	
				Gault	
				Woburn Sands (Lower Greensand)	
Jurassic	Upper	Ancholme Group		Kimmeridge Clay	
				West Walton & Ampthill Clay	
				Oxford Clay	
	Middle			Kellaways	
		Great Oolite Group		Cornbrash	
				Blisworth Clay	
				Blisworth Limestone	
				Rutland	
	Lower	Lias Group		Upper Lias	
				Middle Lias	
				Lower Lias	
Carboniferous	Lower	Carboniferous Limestone Supergroup		Undivided	
Devonian				Upper & Lower Old Red Sandstone	

Table 2.1. Solid geological sequence of the study area.
(Old classification of Cretaceous strata is included for completeness).
(After Edmonds & Dinham, 1965, Shephard-Thorn *et al.*,1994 and Hopson *et al.*, 1996).

2.2.1. Jurassic

Oxford Clay

The Oxford Clay, together with the Ampthill Clay (see below), forms a low lying strike vale running in a northeasterly direction from Marston Moretaine, south of Bedford, across to the River Ivel and beyond to continue northeast of Sandy**.** It consists of a sequence of mudstones with thin bands of septarian nodules (Shephard-Thorn *et al.,*1994).

'Corallian Beds'

The Ampthill Clay and the West Walton Formation (Corallian Beds) are shown undifferentiated on BGS 1:50,000 Sheets 220 and 204. However, Shephard-Thorn *et al.* (1994) noted that, although these deposits have been recognised separately in boreholes, it is not possible to differentiate them at the limited number of drift free outcrops. Both comprise mudstones, often silty, with cementstone nodules. The Ampthill Clay is described at the BGS Ampthill borehole (TL024380) as a pale grey argillaceous mudstone. Both of these formations contain many bivalves and ammonites, those most likely to survive weathering being the thick shelled *Gryphaea*.

2.2.2. Cretaceous

Woburn Sands

As mentioned above, the Woburn Sands form a prominent ridge running approximately 45 km diagonally across the study area. Occasionally they are drift covered, often masking the scarp outline. Part of the Lower Greensand Group, they unconformably overlie Jurassic strata and comprise ferruginous and glauconitic quartzose sands usually oxidised at outcrop to an ochreous brown colour. These deposits vary from loose sands to poorly and moderately well cemented sandstone and contain seams of Fuller's Earth (calcium smectite). Small outcrops of the latter are found around the village of Woburn Sands (Shephard-Thorn *et al.,* 1994).

Gault & Upper Greensand

Gault Clay outcrops in a broad strike vale of low to moderate relief, much of which is covered with drift. It is typically blue grey/green with ammonites, bivalves, gastropods and belemnites and occasional layers of phosphate nodules and gives rise to heavy impervious clay soils. Shephard-Thorn *et al.* (1994) noted that occasionally the clay contains small whitish secondary calcareous nodules (race) which in the past has possibly led to it being erroneously identified as chalky till.

The Upper Greensand succeeds the Gault and represents a sandy silty facies of the latter (Shephard-Thorn *et al.*, 1994). It outcrops in a small area to the west of Dunstable.

Cambridge Greensand

The Cambridge Greensand comprises a thin bed of glauconitic micaceous marl lying at the base of the Lower Chalk. It contains concentrations of dark brown phosphatic nodules together with glauconite grains (Edmonds & Dinham, 1965).

Chalk

Upper Cretaceous rocks form a generally northwest facing scarp running diagonally across the study area (Figure 2.2). East of Therfield the aspect of the scarp changes to face north, possibly due to a slight variation in dip direction from the more general southeast to a more easterly direction across a small anticline (Hopson, 1995).

Two resistant bands within the Chalk Group are responsible for prominent breaks in the scarp slope. A wide bench of Lower Chalk (now the Zig Zag Chalk Formation) runs along the northern foot of the scarp and includes bands of Totternhoe Stone. A resistant band of Melbourn Rock, approximately 2-3 m thick, marks the base of the Middle Chalk (now Holywell Nodular Chalk & New Pit Chalk Formations) which forms the steepest part of the scarp. A further band of resistant Chalk Rock lies at the base of the Upper Chalk (now Lewes Nodular Chalk Formation) (Moorlock *et al.,* 2003). The latter forms much of the backslope shown on BGS 1:50,000 Sheet 221 (Hitchin) although a good deal is drift covered.

2.2.3. Discussion

Ice entering the region from different directions would pass over and erode different bedrock lithologies. As a result, a variety of clasts and finer sediments would be picked up and transported into the study area to be deposited as till. For this reason, knowledge of the bedrock geology is important when considering till lithologies as indicators of ice flow directions. Because the regional strike of the geological formations is aligned in a northeast-southwest direction, ice passing south-westwards along the strike of the Jurassic Clay to the northeast is likely to deposit a clay-rich till, whilst ice approaching from the northwest would cross the Jurassic Clay at right angles to the strike, so ingesting and then depositing a minimum of clay (Figure 2.2).

2.3. Relief

The southern half of the area is dominated by the dramatic Chalk uplands. This range of hills, oriented approximately northeast-southwest, comprises Middle and Upper Chalk, the Lower Chalk forming a bench–like feature along the northern foot of the scarp. A major break in the escarpment occurs at Hitchin, shown in Figure 2.3 and described in Section 2.5. The main road and rail networks utilise this Gap which now carries the A1(M) and main east coast railway line.

Hills to the west of the Gap form part of the Chilterns which, beyond the western boundary of the study area, rise to a height of approximately 267 m O.D. at Wendover Woods (SP890080) and continue as far as Goring in Oxfordshire. This section of the Chilterns contains six major wind-gaps, the northernmost of which, occupied by the headwaters of the River Lea, crosses the escarpment at Luton to the southwest of the study area. A further minor gap at a higher level (138 m O.D.) exists in the upper Mimram Valley, near Lilley. The highest point within the study area at 195 m O.D, lies close to this gap at Warden Hill (TL092261) (Figure 2.3). To the east of the Hitchin Gap the hills form more subdued topography owing to erosion by the over-riding Anglian ice (Wooldridge & Smetham, 1931; Linton, 1963; Embleton & King, 1975; Clayton, 2000). Rising to a maximum of 168 m O.D. at Therfield (TL332371) and referred to in this report as the North Hertfordshire Chalklands, they continue into southeast Cambridgeshire and northwest Essex.

North of these Chalklands lies a low plateau ranging between approximately

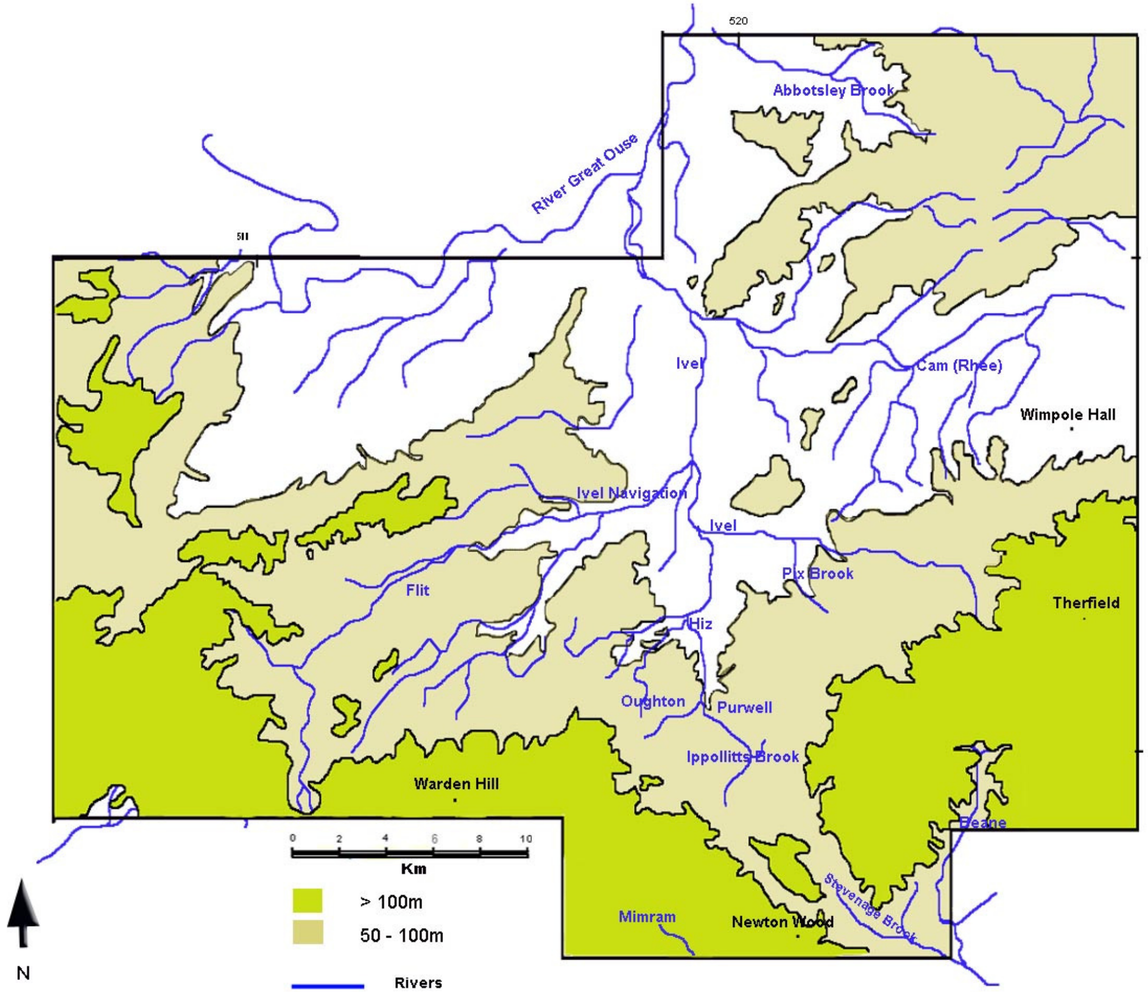

Figure 2.3. Relief & drainage of the study area.

40 and 80 m O.D. This is part of a feature referred to as the "Western Plateau" by Sparks in his study of the Cambridge area (Sparks, 1957). It is largely a feature of the drift cover, the underlying bedrock forming an undulating surface.

The lowest topographic point within the study area lies immediately to the north of the Chalk scarp where the Cam Valley falls away to 20 m O.D in the vicinity of Wimpole Lodge (TL335486). Further south the Chalk backslope gently declines towards the southeast and is deeply dissected by numerous dry valleys. Even more deeply dissected dry valleys on the scarp slope are thought to have been formed by a process of spring sapping (Sparks & Lewis, 1957). Most run parallel to the dip (Coppock, 1968) and some have been shown to be asymmetrical (Ollier & Thomasson, 1957).

The topographic relief of the study area can be an important factor in determining the character of the macrofabrics and textural properties of a till, e.g. deposition of till on a gradient can result in post-depositional flow or slumping. This is therefore taken into account in Chapters 6 and 7. Also the Chalk scarp would have presented a substantial barrier to the passage of ice across the study area. Where the ice was able to surmount higher ground it is possible for compressive flow to occur, with transverse macrofabrics (Allen *et al.,* 1991). In the distal part of the ice sheet, the higher ground may have been responsible for oscillations of the ice margin where relatively minor changes to the surface of the ice sheet could result in a marked retreat or advance (Allen *et al*., 1991). Using the present location of the scarp and inferred rates of glacial erosion, Clayton (2000) determined its likely pre-Anglian position, which is used in Chapter 7 in an attempt to explain certain lithological properties of tills investigated in this study.

2.4. Drainage

Along the southeastern margin of the study area the River Beane rises on the backslopes near Rushden and is joined south of Stevenage by the Stevenage Brook. Then, along with the Mimram in the south, it drains into the Thames via the River Lea. All other rivers within the study area form part of the River Ouse basin (Figure 2.3).

The main catchment divide between these two drainage basins runs along the crest of the Chalk hills until it reaches the Hitchin Gap. Here the two catchments, when defined topographically, become intertwined and the watershed follows a circuitous route around the Hitchin Gap, reaching as far south as Newton Wood (TL228220), southwest of Stevenage (Figure 2.3). Several misfit rivers to the north of the Hitchin Gap are now marked only by drainage ditches (Smith, 1992).

The River Great Ouse and its tributaries dominate the central and northern part of the study area. Tributaries include The Cam (or Rhee) whose headwaters drain the Chalk hills near Ashwell before flowing eastwards across the Gault Clay vale and continuing to its confluence with the Ouse south of Ely. The River Ivel, which rises near Baldock after travelling northeast to Henlow, joins the River Great Ouse at Tempsford, 10 km east of Bedford. The misfit River Hiz rises at Wellhead near Hitchin and is joined by the Purwell and Oughton before flowing through the Hitchin Gap and on to Arlesey, meeting the River Ivel close to Henlow. The area immediately south of Hitchin is drained by the Ippollitts Brook and the Ash Brook. The Greensand Ridge to the west of the Ivel is drained by the River Flit, part of which forms the River Ivel Navigation Channel. The source of this river lies in the Lower Chalk to the south.

On the western margin of the study area, the north flowing River Ouzel rises near Dunstable Downs and occupies a valley that has been overdeepened by ice (Shephard-Thorn *et al.,*1994). The confluence of the Rivers Ouzel and Great Ouse lies near Newport Pagnell, outside the study area.

Many of the present day rivers have been shown to follow the courses of channels either eroded or deepened during glaciation, e.g. the Ivel/Ouse and the Stevenage Brook. However, others, either created or modified during glaciation have been completely infilled with glacial deposits and have no modern equivalent, e.g. the Hatley Channel. In general, glaciation of the region is known to have substantially modified the drainage pattern (Rose *et al*., 2001) so that in many cases the course of glacial outlet streams/channels cannot be known with certainty.

2.5. Hitchin Gap & channels

The breach in the Chiltern Hills at Hitchin that divides the Chalk escarpment has been referred to variously as the **Hitchin-Stevenage Gap** (Hill, 1910; Bloom, 1930; Woodland,1970; Gibbard,1977; Catt,1978; Little & Atkinson,1988; Aldiss, 1992a;. Hopson *et al.,*1996), the **Stevenage Gap** (Sherlock,1924; Wooldridge, 1938; Clayton & Brown,1958), the **Hitchin Gap** (Bloom & Wooldridge,1929; Wooldridge & Smetham, 1931; Brown, 1959; Hopson *et al*.,1996) and the **Hitchin Valley** (Little & Atkinson, 1988). For the sake of simplicity it is referred to in this thesis as the **Hitchin Gap**.

At its northern limit the Gap itself, lying at approximately 60 m O.D., is roughly 9 km wide and separates the Chiltern Hills proper from the North Hertfordshire Chalklands. The Gap was described by Hill (1912) as a complex feature within which lie the heads of two valleys, one draining into the Ouse basin to the north (Hitchin Valley) and one into the Thames basin to the south (Stevenage Valley) (Figure 2.4). Although described by Clayton & Brown (1958) as the Stevenage and Hitchin 'wind-gaps', the exact form of this double feature prior to glaciation remains unclear. The watershed passes through north Stevenage at Symonds Green (TL222256) and then turns south to Newton Wood (TL228220). The course of the Stevenage Valley, therefore, runs southeast to south Stevenage where it is represented by the Stevenage Brook, to join up with the present course of the south-flowing River Beane north of Watton-at-Stone to eventually join the River Lea at Hertford. The Hitchin Valley carries the misfit river Hiz and its tributaries from south of Hitchin northwards to join the River Ivel. The two southeasterly trending valleys overlap, running parallel courses for a distance of approximately 1.5 km either side of a Chalk ridge rising to 120 m O.D.

At the base of each of these valleys lies a drift filled channel, referred to as the Hitchin and Stevenage Channels respectively. Borehole data show the channel within the Stevenage Valley continues beyond the current watershed towards Letchworth, possibly following the route of an ancient valley. However, the deeper and narrower Hitchin Channel is considered to have been formed mainly by glacial processes (Hopson *et al.,*1996). Both are now filled with a complex mix of tills, sands, gravels and lacustrine deposits. A more detailed description

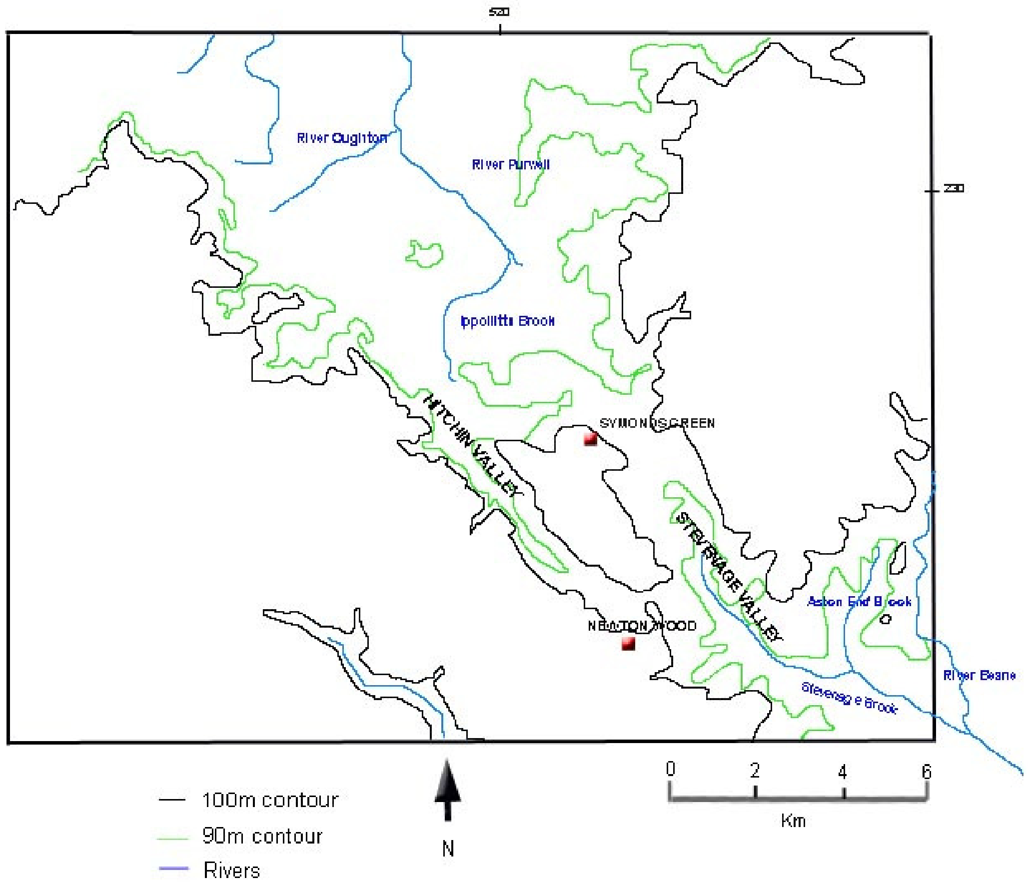

Figure 2.4. Detail of the Hitchin Gap.

of these and other known buried channels within the area is found in Section 3.8.

2.6. Structure

Geophysical evidence suggests the area is located on the London Platform (part of the London-Brabant Massif) of Palaeozoic age (Pharaoh *et al.,*1996) and lies on the northern edge of the Variscan fold belt. In the west it has been shown that the Mesozoic strata unconformably overlie Lower Palaeozoic basement rocks of Ordovician to Devonian age (Shephard-Thorn *et al.,* 1994). To the southeast a Variscan structure known as the Ware anticline (or Ware 'high') trends ESE-WNW (Hopson *et al.,* 1996).

The Chalk hills form part of the northern limb of the London Basin syncline. The regional dip across the area is very slight, trending to the southeast; in the Hitchin region Aldiss (1992a) reports a regional dip of between 0.4^{o} and 1^{o}. This gentle dip of the strata gives the Chalk dipslope a plateau-like character.

Aeromagnetic and residual gravity data have identified a major north-south trending lineament stretching across the area of BGS 1:50,000 Sheet 220 to the west of Leighton Buzzard. A further, roughly parallel, lineament is recognised from gravity data on Sheet 221. These are likely to represent major faults in the sub-Mesozoic basement (Shephard-Thorn *et al.,* 1994).

A southwest-northeast trending structure referred to as the Charlton Axis is also evident from geophysical data and is thought to have influenced the thickness of Mesozoic strata. This structure appears to extend from the vicinity of Oxford as far as Cambridge (Shephard-Thorn *et al*., 1994; Horton, 1995).

A further structure, trending approximately northwest-southeast, is apparent at Lilley Bottom coinciding with the buried valley here. According to Shephard - Thorn *et al.* (1994) the exact nature of this structure is unknown, but it is recognised as having influenced sedimentation during Cretaceous times.

Faulting within Quaternary sediments occurs within the Hitchin Gap. These displacements may be due to settlement within glacial sediments or stress relief at the margins of glacial channels.   However, they may also be explained by subsidence following solution of the underlying Chalk (Hopson *et al.,* 1996).

2.7. Superficial deposits

The following is a brief description of the distribution of superficial deposits within the study area, shown in Figure 2.5, some of which are described in more detail in subsequent sections. Although the age of some of these deposits remains open to question, Table 2.2 gives suggested ages of superficial deposits within the study area.

Large parts of the study area are without drift cover, suggesting lesser deposition (Allen *et al.,* 1991) or considerable downcutting and wastage following glaciation.

2.7.1. Clay-with-Flints

The part of the Chiltern Hills under investigation here is noted by Catt (1983) to represent the approximate northern limit of the rather variable deposit known as Clay-with-Flints. Typically comprising reddish/brown clays, most of which contain abundant flints and gravel, often locally sandy or silty, although Aldiss (1992a) reports some deposits in the Hitchin area, categorised as 'Clay-with-Flints' to be relatively stoneless clays.

Large areas of Clay-with-Flints are found on the higher parts of the Chalk backslopes to the west of the Hitchin Gap. To the east smaller patches exist, particularly close to the scarp edge and around the edges of the till plateaux. Near Weston the inclusion into this deposit of calcrete blocks, up to 40 cm long were noted by Aldiss (1991).

Hey & Perrin (1960) considered the Clay-with-Flints to represent the remnants of weathered Tertiary deposits together with flints derived from the underlying chalk. This view was confirmed by Catt (1983). Although generally less than 10 m thick, in many places Clay-with-Flints has been seen to infill solution pipes within the chalk, where it may reach a thickness up to 15 m (Hopson *et al.,* 1996).

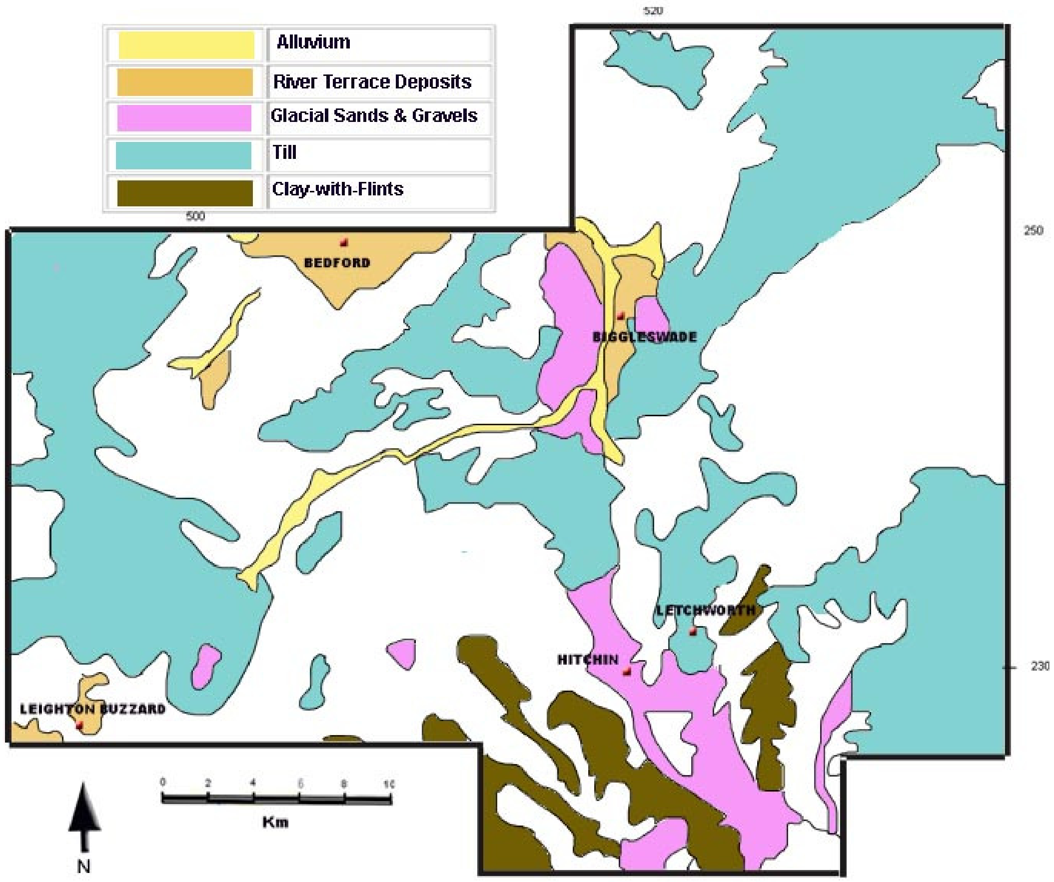

Figure 2.5. Simplified drift deposits of the study area.
Based on BGS 1:625 000 Quaternary map of the United Kingdom [South], 1st edition (1977).

AGE	TYPE OF DEPOSIT
Flandrian to Holocene	Alluvium
Devensian to Holocene	Dry valley deposits
Devensian	River terrace deposits
	Solifluction deposits on Chilterns
	Head
	Alluvial fan deposits
	Coombe deposits
Ipswichian	Brickearths Lacustrine deposits
'Wolstonian'*	River Terrace deposits (Ouse & Ivel)
	Coombe Deposits
	?Tills /Glaciofluvial deposits
Hoxnian and later	Head
Hoxnian and later	Brickearths
Hoxnian	Lacustrine deposits
Anglian	Till
	Glaciolacustrine clays, sands and silts.
	Glaciofluvial clays, sands and gravels
	Channel deposits of Hitchin Gap
Pre-Anglian/Early Anglian	Letchworth Gravels
Pre-Anglian and later	Clay with Flints

*Wolstonian –*sensu* Mitchell, *et al.* (1973)

Table 2.2. Age of drift deposits within the study area.

A close relationship exists between Clay-with-Flints and the till, the two frequently becoming intermixed. It is probable that some of the areas marked on the BGS 1:50,000 Sheet 221 (Hitchin) as inliers of Clay-with-Flints are actually rafts of material held within the till (Aldiss, 1991)

2.7.2. Till

This deposit is generally noted at depth to be a stiff blue/grey clay (typically 2.5YR 4/0 to 10YR 4/1) with clasts of mainly chalk and flint. However, at the surface it frequently appears to have suffered extensive weathering having undergone decalcification and become ochreous yellow (10YR 5/6) in colour. In many areas, especially overlying and south of the Lower Greensand, a sandier matrix exists. In the Biggleswade district Moorlock *et al.* (2003) made the general observation that larger clasts are more frequent at the base.

The till can be roughly divided into that within channel sequences and that forming dissected sheets on high ground between river valleys and across the backslope of the North Hertfordshire Chalklands. That the Anglian ice did not overtop the Chiltern Hills themselves is evidenced by the lack of till on the cuesta to the west of Hitchin.

For the most part this deposit is fairly homogeneous and associated with minor glaciofluvial sands and gravels. Exceptions occur within and above channel sequences where tills are more heterogeneous and glaciofluvial sands and gravels frequently dominate. Descriptions of these tills, which can locally reach depths of more than 30 m, are provided by Aldiss (1992a), Hopson *et al.* (1996) and Etienne (2001).

Away from the channels, the till is of variable thickness generally becoming thinner at the plateau margins. There is extensive till cover on Chalk backslopes in the eastern part of the study area, rising to a maximum height of 168 m O.D. at Therfield. Close to the margin here, till is rarely more than 5 m thick and is frequently intermixed with the underlying Clay-with-Flints.

A large till-covered plateau exists in the northeast of the study area, extending from Royston to Cambourne in the north and almost to Biggleswade in the southwest. This topographic feature appears to be largely a constructional feature of till deposition, the underlying irregular bedrock surface varying between approximately 12 m and 60 m O.D. Although forming part of the "Western Plateau" described by Sparks (1957) in his description of the Cambridge area, for the purposes of this study it will be referred to as the 'Northeastern Plateau'. Sparks noted extremely thick drift sequences here, overlying mainly Woburn Sands, Gault and Lower Chalk in the southeast, providing "monotonous relief". Till cover extends from 80 m O.D. down to below 40 m O.D. in the Ivel Valley and in some areas reaches a thickness in excess of 50 m, although the latter may occur in a buried channel (Section 3.8.5).

To the west of the River Ivel, beyond a large area denoted on the BGS 1:50,000 Sheet 204 as being of glaciofluvial origin (but see Section 2.7.8), a smaller spread of till exists rising to approximately 80 m O.D. Till here reaches a thickness of 12 m at Palaceyard Wood (TL135543) (Edmonds & Dinham, 1965).

Further west, the till mainly lies above 100 m O.D. An extensive northwest/ southeast trending belt caps high ground extending from east of Little Brickhill (SP905325) to the margin of the Lower Chalk outcrop southwest of Toddington (TL005285), reaching a maximum height of 161 m O.D. at Milton Bryan (SP975305). Smaller sporadic outcrops exist on the Woburn Sands and Gault north and northeast of Luton.

Beyond the western margin of the study area till cover descends into the western side of the Ouzel Valley.

2.7.3. Glaciofluvial deposits

These are represented by a variety of sediments from clay, silt, fine to coarse sand and fine to coarse gravel, cobbles and boulders. The provenance of clasts within these deposits often closely reflect their intimate association with the tills.

Like the tills, glaciofluvial sands and gravels can be divided into those associated with channel sequences and those found elsewhere.

i) Buried channel sequences

Glaciofluvial deposits within the Hitchin and Stevenage buried channels form complex sequences, together with glaciolacustrine sediments and till. Within these channels they are present in boreholes as units often in excess of 9 m thick. Aldiss (1992a) describes them as usually well bedded with frequent cross-bedding. Rapid compositional variation can exist, both vertically and laterally. These infill sequences are discussed in detail in Section 3.8.4.

A large outcrop of glaciofluvial deposits is shown on the BGS 1:50,000 Sheet 220 (Leighton Buzzard) running through the centre of Luton within a buried valley in the upper reaches of the River Lea, proven to be in excess of 5 m thick (Hopson *et al.,* 1996). Smaller linear outcrops occur above the buried channel in the Mimram Valley.

Some bodies of glaciofluvial sands and gravels within the Stevenage and Hitchin Channels are considered by Hopson *et al.* (1996) to be the equivalent of the Westmill Lower Gravel (Westmill Member) and Westmill Upper Gravel (Hertford Member) of the Vale of St Albans (see Section 3.8.4 and Table 3.5).

ii) Outside the buried channels

Outside the buried channel sequences, glaciofluvial sands and gravels are exposed in the valleys of the Ivel and the Flit. They are mainly found in thin irregular sheets or bodies below the till.

Sands and gravels also occur on the interfluves between the channels, which in general are similar to those mentioned above. However, gravels around St. Ippollitts appear to be particularly poor in erratic material. These flint rich gravels are noted by Aldiss (1992b) who believed they were “carried by meltwaters from the Chalk scarp rather than from the ice” at the end of the Anglian or during a later cold period. An extensive spread of gravels south of Sandy, following a course to the west of the River Ivel down to Clifton, is denoted on the BGS 1:50,000 Sheet 204 (Biggleswade) as a glaciofluvial deposit, though Edmonds & Dinham (1965) and Moorlock *et al.* (2003) consider that these may represent river terrace deposits (Section 2.7.8).

2.7.4. Letchworth Gravels

The Letchworth gravels will be dealt with in Section 3.5, and are shown separately on BGS 1:50,000 Sheet 221. These may represent early fluvial gravels or, possibly, glaciofluvial deposits.

2.7.5. Glaciolacustrine deposits

Glaciolacustrine deposits are numerous within the confines of the buried channel sequences and may occasionally be exposed at the surface where differentiation from fluvial deposits is difficult. Aldiss (1992a) suggests that the occurrence of minor glaciolacustrine deposits is more widespread than indicated on BGS 1:50,000 Sheet 221 (Hitchin). These are typically grey/brown laminated clays and silts, often containing fine chalk. Further description of these are found in Section 3.6.3.

Sporadic occurrences are found outside the channels on Sheet 221 (Hitchin), in particular two large outcrops in the Offley area.

These deposits are not shown on the BGS 1:50,000 Sheet 204 (Biggleswade) and it is unclear whether any outcrops are present in that area. However, Horton (1970) reported extensive lacustrine deposits in, and adjacent to, the Ivel Valley. The origin of these deposits is yet to be ascertained.

2.7.6. Hoxnian deposits

These lie above the till within the Hitchin Gap, where they are almost entirely obscured by head and brickearth deposits (Aldiss, 1992b). These comprise mainly organic lacustrine deposits and are discussed in more detail in Section 3.9.

2.7.7. Brickearth

These deposits are present in the Hitchin region. In particular brickearth workings exist at Ransom's Pit (TL189283), Jeeves Pit (TL191281), Folly Path (TL189285) and Maydencroft Manor (TL185277). At these sites they are associated with flint implements and fossiliferous remains and frequently rest on Hoxnian interglacial deposits.

Brickearths comprise yellow/brown clayey or sandy silts and reach a maximum thickness in the Hitchin area of 11.6 m at Ransom's Pit. According to Avery *et al.* (1982), these silts accumulated in topographic depressions (dolines) prior to and during the Devensian.

These deposits are not differentiated on the BGS 1:50,000 geological sheets 220 (Leighton Buzzard) or 204 (Biggleswade) and, therefore, the extent of brickearth present within these areas is uncertain. However, at Caddington archaeological remains lie within brickearth infilling dolines in the Chalk (White, 1997).

2.7.8. River terrace deposits

Gravels of the first, second and third terraces of the Rivers Great Ouse and Ivel are extensive, lying between approximately 20 m and 35 m O.D. In the Ivel Valley up to 5 m of thick fluvial sands and gravels are present. It is possible that gravels in all or part of an area mapped as glacial gravel lying to the west of the Ivel between Caldecote and Clifton are fluvial. According to Edmonds & Dinham (1965), these may correlate with gravels of the third terrace overlying Oxford Clay at Blunham (TL145510). Further gravels correlated with the third terrace of the Ouse are found in the southeast of the study area associated with the Bourne Brook and the River Cam (Rhee).

Minor outcrops of terrace gravels of the River Flit lie approximately 5 m above the adjacent floodplain (Shephard-Thorn *et al.,* 1994).

2.7.9. More recent deposits

Head deposits usually comprising silty or sandy gravelly clays are derived by mass movement. However, they are often difficult to distinguish from similar deposits of other origin, unless fabric analyses are employed. Hence areas of dry valley sediments, brickearth, alluvium and the products of soil creep or hill-wash may sometimes be included in this description.

According to Aldiss (1992b), these deposits are particularly extensive in northern Stevenage on the Ouse /Thames watershed. In the west of the study area head is extensive in the Hockcliffe and Toddington areas. Here soft fine flinty sand and clays intermix with re-distributed Gault (Wyatt *et al.,*1988).

Dry valley deposits are frequently found on the floor of valleys within the area of the North Hertfordshire Chalklands and Chilterns. They are mainly composed of silts or clays together with sand or chalk flinty gravel and are probably solifluction deposits. Aldiss (1992a) notes that these can be as much as 3 m thick in the Hitchin region.

Immediately to the east of Baldock, remnants of **alluvial fan** deposits are seen, thought to be remnants of a much larger spread. These are described by Hopson *et al.,* (1996), as orange/pale brown silty medium to fine sands, occasionally gravelly and considered to be the result of transport by flowing water in tributary valleys under periglacial conditions (Aldiss, 1991; 1992b).

Alluvium of variable composition is shown on the geological sheets along most of the present river courses. In the Hitchin area, depths of up to 7 m are noted by Hopson *et al.* (1996), whereas in the Biggleswade area depths are generally less than 3 m (Moorlock *et al.,* 2003).

Floodplain deposits of the River Flit are largely composed of organic rich sediments shown on BGS 1:50000 sheet alongside large spreads of alluvium, the junction between the two being arbitrary (Wyatt *et al.,*1988).