CHAPTER 9
PALAEOGEOGRAPHIC RECONSTRUCTION

9.1. Introduction

This chapter discusses models of glaciation proposed by previous workers in the context of results from the current study, before attempting a reconstruction of the glacial history. Suggested correlations with tills from neighbouring areas are summarised in Table 9.1.

9.2 Prior to Glaciation

There is little doubt that glacial activity during the Anglian was responsible for major erosion of the Chalk escarpment, as suggested by Clayton (2000). The greatest amount of scarp erosion occurred in the extreme east of the study area, gradually diminishing to the southwest - Hitchin marking the position of minimum scarp retreat. The position of the crest of the escarpment was displaced by between 10 and 26 km to the southeast, the base of the chalk being set back by between 5 and 8 km. The height of the scarp was reduced by up to 10 m (Clayton, 2000).

The presence of the pre-Anglian Clay-with-Flints and the lack of glacial deposits suggests that the ice did not overtop the Chilterns to the southwest of Hitchin, although it is likely that minor erosion of the scarp face occurred. Some authors attribute the formation of a bench feature of Chalk Marl along the northwest face of the scarp to glacial erosion (Wooldridge & Smetham, 1931).

The course of the Channel at Hitchin may represent the position of a preglacial chalk stream. Subsequently, a weakness in the scarp at this point was exploited by the ice and a subglacial stream passed through the escarpment causing deep erosion of the Hitchin Channel. The Stevenage Valley probably represented a left bank tributary of the proto-Thames (Hill, 1912; Hopson *et al.,* 1996). It is unknown whether this valley extended to, or breached, the pre-glacial scarp, and thus it is unclear whether ice approaching the Chilterns would have first moved down the Stevenage Valley as proposed by Hopson *et al.* (1996) or the Hitchin Valley. However, only the Hitchin Channel has been deepened by subglacial erosion (Hopson *et al.,*1996).

Hitchin Channel	Stevenage Channel	Deposition phase	Vale of St Albans After Cheshire (1986)
Vicarsgrove Till / Vicarsgrove Member	Graveley Member	Local waterlain and flow tills laid down during final retreat	
Maydencroft Member		Final main re-advance of ice responsible for widespread coverage of region	? Wadesmill/Stortford Member
Charlton Member and associated glaciolacustrine deposits (Thistley Farm member)		Wasting of dead ice within the channel sequences following second ice advance. This phase probably coincides with the episode of decay of Ware Member till during the advance of the Stortford Member ice of Cheshire (1986) into the easternmost part of the Vale of St Albans	Ware Member
Glaciofluvial Outwash (includes Gosmore Member)			
Lower till (includes part of Priory Member of Aldiss (1992a)	Lower till (Stevenage Member of Aldiss 1992b)	First ice advance	
Glaciofluvial outwash & subglacial deposits	Glaciofluvial Outwash		Westmill Member

Table 9.1. Summary of deposits within the Hitchin Gap and a suggested relationship with those of the Vale of St Albans of Cheshire (1986).

A series of drift-filled depressions beneath the Rivers Ivel and Ouse to the north can be traced as far north as Huntingdon and may follow the course of a pre-Anglian river (Horton,1970; Langford, 1999). Langford (1999) also suggested that the Edworth and Hatley Channels (section 3.8.5) may have formed part of this drainage system leading eventually to the Wash. The depressions were considered by Horton (1970) to represent the course of the buried channel and it is suggested by Hopson *et al.* (1996) that these form a continuation of the Hitchin Channel.

9.3. Glacial History

The lower tills within the Hitchin Channel, and possibly the Stevenage Channel, were laid down during an early advance. Those within the Hitchin Channel (including the Langley Till) are investigated in this report. Hopson (1992) reported a lower till within the Stevenage Channel (Stevenage Till) although no samples were made available during the course of this study. These tills may represent an ice lobe that extended south of the main ice sheet advancing from north-northeast, and do not extend beyond the southern end of the Hitchin Channel. A retreat (of unknown duration) is then indicated by substantial quantities of overlying glaciofluvial sands and gravels. Tills found above these glaciofluvial deposits in the channel sequences are correlated with the earliest till in the Vale of St Albans (Ware Till).

The current study has shown that it is possible to divide tills found north of Hitchin into those lying to the west of Milton Bryan and those found elsewhere. Division is based on variations in the acid-soluble contents and the flint/quartz ratios. This difference is considered to be due to variations in the amounts of chalk contained within the tills. To explain these findings, together with the macrofabrics found in the west of the study area (Site 30) - two equally probable scenarios are suggested, as discussed below.

a) Ice advance from a north to northeasterly direction.

There is overwhelming evidence within the study area of at least one advance of ice from a direction between the north and northeast. With the exception of tills in the western part of the study area, north of the Chalk scarp they are chalk-rich, suggesting that they have moved across extensive tracts of Chalk bedrock to the north or northeast. The chalk rafts found at Therfield are believed to have been formed by ice approaching the area from the north (Hopson, 1995), as is the ice push structure at Holwell described by Hopson (1992). Clayton (1979) claims "a large erratic mass of Kimmeridge and Ampthill clay southeast of Biggleswade can only have been transported from the north or the northeast". Further evidence of an advance from this direction is the presence of non-durable Red Chalk, derived from the Wash, Lincolnshire or east Yorkshire, in tills throughout the study area.

The model proposed by Perrin *et al*. (1979) was of a single advance of Scottish ice moving down the western margin of the North Sea basin to a position north of the Wash. From here it spread out in a radial pattern across central East Anglia. This forms the "traditional" view described by Gibbard (in Clark *et al.,* 2004). An alternative model suggested by Fish (2000) and Fish & Whiteman (2001) who, like Baden-Powell (1948) and West & Donner (1956), recognised both an upper paler (chalkier) and a lower darker till (Section 3.17.3), also invoked a single ice advance. They believed the lower till was laid down by ice that flowed south through Yorkshire and Lincolnshire before fanning out over East Anglia and the upper till followed a similar pattern but with the locus of ice flow shifted eastwards (Chapter 3 - Figure 3.10). During the later phase of this glaciation, flow was increasingly over the Chalk of the eastern part of England and the North Sea Basin. This would result in early ice moving into the study area from the north followed by later ice from the north to northeast. The variation in lithological content of tills north of the Hitchin Gap may be due to these different trajectories shown in Figure 9.1. Ice entering the west of the study area following the trajectory of the earliest advance in Figure 9.1 would move over a smaller outcrop of Chalk at a greater distance from the study area, depositing a till with a low chalk and flint content, such as is seen at Sites 27 – 30. In this case the tills in these sites may be representative of the lower till suggested by Fish (2000). Ice entering the east of the study area would pass over the greatest distance of Chalk bedrock, depositing chalk-rich tills.

Only two macrofabrics were obtained from the central and eastern areas north of the escarpment, at Sites 16 (Moggerhanger) and 22 (Cockayne Hatley).

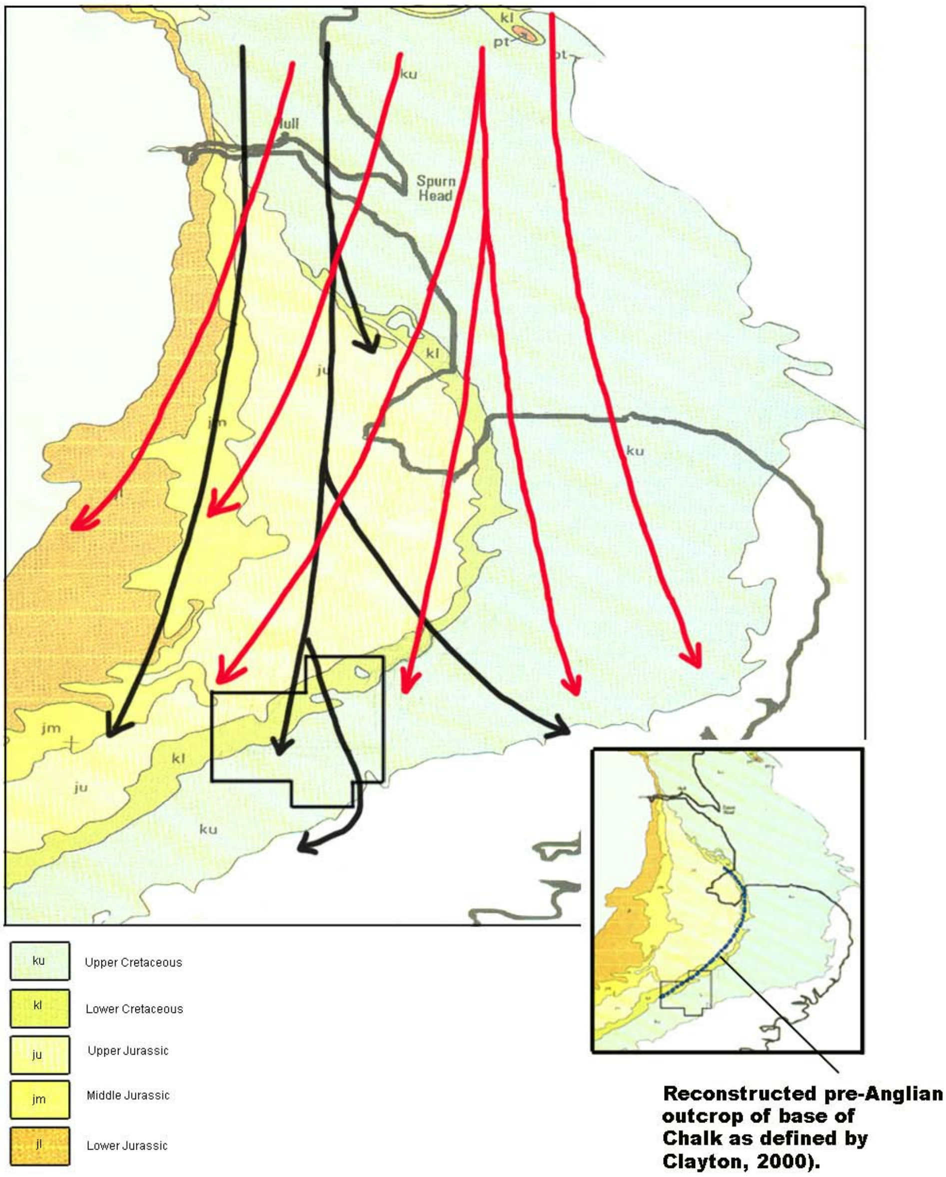


Figure 9.1.
Relationship of the ice flow trajectories suggested by Fish & Whiteman (2001) to the sub-Pleistocene geology
Black arrows: early part of glaciation   Red arrows: later part of glaciation

(Inset : Reconstructed pre-Anglian outcrop of base of Chalk as defined by Clayton, 2000).

(modified from Cameron *et al.,* 1992).

Only the fabric at Moggerhanger recorded a NNE/SSW clast alignment. However, despite showing the highest vector magnitude in this study (70%), this till was deposited on sloping ground and is interpreted as a slumped or flow till (Section 6.6.2). This is likely to have modified the original till fabric.

Very few macrofabric analyses have been carried out in the area lying west of Milton Bryan, although measurements made at Bedford (TL044519) of 040/220° and Meppershall (TL157374) of 050/230° by West & Donner (1956) can perhaps best be explained by ice moving from the northeast. At Site 30 (Heath and Reach) fabrics may record the path of this ice sheet as it was deflected by the Chalk scarp along a ENE – WSW to east-west direction into the Vale of Aylesbury.

In this model lithologies from the northwest would be of secondary derivation transported by rivers (such as the Bytham) into the path of the ice sheet from the north – northeast.

b) Ice advance from a direction between northwest and NNE.

An alternative hypothesis is that ice also entered the study area from a more westerly direction. The trajectory of this ice would follow that of the initial advance of Baden-Powell (1948) and West & Donner (1956) (shown in Figures 3.7 and 3.8 respectively). The suggested coverage of this ice in the study area is shown in Figure 9.3. The above authors considered this ice reached the east coast and extended south to Hertford, depositing the Lowestoft Till and, according to West & Donner (1956), the Lower Boulder Clay of Hollingworth & Taylor (1946) near Northampton. The eastern limit of the Thrussington Till, deposited as part of the Wolstonian Glaciation of Shotton (1953), is unknown (Rice & Douglas, 1991). However, it is possibly the equivalent of the Lower Boulder Clay of Hollingworth & Taylor (1946) and has been recognised at Witham on the Hill by Fish (2000). This till is composed of mainly Triassic material, although Rice (1981) described it as a chalky grey till at Dunton Bassett immediately south of Leicester. Perrin *et al.* (1979) dismissed the idea of northwesterly ice entering East Anglia, suggesting instead that the tills of Leicestershire, Lincolnshire and East Anglia were all deposited by a single ice sheet advancing through the Wash.

Rose (1992, 1994 and in Clark *et al.,* 2004) proposed a revision to the "traditional model" of ice advance described in a) above. This involved a revision of the idea that Pennine ice, responsible for deposition of both the Thrussington Till and the Lower Till at Northampton, formed an early part of the Lowestoft Glaciation. Rose (in Clark *et al.,* 2004) reported a Lower Till in Buckinghamshire, correlated with that of Hollingworth & Taylor (1946). He considered an advance from the northwest to precede that from the northeast, the two being attributed to different marine isotope stages (see below). The later advance was shown to extend west to the south Midlands. However, Rose (in Clark *et al.,* 2004) considered the lithologies of the tills deposited in both of these advances to be indistinguishable, making the identification of an eastern limit difficult. Nevertheless, Rose (1992, 1994, 2007) suggested that the earlier advance extended across the whole of East Anglia to the east coast, though in Clark *et al.* (2004) he suggested a more limited extent, possibly halting at the Chalk scarp along a line running between Luton and north Norfolk.

It is possible that evidence of this advance is found in the west of the study area. This study has shown that the western tills possess different lithological characteristics to those in the east, with lower flint/quartz ratios and less acid-soluble material. Erratics, including Triassic sandstone and crystalline rocks from Charnwood, may have been brought into the western part of the study area by ice from the northwest - NNW. Fabrics obtained from Site 30 (Heath and Reach) indicate a clast alignment in an ENE-WSW direction. These could represent a transverse fabric resulting from either the ice sheet moving across the Oxford Clay/Lower Greensand boundary, or the ice front to the south encountering the Chalk scarp. If ice of a more northwestern provenance did enter the study area, evidence of it is not apparent east of Milton Bryan. The subsequent (main) ice advance through the Wash could have assimilated the earlier tills and re-deposited them as a homogeneous mixture of material from both the northeast-NNE and northwest-NNW. The tills deposited across the northeastern part of the study area are chalk-rich, deposited by ice that passed over the easily eroded Chalk bedrock. However, incorporation of the chalk-free tills from northwest - NNW of the study area would reduce the chalk content of the material finally deposited in the west of the study area.

As a result of field mapping and research undertaken since the publication of Perrin *et al.* (1979), Rose (2007) published map (reproduced in part in Figure 9.2 in relation to the current study area) showing areas where the various tills have been identified. Triassic, Pennine and Jurassic tills from the northwest are seen to reach a limit just east of Site 30 at Heath and Reach, rather than to continue across the whole of East Anglia. This situation is supported in part by the findings of the current study, in that greater amounts of Jurassic material and less chalk is seen in the Heath and Reach area, together with a greater amount of Triassic material.

Further stratigraphic evidence is required before any resolution of these two scenarios can be attempted.

9.4. Timing of advances

As mentioned in Section 9.3 (a) an early ice advance into the Hitchin Gap may have taken the form of a lobe extending south of the main ice sheet advancing from the north-northeast. The overlying glaciofluvial deposits mark a retreat before a further advance from a similar direction. In the event of a northwesterly ice sheet entering the west of the study area as proposed in Section 9.3 (b), it is uncertain whether this would have occurred during, before or after the initial glaciation of the Hitchin Gap.

Previous researchers claim that any advance into the region from the northwest preceded that from the northeast. Early work (Baden-Powell, 1948; West & Donner,1956) considered the Lowestoft Glaciation to be followed by the Hoxnian interglacial, followed in turn by the advance of the Gipping ice sheet, leading to correlation of the Lowestoft Glaciation with the Elsterian (MIS 12) and the Gipping Glaciation with the Saale (MIS 10). However, to date no evidence of interglacial deposits has been discovered between these tills (Fish, 2000).

The Thrussington Till, seen to the west of the study area, formed an early part of The 'Wolstonian' Glaciation of Shotton (1983a). This was correlated with the Gipping, although Perrin *et al*. (1979) equated the chalky till (Oadby Till) at the top of this sequence with the main till sheet in East Anglia, believed to originate in MIS12. Recent studies by Rose (in Clark *et al*. 2004) and Rose (2007)

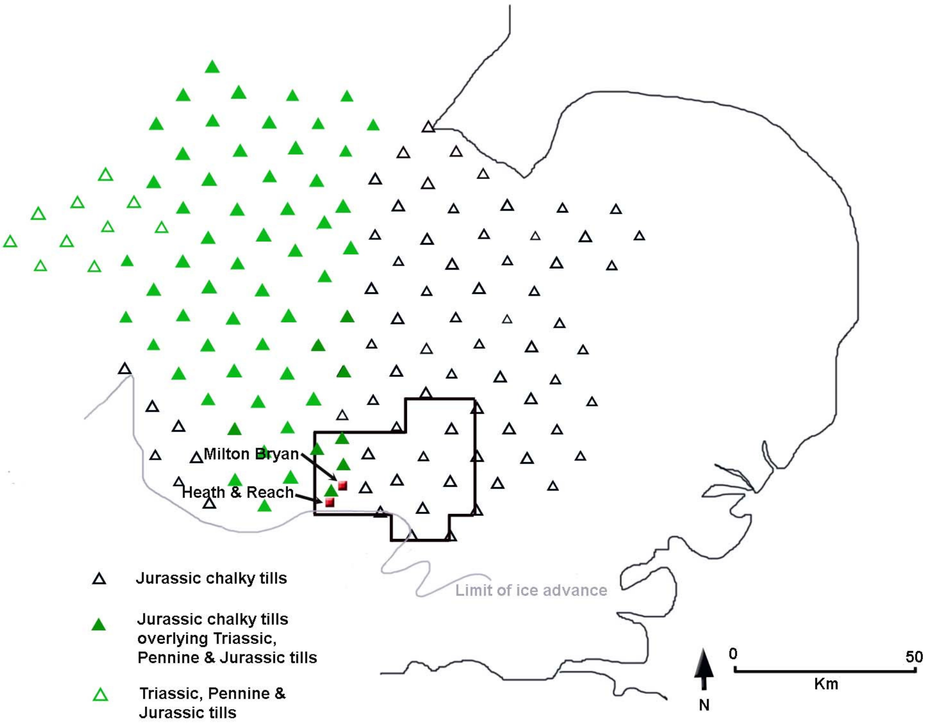


Figure 9.2. Results of field mapping and research reported by Rose (2007)

consider the Lowestoft Till to have been deposited over two marine isotope stages – MIS 12 and 10, the Thrussington Till forming a major part of the MIS 12 advance. He believed that the advance from the northeast occurred during Stage 10, although this is controversial (Gibbard, in Clark *et al.* 2004).

Thus, if two separate ice advances are responsible for tills found within the study area as proposed in Section 9.3 (b), that from the northwest-NNW could have preceded that from the northeast. Stresses operating within an ice sheet advancing over previously deposited till would modify or destroy the pre-existing fabric. So if ice from the northeast over-ran till laid down by the earlier northwestern ice, it may have created the northeast-southwest to east-west macrofabrics noted by West & Donner (1956) (Section 9.3 a) and found at Site 30 (Heath & Reach) of the current study. This suggests that the two advances were separated by a non-glacial interval, but one of unknown duration.
It is of course, entirely possible that ice sheets from both these directions were active at the same time –further stratigraphic evidence is required to resolve this issue.

If a single advance was responsible for tills found both in the east and west of the study area (Section 9.3a), the pattern of advance would be that suggested by Fish and Whiteman (2001). The earliest ice reaching the west of the study area, following the trajectories shown by the black arrows in Figure 9.1, would deposit a till with low chalk content. This would then be overrun by ice moving along the trajectory shown in red.

The later tills of northeastern provenance present within the Hitchin Gap show associations with Cheshire's Ware Member; the earliest till of the Vale of St Albans. This till-type is also found on the interfluves in the Hitchin Gap and it is likely that it was during this advance that ice blanketed the study area (with the exception of the Chiltern Hills southwest of Hitchin) and advanced into the Hitchin Gap. It is not known whether the ice passed through the Gap to reach the Vale of St Albans from the north, or whether, as Cheshire (1986) suggests, the ice curved around the North Hertfordshire Chalklands to enter the Vale from the northeast. Lack of similarity between higher tills at the southern end of the

Hitchin Channel and those found in the Lower Beane Valley (Section 7.4) suggest the latter to be the case.

9.5. Discussion

Very little is known about the first advance into the Hitchin Gap, except that considerable subglacial erosion occurred within the Hitchin channel. If it took the form of a lobe of ice this erosion would suggest that the main ice sheet lay a short distance to the north, meltwaters being funnelled into the Gap.

No evidence was found in this study of the two layers of till suggested by Baden-Powell (1948), West and Donner (1956) and Fish & Whiteman (2001), although north of Hitchin with a few exceptions, samples were obtained from tills at most 2 to 3 m thick where vertical compositional variations due to provenance changes would have been difficult to detect.

The evidence for an advance from the northwest-NNW into the study area as described in Section 9.3 (b) is inconclusive. The presence of durable northwestern erratics can be explained by river transport eastwards into the path of a subsequent ice advance. Most, if not all, of the Triassic quartzites seen in tills within the study area are well-rounded pebbles. In addition, the lithological differences found in tills in the western part of the study area can also be accounted for by ice from the north or northeast following different trajectories as suggested by Fish and Whiteman (2001).

Ice from a northwesterly direction may have advanced as far as the Chalk escarpment but this study found no evidence of the advance east of Milton Bryan (Site 27). However, the Letchworth Gravels are dominated by coloured quartzite and quartz lithologies from the Midlands, northwest of their current position (Smith & Rose, 1997). It is possible that these gravels, now shown to be of glaciofluvial origin (Cheshire pers. comm.) and lying beneath what are considered to be Anglian age tills, were laid down by meltwaters from ice approaching from the northwest.

9.6. Reconstruction of glacial events

The following reconstructions are proposed based on the alternative scenarios given in Section 9.3. As described above, an interval of unknown duration is likely to have occurred between any possible advances of the northwesterly ice and those from the northeast, although the possibility of simultaneous encroachment of ice from both directions cannot be dismissed. Figures 9.3 to 9.5 show coverage of the study area during the advances discussed below.

1. Model proposing a single ice advance from the north to northeast.

Movement of ice into the study area from the north-northeast (Figure 9.4) may have resulted initially in an ice lobe extending south of the main ice mass down the Ivel valley as suggested by Horton (1970). No evidence has been found to support this, except that the only examples of lower tills attributable to this early advance from the north-northeast within the study area are those within the buried channels. However, later ice from this direction could have obliterated evidence of the first where not protected by a thickness of outwash sands and gravels, as in the Hitchin and Stevenage Channels. Ice following the easternmost trajectories of the later part of the advance (Figure 9.1), passed over greater distances of Chalk bedrock, depositing tills in the east that are richer in chalk and flint than those in the west.

Meltwater from an approaching ice sheet may have travelled down the pre-glacial Ouse/Ivel Valleys as suggested by Horton (1970), eroding or enlarging the gap in the Lower Greensand at Sandy and continuing south to Hitchin (Hopson *et al.,* 1996). As the ice moved into the study area from the northeast, proglacial streams would have been directed to the southwest by the line of the Chalk escarpment. The course of the Hatley Channel of Edmonds & Dinham (1965) approximately coincides with that of the pre-Anglian Chalk scarp shown on Figures 9.3 and 9.4a. It is possible, therefore, that this represents a former ice marginal drainage channel directing flow towards the Hitchin Gap. Glaciofluvial water entering the Hitchin Gap flowed through either one, or both, of the Stevenage and Hitchin Valleys to reach the Vale of St Albans via the Lower Beane Valley. Smaller quantities of glaciofluvial deposits exist at the base of the Stevenage Channel, suggesting the Hitchin Channel was the main drainage route.

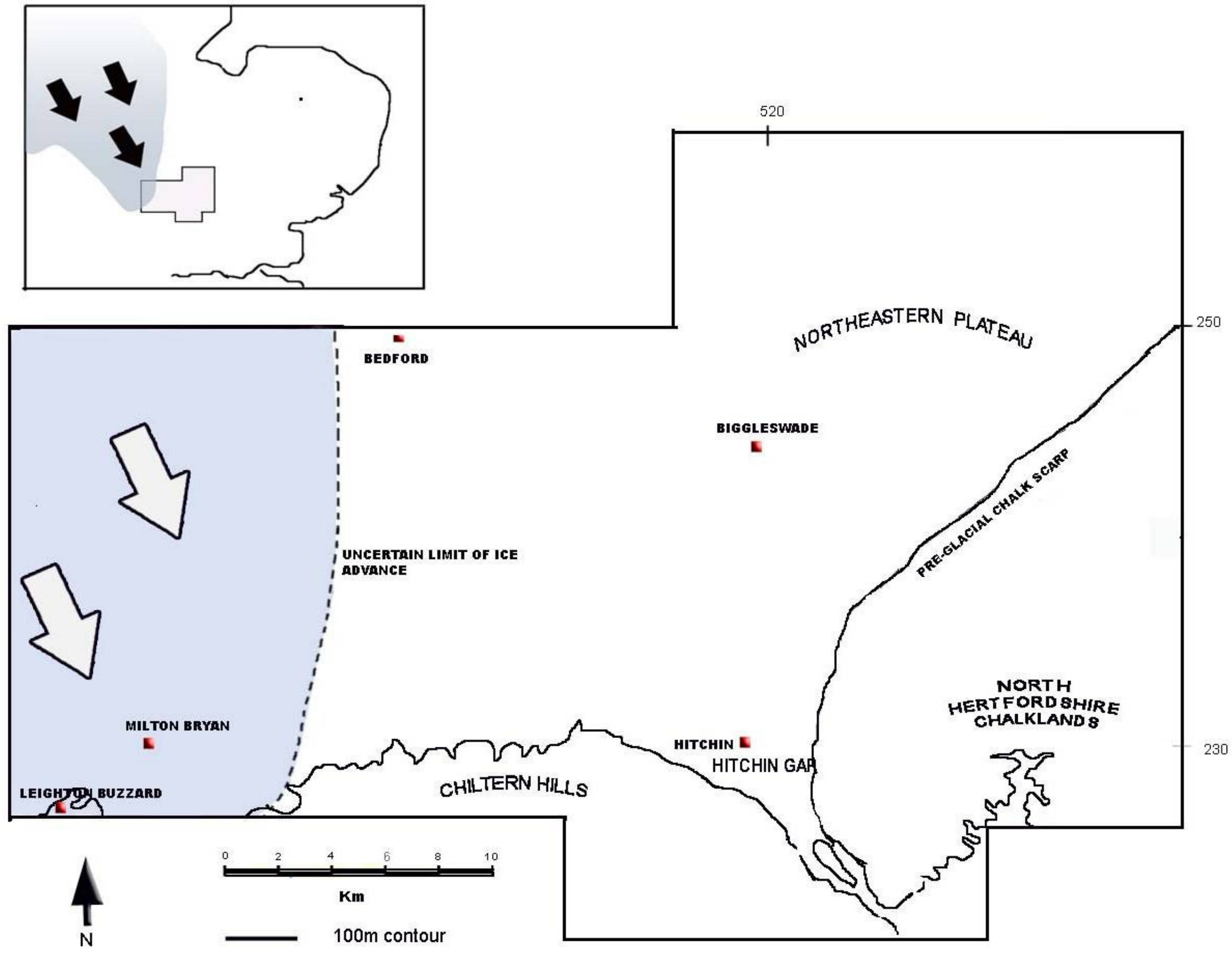
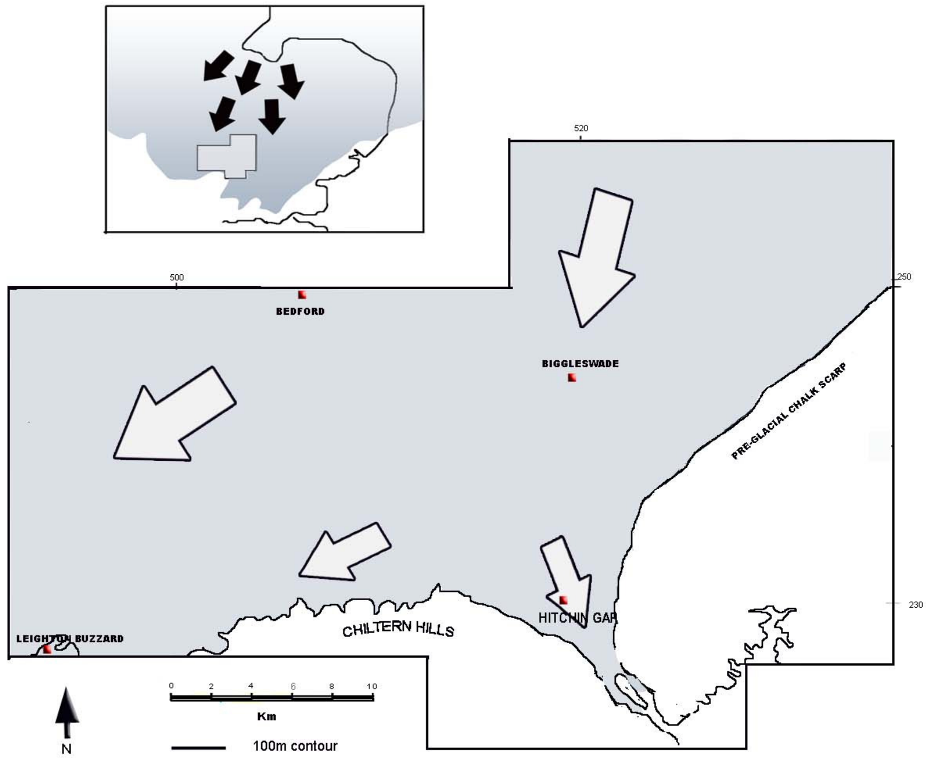


Figure 9.3. Likely extent of a possible ice advance from the northwest-NNW.

a



b

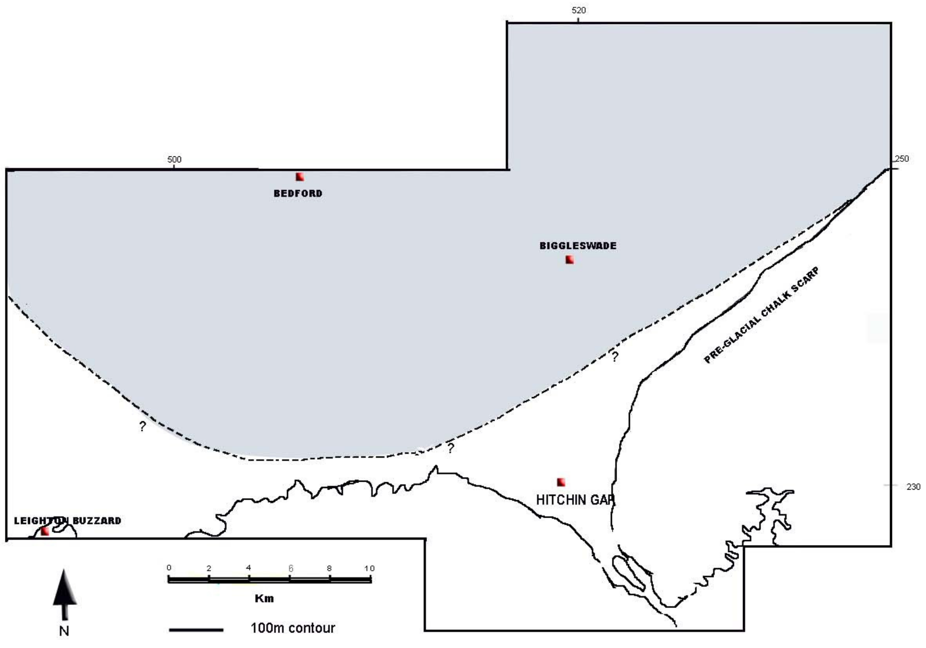


Figure 9.4. a. Maximum extent of first advance from the northeast into the Hitchin Gap.

b. Retreat of ice (extent uncertain).

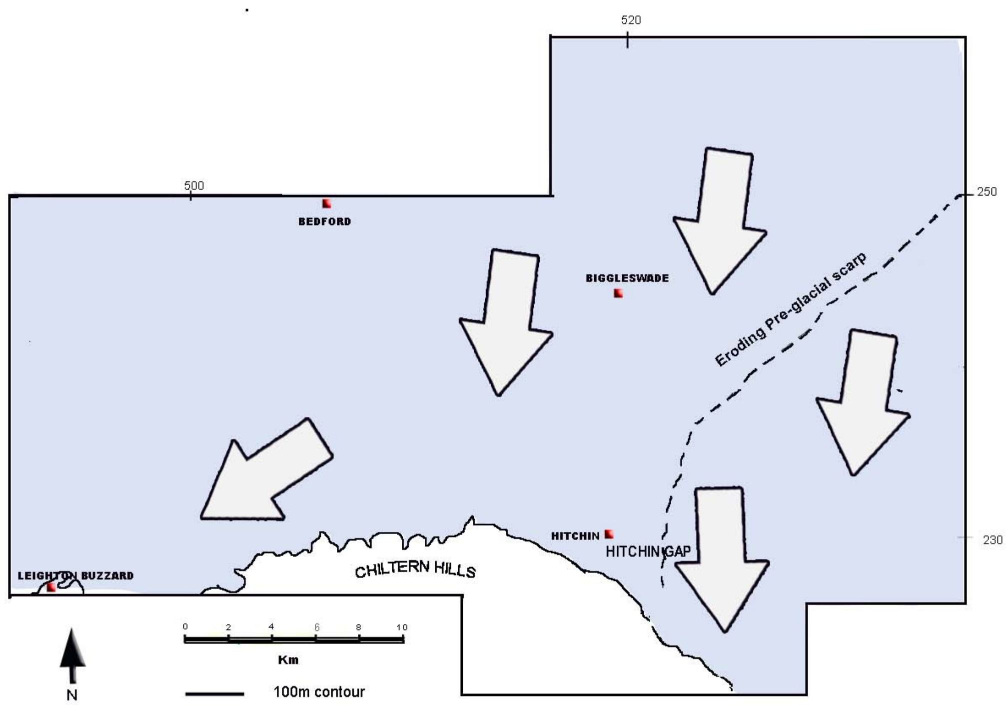


Figure 9.5. Maximum extent of the second advance from the northeast which moved across the North Hertfordshire Chalklands.

During this advance the powerful meltwater stream entered the Hitchin Valley and subglacial waters under hydrostatic pressure were responsible for deepening of the Hitchin Channel. Hollows in the base of the channel were excavated and subsequently infilled with sands and gravels (Hopson *et al.,* 1996). Gravels in the Lower Beane Valley, showing lithological similarities to those within the Hitchin Channel (Cheshire, pers. comm.), suggest that the drainage water was funnelled down this channel passing through the narrow outlet northeast of Langley and on to the Vale of St. Albans. These glaciofluvial deposits are probably the equivalent of the Westmill Lower Gravels (Westmill Member) in the Vale of St Albans, as suggested by Aldiss (1992a). Overlying these the early advance is represented by the lower tills sampled in this study at Site 8 (St Ippollitts), Site 11 (Primrose Hill Quarry) and probably also near Langley at Cannocks Wood (Site 3). The shallower Stevenage Channel was also possibly deepened at this time, although there is no evidence for a sub-glacial stream entering the Stevenage Valley. The extent of the lowest till in this channel (the Stevenage Member) is largely unknown as it is only recorded in a small number of boreholes in the Little Wymondley area (Hopson *et al.,* 1996).

As mentioned previously, it is unclear whether the initial glaciation of the Stevenage and Hitchin Channels was the result of a lobe of ice extending south of the main ice sheet or whether the main ice margin reached the Chalk scarp during this advance. Hopson *et al.* (1996) were of the opinion that an ice lobe at this time passed down the Hitchin and Stevenage Channels and on to the Vale of St Albans where it deposited the Ware Member till of Gibbard (1974). A comparative study of these lower tills in the Hitchin Gap and those of Ware Member till show low similarities in particle size distribution and small clast lithology. It would appear more likely, therefore, that this ice stopped at the southern end of the Hitchin Channel and presumably at an equivalent point in the Stevenage Channel. Further progress may have been prevented by the ridge of Chalk bedrock, rising to within 2.5 – 7.5 m of the ground surface, within the Hitchin Channel at Langley. Van Dijke & Veldkamp (1996) suggested such a “threshold” feature denotes the position of a stationary or very slowly moving ice front (Section 3.8.6).

No evidence remains of tills from the initial advance from the north - northeast within the study area north of the escarpment, possibly because a subsequent re-advance may have removed or assimilated pre-existing till. Following deposition of the lower tills by ice from the north-northeast, Hopson *et al*. (1996) speculated that a climatic amelioration occurred, but the extent of any retreat remains uncertain. However, large quantities of subglacial and/or glaciofluvial deposits were subsequently laid down at the base of the Hitchin Channel leaving only small pockets of the lower till at Hitchin and Langley.

A re-advance of the ice into the channels then followed. This is evidenced by the Charlton Member of Aldiss (1992a). Deposits found at similar altitudes to this till have been shown in this study to possess similarities to Cheshire's Ware Member till. For this reason it is the Charlton Member that is considered to be related to the advance responsible for the Ware Member in the Vale of St Albans, thought to have approached the Vale from a northeasterly direction. The Charlton Member is interleaved with glaciolacustrine deposits and the tills at Sites 1 (Knebworth Park), 2 (Norton Green) and 3 (Cannocks Wood) are shown in Chapter 6 to be melt-out, flow or slumped tills. It is possible, as suggested by Hopson *et al*. (1996), that the presence of beds of clay and fine silt indicate the presence of small proglacial lakes within both the Stevenage and Hitchin Channels into which waterlain and flow tills were deposited. They considered that, as the ice which deposited the Stevenage Member retreated along the Channel, hydrostatic pressure was reduced and the water formed lakes as it was unable to escape over the threshold at Langley. However, Cheshire (1986) speculated that at the end of the Ware Member advance a body of dead ice remained in the Vale of St Albans and formed a barrier to the expansion of the Stortford Member ice. It is possible that a body of stagnant Charlton Member ice (equivalent of the Ware Member) may have remained in the Hitchin Gap at this time. Thus, the glaciolacustrine deposits and waterlain tills may have been deposited from the decaying body of dead ice and associated lakes within the channels following the second (Charlton Till) advance of ice into the Stevenage and Hitchin Channels.

The extensive glaciofluvial deposits at Primrose Hill Quarry (Site 11) suggest deposition during a minor retreat of the ice front (Figure 9.4b), which was followed by a re-advance depositing till of a similar nature. This final part of the glaciation was the most widespread (Figure 9.5) and is believed to be responsible for extensive till coverage of the study area and neighbouring regions. The lack of glacial deposits on the Chiltern Hills southwest of Hitchin suggests the ice did not mount the scarp there, but split into two lobes - the point of birfurcation being Deacon Hill (TL120298). One lobe advanced into the Hitchin Gap, the other passed parallel to the scarp down the Vale of Aylesbury (Figure 9.3a) as may be indicated by the macrofabrics obtained from Sites 27 and 30 of this study. In the Hitchin region this advance is equated by Hopson *et al.*, (1996) with the deposition of the Maydencroft Member.

Many samples of higher tills within the Hitchin Gap and surface tills as far north as Upper Stondon show strong similarities with the Ware Member till south of the study area. These include both the sample of middle till at Primrose Hill Quarry (Site 11 this study) and the upper till at this quarry (Brownsell, 1996) together with a sample from Site 9 close to the Maydencroft typesite. Thus, the ice advance responsible for deposition of the Ware Member is considered in the Hitchin Channel to be the same as deposited the Charlton Member described by Aldiss (1992a) and the Maydencroft Member (a lodgement till) outside the channel. The Graveley and Vicarsgrove Tills are probably local tills associated with decay of this ice sheet.

However, the possibility remains that this final re-advance of ice may have merely followed a similar path to that of the Charlton Member till ice giving it similar characteristics and rendering the Charlton and Maydencroft Members indistinguishable.

The ice sheet depositing the Maydencroft Till appears to have been dynamic and it is envisaged that it was during this phase that major erosion of the Chalk northeast of Hitchin occurred. It is probable that at the Chalk scarp progress of the ice was hindered. As the ice thickened, stresses built up sufficiently within the ice to cause considerable erosion of the landscape as the ice climbed over the North Hertfordshire Chalklands. Rafts of Chalk were detached from the scarp and transported for several hundreds of metres (Hopson, 1992). Similarly northwest of Hitchin at Edworth (Edmonds and Dinham (1965) excavation of clay bedrock resulted in re-deposition of clay rafts some distance away. Rafting of till may be also indicated at Baldock (Site 10, this study).

According to Cheshire (1986) this ice probably extended east of the study area, taking a curved path around the high ground before turning to enter the Vale of St Albans. Ice approached the Lower Beane Valley from the northeast across the Chalklands and may have also entered the Stevenage Channel from a northeasterly direction. The Stevenage Channel is therefore likely to have been blocked south of the junction with the Hitchin Channel, trapping the southerly flowing meltwaters and forming the proglacial lakes mentioned above.

To the north of the Hitchin Gap, large quantities of till were deposited on the Northeastern Plateau blanketing the pre-existing topography. Only one massive till is present here, up to 67 m thick in boreholes at Hatley (Section 3.6.2.), perhaps indicating that the main ice mass had remained present throughout the two or more ice advances identified further south. To the east of the study area, three further minor re-advances occurred, each originating from the main ice mass northeast of the study area (Cheshire, 1986). This same ice mass was also responsible for widespread lodgement tills forming the Blakenham Member in Suffolk Allen (1983) and the Great Waltham Member in Essex (Whiteman, 1987).

2. Model proposing an advance from the northwest-NNW.

An early ice advance from the northwest-NNW may have encroached into the western part of the study area, depositing chalk-free tills. This glaciation may have extended no more than a few kilometres east of Milton Bryan. The Letchworth Gravels (Section 3.5) may represent a remnant of the outwash of such an advance. If fabrics at Site 30 (Heath and Reach) represent the re-orientation of clasts within the ice during the second (northeasterly or north-northeasterly) advance, then a retreat of ice from a northwestern direction prior to its arrival is suggested. There is no indication that this early ice surmounted the Chalk scarp.

The subsequent advance from the northeast may have either followed after an interval of uncertain duration or the two advances could have formed part of a single glacial event. Either way, tills in the west of the study area comprise a mixture of both northeastern and northwestern debris. The lack of chalk within ice from the northwest or NNW would have diluted the acid–soluble content of the final till.

9.7. Post glacial events

The Hoxnian interglacial followed the final retreat of ice from the study area. Remnants of the Hoxnian land surface are to be found across the Stevenage/Hitchin area, where up to 8.5 m of terrestrial deposits include organic rich clays and peats (Hopson *et al.*,1996). These deposits survive in numerous small depressions in the glacial sediments, thought to represent 'kettle-holes" formed in dead ice within the channel fill sequence.

9.8. Regional stratigraphic correlations

Tentative correlations with stratigraphies of neighbouring areas are shown in Table 9.1.

The first advance into the Hitchin Gap from the north-northeast appears to be earlier than the first ice seen in the Vale of St Albans. However, the only deposits separating tills of this earlier advance from the overlying tills are ~16 m of outwash deposits seen in the Hitchin Channel. It may be therefore, that as suggested above, the first advance from the northeast was of a lobe ahead of the main ice sheet and that this followed the pre-glacial river Ivel/Ouse valleys south to penetrate the Hitchin Gap.

The overlying tills (Charlton Member), may have been deposited at the same time as the Ware Member. At Primrose Hill Quarry, up to 10 m of the Lower Holwell Sands lie above the Charlton Member but below the Maydencroft Member. A similar stratigraphy exists in the Vale of St Albans where deposition of the Ware Member is interrupted by sands and gravels laid down by a south-flowing outwash river. Thus, it is believed here that the Maydencroft lodgement till, in common with other surface lodgement tills seen across the study area can be equated with a later part of the Ware Member. However an alternative scenario is that the Maydencroft till was contemporaneous with one of Cheshire's later advances, i.e the Stortford or Wadesmill Member. Tills representative of these members lie a distance to the northeast of those investigated in this study and would not necessarily have arrived via the same path, so that they would not exhibit similar lithological characteristics to those seen by Cheshire.