CHAPTER 10
SUMMARY AND CONCLUSIONS

This thesis represents an attempt to understand the glacial geology of the south Bedfordshire/north Hertfordshire area and its relationship to adjacent regions, and the course of events during the period relating to deposition of the glacigenic sediments.

The objectives were:

1) To review previous research both from within the study area and adjacent areas and to assess the validity of the conclusions reached.
2) To gather new data on till deposits within the area.
3) To establish a local lithostratigraphic sequence.
4) Where possible, to correlate major units in this sequence with those in adjacent areas.
5) To reconstruct the glacial dynamics and glacial palaeogeography of the study area and to put this into a regional context.

A total of 68 samples from 29 sites were selected. 27 samples were from boreholes not previously investigated within the area of the Hitchin Channel. Previous borehole data, especially to the north of Hitchin, are sparse and often rather dated, yielding vague and unreliable information. Thus the additional data from this study provided a valuable input to research.

Macrofabric analyses were performed on 35 samples and the results were subjected to further statistical analysis in order to gain an insight into the depositional processes. The results suggest most of the tills within the study are deformed lodgement tills. This type is considered common above deformable bedrock (Hart *et al.,* 1990) such as the Gault and Oxford Clays and the Woburn Sands present across a major part of the study area. Deformed lodgement tills were also found within the Hitchin and Stevenage Channels where they have been deposited above glacial sand, gravels or silt. Results from the Hitchin Channel also indicated the presence of melt-out or flow till and two instances of undeformed lodgement till (Site 1 at Knebworth Park & Site 5

at St Ibbs). A thick (~29 m) section of probable melt-out or possible flow till exists at the southern end of the Hitchin Channel near Langley (Site 3 – Cannocks Wood). A lack of similarity between these tills and those in the Vale of St Albans to the south suggest they probably represent the limit of an early advance/advances of ice entering the Hitchin Channel from the northeast.

In general, fabric measurements indicate a general direction of ice advance towards the SSW or southwest across the study area, and clearly mark the bifurcation of the ice as it encroached upon the higher Chalk scarp southwest of Hitchin. Measurements within the channels indicated clast 'a' axis alignment to be influenced by the topography of the channels rather than the regional direction of ice advance. An alternative hypothesis is that fabric measurements from Site 30 (Heath and Reach), showing ENE-WSW orientations, may represent transverse fabrics created in ice approaching from the northwest - NNW in response to bedrock conditions or encroachment of the ice margin on the Chalk scarp to the southwest.

The particle size distributions and carbonate contents of the tills were measured at half-phi intervals for the size fractions between -4.5 and +4.0 phi. Particle size characteristics were remarkably uniform across the study area, most having modal values between +2.0 and +3.0 phi. 14 samples possess modes between +3.0 and +4.0 phi and two samples from Southill (Site 15) and one from Warden Street (Site 18), possess primary modes at +1.7 phi, thought to be due to assimilation of underlying Woburn Sands. Principal component analysis of the finer matrix fraction suggested the largest variation in these data lay in the fine/medium silt and clay size fractions. At Sites 1 (Knebworth Park), 2 (Norton Green-Upper Till), 7 (Great Wymondley), 11 (Primrose Hill Quarry-Middle Till) and 16 (Moggerhanger) samples with reduced fine content indicated the presence of waterlain or flow tills. The highest content of fine material was found in samples of Lower Tills within the Hitchin Gap at Sites 2 and 11 and 8 (St Ippollitts), where values range between 85.2 and 93.8%.

At Primrose Hill Quarry (Site 11) the proportion of acid-soluble material was highest in the Middle Till (unit 8), smaller amounts being present in the Upper Till (unit 15) at this site, as noted by previous authors (e.g. Etienne, 2001; Hopson, 1992). Large amounts also occurred in samples from sites

immediately to the north at Edworth (Site 19) and Millowbury Farm (Site 20). The Lower Till (unit 5) at Site 11 also contains less carbonate, as did with other tills within the Hitchin Gap. An attempt was made to group samples based upon total acid-soluble content. Tills in the west were found to have an average of 4.8% whilst those on the Northeastern Plateau averaged 6.3%. Some of the highest percentages were found in the centre of the study area where a wide range of values were recorded.

All samples were subjected to small clast lithological analysis and data for each of 14 lithologies were recorded for five half-phi size fractions between -1.0 and +1.0 phi. Outside the Hitchin Gap, flint/quartz ratios were shown to be generally lower in the west with values averaging 0.041. Highest values were found in a central corridor running north of Hitchin, where the average was 0.135. Tills within the channel sequences however, possessed very variable flint/quartz ratios, due to assimilation of the underlying flint-rich Upper Chalk.

Data from the above analyses were assembled into a main database and subjected to multivariate analysis. To enable the use of principal component analysis this dataset (Database 1) was then split into subsets with fewer variates. Thus five subsets (Datasets A to E) were used to analyse the data described above. Cluster analysis was also performed on each dataset and the results of the two analyses compared. Data from within the Hitchin Gap showed variable characteristics, possibly particular to the channel, and this might mask patterns in the data from the remaining sites. Therefore a further subset (Dataset F) was designed to analyse all samples except those from Sites 1 to 8 within the Hitchin Gap. However, the grouping of data suggested by this analysis indicated a similarity of sedimentological characteristics in tills from various heights and geographic locations, rather than the presence of individual stratigraphic units. A further subset (Dataset G) was constructed to assess data from Sites 1 to 8 within the Hitchin Gap, together with Site 9 outside the channel sequence at Hitchin and Site 11 within the channel at Holwell. Cluster analysis of this dataset separated samples whose macrofabric characteristics pointed to deposition by melt out or flow, from lodgement tills.

The combined results of the multivariate analyses were assessed and, although no broad division of samples was possible, at three sites (Site 2 (Norton Green), Site 3 (Cannocks Wood) and Site 11 (Primrose Hill Quarry)), where more than one till unit was present, identification of different stratigraphic units based on the sedimentological and lithological characteristics mentioned above, was possible. At a fourth site (Site 8 – St Ippollitts) different stratigraphic units were also indicated, although the evidence was weaker.

The overall results of the statistical analyses suggested that ice entered the study area following different trajectories. Tills from sites at Milton Bryan (Site 27), Potsgrove (Site 28), Mundays Hill Quarry (Site 29) and Heath & Reach (Site 30) differed in acid-soluble content and flint/quartz ratios from samples elsewhere. Ice following the trajectories shown in Figure 9.1 could account for the lithological differences as described in Sections 7.4.2. and 7.4.3. An informal examination of the lithologies collected at Heath and Reach revealed the presence of clasts from Triassic outcrops and a crystalline lithology possibly from Charnwood (Plates 5.4 & 5.5). These lithologies may have been carried into the path of the ice by the Bytham River (Section 3.5), before being transported into the study area. An alternative hypothesis is that they may indicate an incursion of ice into the study area from the northwest-NNW. This was proposed by various workers over the last sixty years (Baden-Powell, 1948; West & Donner, 1956; Rose, 1992, 1994, in Clarke *et al*., 2004, 2007); supporting evidence quoted by these authors has included macrofabrics (West & Donner, 1956) and stone counts (Baden-Powell, 1948). However, the presence of Red Chalk observed during fabric analyses indicates that there is also a northerly or northeasterly component to these tills. The macrofabrics seen in the west of the study area are ambiguous and can be interpreted either as a result of an ice advance from the northeast following a course parallel to the Chalk scarp, or as an advance from the northwest in which clast 'a' axes reflect a transverse fabric created in response to a change in bedrock conditions, or to the obstacle presented by the Chalk scarp.

An earlier till lies at the base of the Hitchin Channel signifying a pre-Ware Member advance of an ice lobe extending through the Hitchin Gap and along the Hitchin Channel as far as Langley. No samples of lower till from the

Stevenage Channel were made available during this study; therefore comparison of the early tills within the two channels was not possible. A comparison dataset was constructed in which data supplied by Dr D.A. Cheshire was compared statistically with those obtained in this study. Representative samples of Cheshire's four local tills were used. A similarity matrix was produced and a threshold similarity coefficient of 99.6% was assigned, being the equivalent to that used by Cheshire to discriminate between observable lithostratigraphic till members at Westmill Quarry. The results indicated that many of the tills within the Hitchin Channel possess similar characteristics to those originating from the first (Ware Member) ice to enter the Lower Lea Valley and the Vale of St Albans. This suggests that the Ware ice covered most of the region to the south and southeast, and all of the study area, with the exception of the highest Chilterns to the southwest of Hitchin.

In the Hitchin Gap, the main deposits lying above the basal tills and glaciofluvial sands and gravels, are believed to have originated by the wasting of a body of dead ice interspersed with bodies of water and are correlated with the Charlton Member. They show strong associations with tills outside the channels suggesting that the Maydencroft Member may originate from the same advance as the Charlton Member, both showing associations with Cheshire's Ware Member.

Results from this study also necessitate revision of the subglacial contour map of the Hitchin channel in the area immediately south of Hitchin and at Langley, where the channel has proved to be deeper than previously envisaged.

The main conclusions of this study are set out below:

- The study area was subjected to at least two phases of advance and retreat of ice from the northeast or NNE.

- During the first advance from the northeast/NNE, the lower till, including that at Gosmore (TL12NE27), Ransom's Brickyard (TL12NE24), St Ippollitts (Site 8) and the Langley Till at Cannocks Wood (Site 3), was deposited within the Hitchin Gap. The characteristics of this till differ from those of

overlying tills with a generally greater content of fine material and wide ranges of acid-soluble contents and flint/quartz ratios.

- The lower acid-soluble content and lower flint/quartz ratios found in tills in the west of the study area may be the result of ice following the trajectories proposed by Fish & Whiteman (2001), or may be due to an incursion of chalk-free ice from the northwest-NNW.

- The final advance from the north/NNE resulted in the widespread deposition of till across the study area and also the North Hertfordshire Chalklands. The Chiltern Hills to the southwest of Hitchin remained ice free. Glaciotectonic structures such as rafts found near Site 19 (Edworth), Therfield (just east of the study area) and possibly at Baldock (Site 10 this study) together with overfolding seen at Holwell (Hopson, 1992) witness the dynamism of this advance.

- The tills within the study area are mainly of deformed lodgement type with a few instances of undeformed lodgement till at Sites 1 (Knebworth Park) and 5 (St Ibbs). Within the channel sequences there are numerous examples of slumped, melt-out or flow tills likely to have originated from a body or bodies of stagnant ice associated with the second advance down the Hitchin Channel.

- Petrographic characteristics of tills within the area are heavily influenced by local factors. These include the depositional processes mentioned above, which affect the macrofabric and particle size characteristics. In addition, assimilation of local bedrock may be responsible for variations in sand content across the study area. Tills within the Hitchin and Stevenage Channels are complex and diverse, with a wider range of characteristics than found elsewhere in the study area.

- Petrographic and statistical analyses suggest the presence of more than one stratigraphic till unit within the Hitchin Channel and a lower till is separated out on this basis. A further division of the higher tills into two

units (Maydencroft Member and Charlton Member as suggested by Hopson *et al*. (1996), is not supported by this study.

This work has made specific contributions to Quaternary studies and the results are significant for future stratigraphic and palaeogeographic research. The results from this study indicate two equally possible ice advance patterns into North Hertfordshire and South Bedfordshire, with the recognition of the possibility of the presence of an ice sheet from the northwest-NNW extending at least as far east as Milton Bryan. This represents an eastward extension of the ice advance recognised in Northamptonshire and Buckinghamshire, which would have been followed by an advance from the northeast. The alternative hypothesis is that ice moved into the study area following the two stage model of Fish & Whiteman, (2001) with early ice from the north accounting for the different lithological content of tills in the west of the study area.

The presence of a lower till indicating an early advance into the Hitchin Gap, suggests the pattern of Middle Pleistocene climatic oscillations resulting in repeated advance/retreat of the ice front as seen in the Vale of St Albans and southeast Hertfordshire continues into north Hertfordshire and south Bedfordshire.

The following comments relate to the methods used in this study:

This work has highlighted problems with the eigenvalue method of determining till genesis. It has been shown that various data from current and past studies relating to the Lowestoft Till fail to plot in a consistent way in the published process fields relating to till genesis. This seriously hampered any attempt to assign a till-forming process to a deposit of unknown genesis. An in-depth assessment of all macrofabric, textural and lithological characteristics was undertaken in order to obtain a fuller and more reliable description of each till. Much further work is required, including the collection and processing of a good deal of field data using standardised techniques before the method can be properly evaluated.

The laser diffraction method to obtain a particle size distribution within the finer fraction of tills allows rapid comparison of till samples. It must be remembered however, that particle size distributions obtained using different techniques measure different physical properties of the clasts, and should not be integrated into a single particle size distribution curve.

Macrofabrics were successfully determined from oriented borehole samples, although some problems were encountered where clast numbers were low, rendering statistical analysis unreliable. It is considered these problems could be alleviated if the minimum size of clast measured were to be reduced from that given in Section 4.4.1.

Methods adopted by Cheshire (1986) were selected for this study to facilitate accurate comparison of tills with those in central Hertfordshire and west Essex. Overall, this use of standardised methods in the collection of sample data has considerably increased the ability to compare data across regions. The use of multivariate analyses to process these data allowed a rapid, statistical assessment to be made.

10.1. Recommendations for Future Work

Separate identification of the source and quantity of the limestone content of tills in the Leighton Buzzard area would lead to a better indication of the proportion of chalk found in these tills. This in turn would lead to a better understanding of how the chalk content of tills decreases towards the west.

The use of Spilsby Sandstone erratics as an indicator lithology would enable identification of tills deposited by ice that had moved over this very localised outcrop in Lincolnshire. Kelly & Rawson (1983) found this sandstone in drift deposits as far south as Highgate, North London in the south. Identification of this erratic would perhaps provide further evidence of ice flow trajectories.

Both of the above analyses would entail identification of lithologies before the sample was subjected to acid treatment. For size fractions investigated during the current study, i.e. -1.0 to +1.0 phi, it was difficult to distinguish chalk fragments from other acid-soluble clasts. However, this distinction would be

easier for clasts larger than -2.0 phi, although larger till samples would be required to obtain statistically valid counts. If a new method was devised it would enable the tills recognised in south Bedfordshire to be traced to the north and west of the study area, possibly linking the stratigraphy with that of the South Midlands.

It is likely that further data from boreholes in the Hitchin area will provide additional information regarding the complicated sequence of glacial, glaciofluvial and glaciolacustrine deposits found there. There is a need for more information from the area surrounding the junction of the Stevenage and Hitchin Channels and north of Holwell where the route of the Hitchin Channel is believed to extend to the vicinity of Broom. Additional data from the northern end of the Stevenage Channel may provide a better understanding of the stratigraphy there and the position of this channel in relation to the Chalk scarp.

The petrographic investigation of deposits to the west of the present study area, for example in the area between Leighton Buzzard and Northampton, where instances of a lower till become increasingly common, needs to be undertaken. Correlation of these deposits with both those featured in this study and those in the South Midlands may lead to a better understanding of the relationship between the tills from the two advances.