Summary of Ph.D. thesis presented by S.W.Foster to the University of Hull, November 1985. ("The Late Glacial and Early Post-Glacial History of the Vale of Pickering and Northern Yorkshire Wolds").

This thesis is an attempt to combine a number of different approaches as part of a wider attempt to re-interpret the late Quaternary history of the Vale of Pickering and Northern Wolds in Yorkshire. This involved the critical analysis of part evidence together with the collation and interpretation of data from a variety of sources, some published, some unpublished but mostly from field work.

The course of the research followed a number of different lines. The first of these was to study the sedimentary data from glacial and pro-glacial deposits in the Vale of Pickering to assess their age and environment of deposition. The sediments were mapped in the field and analysed in the laboratory. A glacial outwash rather than lake-beach origin was proved for an important group of these sediments. The sedimentary data from the Vale of Pickering showed that ice had undoubtedly advanced further into the area than had been envisaged by Kendall at the turn of the century.- this was supported independently by geomorphological evidence and more sedimentary data from the northern Yorkshire Wolds escarpment. In the western end of the Vale, a thicker lobe of ice than that supposed by Kendall seems to have advanced into the area from the Vale of York, but its furthest limits cannot be shown from data available at the moment.

On the Yorkshire Wolds an attempt was made to delineate the advance of the Late Quaternary ice, but unfortunately the data was so poor that no firm limits could be drawn. Glacial outwash sediments were found at several scattered sites and compared with those found in the Vale, - some similarity was proved, suggesting that meltwater from late Quaternary glaciers had flowed across the Wolds and that ice from the Vale had overtopped the Wolds scarp along much of its length. The soils were analysed and found to have a higher blown sand content than suspected previously. The blown sand content increased towards the northwest, suggesting a probable glacial outwash source.

The dry valleys were studied and new light shed on the processes which may have contributed to their formation. In addition evidence of periglacial evidence from the whole region was collected, described and assessed.

Finally it was found that the structural lines of disturbance which traverse the chalk of the northern Wolds could easily be mapped from aerial photographs. These were mapped and included in the thesis as a small contribution to the solid geology of the area, even though they only impinge indirectly upon the main scope of this study.

THE UNIVERSITY OF HULL

The Late Glacial and Post Glacial History of the Vale of Pickering and Northern Yorkshire Wolds

being a thesis submitted for the degree of

Doctor of Philosophy

in the University of Hull

by

Stephen W. Foster, B.Sc.

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To Ann and Brian

"A little reading, a little hammering and a little thinking".

C. Darwin

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INTRODUCTION

The idea of Lake Pickering is not a new one. W. Marshall first remarked upon the similarity of the Vale of Pickering and the site of a former lake nearly 200 years ago. The scientific evidence for the lake is less than a century old and the current theory - that a lake was formed by the blocking by ice of the eastern and western ends of the Vale and that the waters drained via and cut the Kirkham Valley - is less than 90 years old. Yet Lake Pickering was one of the first glacier-dammed lakes to be described in Britain and is one of the last which has been properly re-investigated. The reasons for this lack of any re-survey are probably numerous and complex but among them must be the lack of detailed evidence of the subsurface geology of the Quaternary sediments and the paucity of suitable surface exposures. In addition Kendall's theory is one which best fitted the facts as they are generally known and hence there appeared to be no need to carry out a re-investigation of the area.

However, during the years since Kendall published his glacier-dammed lake theory (in 1902), our knowledge and understanding of the processes which operate in, under and around the margins of continental ice sheets haveexpanded enormously. In addition our knowledge of the processes which operate in the periglacial environment has also increased. Thus we are in a far better position today to attempt to reconstruct the events of the past from the evidence of the sedimentary sucessions and landforms of the Quaternary and as a result the limits of advance of Devensian ice-sheets in Britain are much clearer today. Except, that is, for the area which consists of the North Yorkshire Moors south of Eskdale and a few kilometers inland from the coast, the Vale of Pickering and Howardian Hills, and the Yorkshire Wolds. In these three regions there is still no substantial or detailed evidence which relates to the problems of the maximum limits of advance of the Devensian ice-sheets, only scattered information related to various isolated groups of deposits or to single groups of sediment which has been gathered over the years by a variety of workers, each pursuing different aims. This is still largely true even today.

The Vale of Pickering and northern Yorkshire Wolds lie in the centre of this almost blank region. There were many reasons for selecting this site as a starting point for tackling the problems of the late Devensian history of the area, among the more important being that this was the largest lowland area and hence had the best chance of preserving a more complete sedimentary record of the events of the geologically recent past It was also the region where the proposed margins of the Devensian ice-sheet were most suspect. For example Fox-Strangways had récorded drifts of possible glacial origin in the central and western Vale of Pickering 20 years before Kendall published his lake-theory, and evidence provided by McLaughlin (1904) and Harrison (1936) from the Ampleforth area suggested that the former positionsof the ice-margins in this area were far from clear. This being the case it was felt by the author that the margins of the Devensian ice which had been drawn in the eastern end of the Vale of Pickering could be equally suspect - this has been confirmed by Edwards (1978). If, however, Lake Pickering was a phenomenon of the glacial retreat stage, and the currently accepted limits of advance of the Devensian ice-sheets were suspect or even incorrect, where were the maximum limits of advance of the Devensian ice to be drawn ? Further what criteria was to be used in defining the new limits ? Finally if the Vale of Pickering had been occupied by Devensian ice (and it seemed likely from an early stage in the research that this was the case) how much of the surrounding hills had likewise been enveloped by ice ?

The latter question raised problems which were largely beyond the scope of this thesis. However, some effort was considered worthwhile to try to establish the positions of the former ice margins on at least one area of the surrounding hills - in this case the Yorkshire Wolds. The Wolds were chosen because the geology and petrology of the rock is superficially very simple - pure limestone and flint - and easy to recognise. Any erratics (other than moved chalk and flints) are instantly recognisable as such - in addition many different rock types had been found in the area. A study of the soils and other superficial sediments was also undertaken to try to establish whether any patterns existed which might shed further light upon the former position of the ice-margins in this area.

Investigations into the northern Wolds inevitably led to an analysis of the periglacial landforms of the area, especially the dry valleys. The problems of the origin of dry valleys is still far from resolved but the possibility that ice-meltwater may have contributed to the formation of these features was a new factor which could not be ignored. Study of aerial-photographs revealed new evidence about the periglacial environment and dry valley system. It also unexpectedly shed much new light upon the tectonic structures in the chalk and indirectly suggested that a relationship between the tectonic structures, and the valley pattern and slope development, may exist. The new evidence concerning the tectonic structures and the ground evidence which was found in support of the aerial-photographic material is presented in Chapter II.

During the course of this study a variety of different techniques and methods of analysis have been used. This has undoubtedly led to a rather broad and in places perhaps a rather less detailed view of the sequence of events which occurred in this area during the late Quaternary period. This can be defended on the grounds that in view of the wide variety and diverse nature of the evidence collected, and the large amount of ground which had to be covered in bringing the Vale of Pickering from the ideas of the turn of the twentieth century into sympathy with ideas of the 1980s, a broad approach was the best. More detailed analyses of particular lines and fields of evidence has been left to others whom, it is hoped, will take up the challenge offered by this unique and interesting tract of country.

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CHAPTER I

HISTORY OF RESEARCH

The Vale of Pickering and Northern Yorkshire Wolds have been the subject of conflicting theories for many years, yet neither has been subjected to much detailed study until recently. Thus the problem which confronts any researcher is not a lack of theories but rather a lack of evidence, as the following review shows.

A. The Vale of Pickering

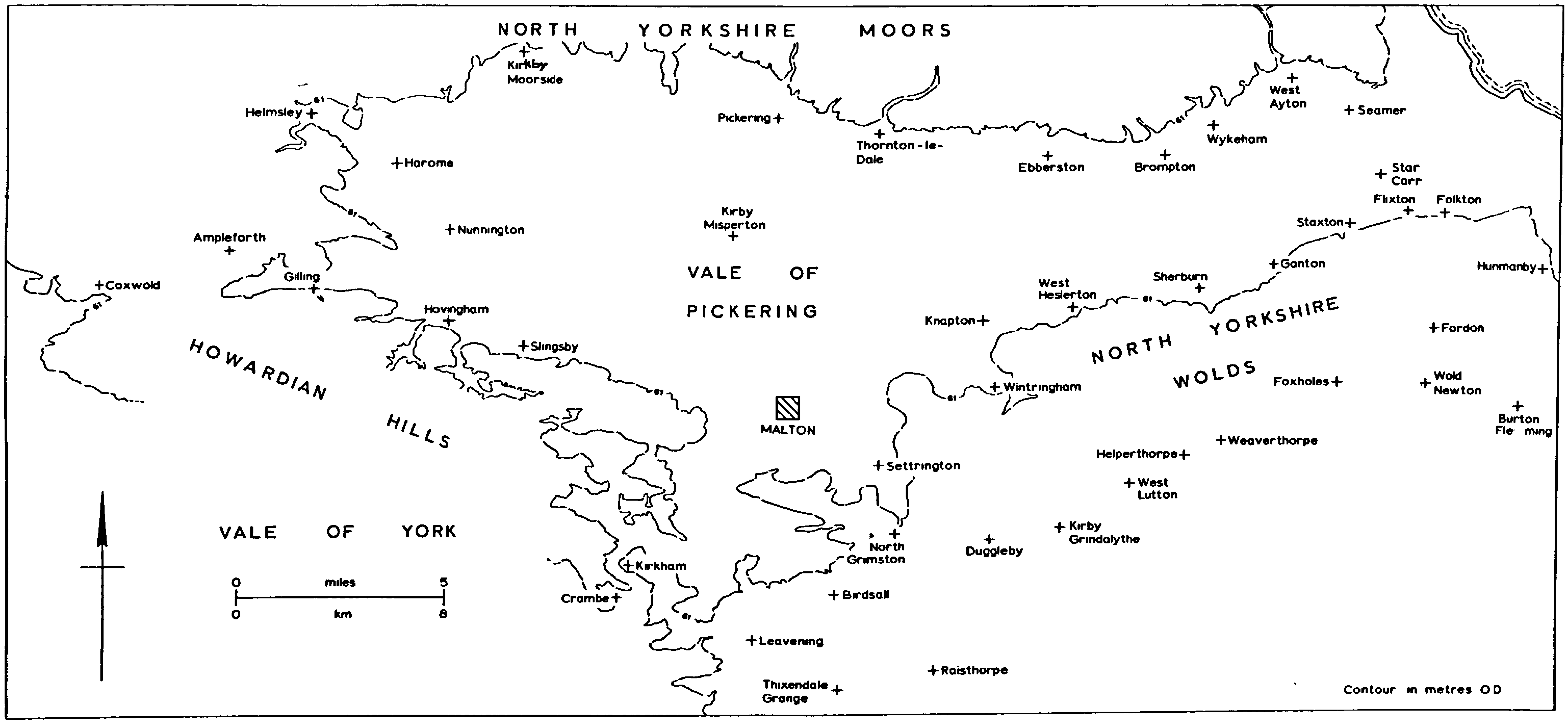
The first author to remark upon the similarity of the Vale of Pickering and the site of a possible abandoned lake was Marshall (1788) who wrote:

"the Vale of Pickering is a singular passage of country. A lake left dry by nature. A basin formed by eminences on every side, save one narrow outlet of the waters collected within its area, and upon the adjacent hills. Nature, perhaps, never came so near forming a lake without finishing the design."

Buckland (1822) thought that a lake may have existed in the Vale at some time although he did not suggest any specific period. He mentioned that the Kirkham valley would have been the most likely outlet for impounded waters which would have drained from the area. Phillips (1853) also considered that a lake could have formed here in the past, or alternatively that the sea had once occupied the Vale. He wrote:

"the level Vale of Pickering partly formed upon a surface of boulder-clay, may be regarded as a large pre-glacial lake or sea-loch, which became blocked during the glacial depression by drift at its eastern end. Through this drift short streams have since cut their way to the sea, to which, in earlier times, the Derwent had probably flowed by a short and rapid course, accompanied, most likely, by The Seve n, Rye and other

Fig. 1 Map of major place names mentioned in the text.


NORTH YORKSHIRE MOORS
Kirkby Moorside
Helmsley
Harome
Nunnington
Ampleforth
Gilling
Coxwold
Hovingham
Slingsby
HOWARDIAN HILLS
VALE OF YORK
miles
km
0
5
0
8
Pickering
Thornton-le-Dale
Kirby Misperton
VALE OF PICKERING
MALTON
Crambe
Kirkham
Leavening
Thixendale Grange
Birdsall
North Grimston
Settrington
Duggleby
Raisthorpe
Kirby Grindalythe
West Lutton
Helperthorpe
Weaverthorpe
Wintringham
Knapton
West Heslerton
Sherburn
Ganton
Staxton
Ebberston
Brompton
Wykeham
West Ayton
Seamer
Star Carr
Flixton
Folkton
Hunmanby
Fordon
Wold Newton
Foxholes
Burton Fleming
NORTH YORKSHIRE WOLDS
Contour in metres OD

western waters, which now descend to the Humber through the gorge at Malton."

The first geological survey of the Vale of Pickering was carried out by Fox-Strangways in the late 1870's: the results were published in both map and memoir form in 1880 and 1881 supplemented by a later memoir in 1892. Unfortunately only a few short paragraphs were devoted to the drift geology of the area and these concentrated mainly on the deposits of the northern and southern fringes of the area. He considered that in the eastern half of the Vale the sands and gravels which form the Ayton-Hutton Buscel terrace system in the north, and the Sherburn Sands in the south were probably deposited contemporaneously. However, he was not specific as to what processes were involved although he hinted at the agency of wind for the Sherburn Sands when he wrote that they were found:

"frequently in sheltered situations where there is a slight bend in the Wolds escarament, where they run up above their ordinary level as if they had been collected by the agency of the wind" (1880, p. 32).

However, it seems that he considered that the bulk of the sands were water-laid and only modified to a minor degree by wind action. He believed that the Ayton-Hutton Buscel terrace gravels represented a remnant of a raised beach which formed under marine conditions during a high pre-glacial sea-level phase when the Vale had formed part of an estuary. In this connection he regarded the chalk-gravels at Knapton as having formed at the base of a cliff (probably marine although this was not specifically stated), which had suffered partial cementation and rotation slip after deposition. He did not explain how normally dipping sands and gravels which overlie the steeply dipping material came to be deposited. He said little about the eastern-central parts of the Vale because the scanty evidence prevented him from interpreting clearly the solid and drift geology of the area. The only reference that he made to any sections (apart from borehole data) was to a brick-clay pit at Brompton which showed "laminated clays" passing eastwards under gravel.

The second of Strangways' memoirs (1881) gave equally brief descriptions of the drift geology in the western Vale, although sections were recorded which have subsequently been either forgotten or ignored. He believed that remanie boulder-clay could be found at several localities in the western Vale, especially at Kirby Misperton and Barugh up to a thickness of 2m (7 feet). These tills capped the low hills near the above villages and appeared to thin towards the fringes of the alluvial flats of the lowlands. No till deposits were recorded from beneath the alluvial deposits. A gravel mass of unspecified dimensions and origins was recorded at Kirby Misperton. In addition over 8m (25 feet) of "boulder-clays" were recorded in the railway cutting south of the village of Thornton-le-Dale, in which erratics appeared to have been derived entirely from local rocks. Doggers (i.e. concretions) from the Calcareous Grit and masses of black shale from the Kimmeridge Clay appear to have been especially abundant. Little mention was made of alluvial or lacustrine deposits in the central lowlands region except that once again "finely laminated clay" was present in some boreholes and sections. On the southern margin of the Vale, flanking the northern edge of the Howardian Hills between Malton and Hovingham, sands and gravels were mapped. These varied in thickness from 2.4 - 3m (8 - 10 feet) and "false-bedding" was frequently mentioned in descriptions of the sands. "Laminated-clays" were found underlying the sand and gravels locally.

In his later memoir Fox-Strangways (1892) discussed at slightly greater length the drift geology of the whole of the Vale of Pickering. He also tried to correct the false impression given by the geological map of the western vale (Pickering, sheet 92), on which mounds of "Kimmeridge Clay" were overlain by scattered erratics: these were published as areas

Fig. 2 Relief and drainage of the Vale of Pickering and adjoining areas.


NORTH YORKSHIRE MOORS
HOWARDIAN HILLS
NORTH YORKSHIRE WOLDS
VALE OF YORK
R. DERWENT
R. Hertford
R. Rye
R. Riccal
R. Dove
R. Seven
Hodge Beck
Costa Beck
Pickering Beck
Thornton Beck
Holbeck
Wath Beck
Wintringham Beck
Settrington Beck
CONTOURS IN METRES O.D.
MAJOR RIVERS
NORTH SEA COAST
miles
km

of boulder clay (and are still on the 1973 reprint) even though he emphasised that only scattered erratics were present. These boulders and pebbles were thought to have been deposited by a local glacier which occupied the valley: no lake was considered to be present at this (glacial) stage. Fox-Strangways believed that the lake was a post-glacial phenomenon which was blocked at its eastern end by the morainic ridge which runs from Filey to Speeton, and in the west by a ridge of low hills in what is now the Coxwold-Gilling or Ampleforth gap (fig. 3). In post-glacial times both of these dams suffered considerable erosion and this, combined with infilling of the lake-basin with fine-grained sediments and the downcutting of the overflow channel at Kirkham, had contributed to the draining and infilling of the lake.

During the interval between the publication of the second and third Geological Survey Memoirs, Carvill-Lewis (1887) published a paper which was to have some far-reaching consequences for British glacial geology. He stated that the position of maximum advance of every glacier is marked by a terminal moraine. This meant that the maximum limits of advance of the Quaternary glaciers could be easily defined in the Vale of Pickering and Vale of York by the Wykeham and Escrick "moraines" respectively. Superficial deposits found beyond these "moraines" were considered by Lewis to be of lacustrine origin, having accumulated on the floors of large extra-morainic lakes. Thus at the stage of maximum advance of the Quaternary glaciers Lake Pickering and Lake Humber, (which occupied the Vale of York), would have formed part of a continuous sheet of water and as the glaciers retreated and the water-levels of the major lake fell, two separate smaller lakes formed with Lake Pickering draining into Lake Humber via the Kirkham valley (Carvill-Lewis 1887). Although it was soon realised that some deposits in the Vale of York south of Escrick moraine were really of glacial origin, the drift deposits west of Wykeham in the

Fig. 3 Lake Pickering after Fox-Strangways (1881). N.B. this is a reconstruction based on Fox-Strangways' memoir - no map was ever published by him.

+K.M.
He+
+P
T.D.
+B.
+W.A.
Wy.
+Sr.
St.
H+
Sh+
+Ka
+C.
Gi.
+Sl.
+M.
Se
+K.
0 miles 5
0 km 8
Beach & Delta
Lake margin
Moraine & Clay dams
Contours in metres O.D.
Till margin

Vale of Pickering were never properly re-examined.

P.F. Kendall's first published contribution to the glacial history of the Vale was made in 1894. Although he did not support the lake theory at this stage, he did set out the criteria which he considered would need to be met before the existence of a lake could be firmly supported. These were the presence of lake-floor deposits, deltas, beaches and an overflow channel or outlet for the excess water. "This" he wrote, "is what we would expect: and it has yet to be shown that the facts accord". In 1896 he advanced a little from his earlier position by stating that if a lake had existed in the Vale it would have been dammed at its eastern end by ice (as had occurred at the Marjelen See) and not by moraine as proposed by Fox-Strangways. This helped to remove the major weakness of Fox-Strangways theory and resulted in Kendall's important paper of 1902 ("A System of Glacier-dammed Lakes in the Cleveland Hills"), which has been generally accepted as the most authoritative account until the present. Kendall considered that three of the four major criteria which he had set out 8 years previously had been met and that deltas, lake-floor deposits and an overflow channel were present. The deltas were to be found at Pickering and as part of the Ayton-Hutton Buscel-Wykeham gravel ridge; lake floor deposits up to 30m (90 feet) thick were recorded from several boreholes in the eastern and central parts of the Vale|| the Kirkham valley provided an excellent example of a lake-overflow channel. Thus the existence of Lake Pickering was, from some points of view, proved beyond reasonable doubt (fig. 4).

The following year Kendall expounded his ideas and enlarged upon the aspects of the theory which concerned the derivation of the water supply of Lake Pickering. He thought that all of the water derived from the area drained by the Forge Valley and Newton Dale systems reached Lake Pickering. A large map was published at the same time showing how Lake

Fig. 4 Lake Pickering redrawn after Kendall (1903b - map supplement).


Lake Pickering
North Sea Glacier
Glacier of the
Vale of York
+K.M.
+W.A.
+Sr.
+Wy.
+B.
+P.
+T.D.
He+
Gi.
+C.
+Sl.
+M.
Se+
+Ka.
Sh+
H.+
+K.
0 miles 5
0 km 8
GLACIER MARGIN
LAKE MARGIN
CONTOURS IN FEET O.D.
AT 100 FEET INTERVALS

Pickering formed a major part of the glacial drainage system of the whole of the Cleveland Hills (Kendall 1903a, 1903b).

In the years immediately following the publication of Kendall's work local geologists added minor details to the picture. McLaughlin (1904) described a series of successive overflow channels which had been cut on the northern edge of the Coxwold-Gilling gap north-west of Ampleforth village. These channels were thought to have been cut by water draining from a lake trapped in Shallowdale (a minor tributary valley to the Coxwold-Gilling gap), escaping along the margin of the glacier which at that time occupied the Ampleforth gap. In the same year Sewell (1904a) described in some detail the form and nature of the erratics found on the site of the Pickering delta. Later Sewell (1904b) described how Newton Dale had been cut and modified by successive retreat stages of the ice-sheet in the Eskdale area. Howarth (1908) summarised the erratic records compiled by the Yorkshire Boulder Committee for the Vale of Pickering and other parts of eastern Yorkshire.

Just prior to the publication of Kendall's major (i.e. 1902) paper, Cowper-Reed (1901) discussed at length the anomalous course of the river Derwent between Forge Valley and Kirkham. Reed accepted the lake hypothesis but was not certain whether ice or moraine was responsible for damming the eastern end of the Vale. He did however propose that the western end of the Vale at Ampleforth had been blocked by ice (and this preceded Kendall by one year). He further attempted to show that the Kirkham Valley was cut during post-glacial times and that the original col over which the lake waters had spilled was between Cram Beck Bridge and Crambe.

The whole picture was summarised by Kendall some years later - on the whole the picture had only changed in minor detail (Kendall & Wroot, 1924).

Melmore (1935) was the first person to suggest that modification to Kendall's theory was necessary when he questioned the original height of the col at Kirkham prior to the excavation of the valley by the overflowing lake waters. He proposed that instead of 75 m O.D. (225 feet) being the original height of the col it must have been slightly below 66m O.D. (200 feet) because another col, between Galley Gap and Weston is only just above 66 m O.D. (200 feet). He also suggested that headward erosion by a tributary of the River Ouse effected the capture of the headwaters of a northward flowing stream draining into the Vale of Pickering via Malton, thus lowering the Kirkham col considerably. Referring to this particular problem he pointed out that the level of the rock floor of the valley at Norton was found 7m (20 feet) below the present ground surface and therefore that deposition and not erosion, must have been an important factor in the sequence of events which resulted in the utilization of the Kirkham valley by the River Derwent and the reversal of drainage which was thus caused. Melmore also thought that a buried cliff, similar to that which runs along the eastern edge of the Yorkshire Wolds from Sewerby to Hessle, could be traced from Malton to Thornton-le-Dale and that this marked the western limit of a pre-glacial estuary. A later paper (Gayner and Melmore 1936) helped to add more details to our knowledge of the scattered drift deposits which cap the low hills in the western Vale, although the significance of this new evidence was not discussed.

For a long time, in fact since Cowper-Reed, it had been assumed that the ridge of high ground which extends in a wide arc south of Ampleforth village was composed of boulder clay and represented the terminal moraine of a distributary glacier of the Vale of York glacier. Fox-Strangways (1892) had included this area when he tried to correct the false impression, given by the geological map, of widespread deposits of boulder-clay in the western Vale (see above). However, it was not until

Harrison (1936) re-mapped the area that this ridge of high ground was once again shown to be composed of Kimmeridge Clay capped with scattered blocks of gritstone and other assorted sedimentary and igneous rocks, thus restoring Fox-Strangways' original picture. In addition he described two new patches of gravel, containing many exotic pebbles, in the area south of Ampleforth village.

The theory that the Vale of Pickering had once formed an arm of the sea in pre-glacial times has occasionally been revived after Phillip's original suggestion, e.g. Anderson (1939) believed that the Ayton-Hutton Buscel-Wykeham terrace was of marine origin (as was suggested by Fox-Strangways) and that it could be correlated on altitudinal grounds with "beach" deposits in other parts of Britain. This formed part of his evidence for widespread high pre-glacial sea-levels in Britain.

Oakley et. al., (1942, 1944) favoured the lake hypothesis however and supported Kendall's interpretation of the borehole evidence from the central Vale i.e. that the "laminated clay" so often recorded represented a thick accumulation of lacustrine deposits.

Hollingworth (1952) was the first critic to question seriously the pro-glacial lake theory of Kendall. He thought it highly unlikely that an open body of water of such size would remain unfrozen in a location so close to the Devensian ice sheets, rather he would have expected a compact mass of packed snow and ice to have accumulated in such a situation. This would probably have melted more rapidly than the retreating glaciers and may have given rise to a late or post-glacial lake system. This idea has tended to swing the pendulum back towards the lake theory as first proposed by Fox-Strangways.

The post-glacial lake hypothesis also received support from Clark et. al., (1954) in the report of the excavations at the Star Carr Mesolithic site in the central part of the eastern Vale. Clark et. al., believed that quite extensive and deep lakes existed in the early post-glacial period in the area now occupied by the carrs and that these represented the shrunken remnants of a more extensive sheet of water. Shepherd (1956) supported this hypothesis and produced a serious of diagrams showing the stages of evolution from Kendall's pro-glacial lake to the stage described by Clark et. al.

In both the past and at the present Kendall's Lake Pickering was and is considered to be the best example of a late Quaternary glacier-dammed lake site to be found in England (e.g. Bennison and Wright (1969), Sparks and West (1972),) and the theory still receives much support. In fact, views summarised by Penny and Rawson (1969) and Penny (1974) that "it is not yet time to erase Kendall's Lake Pickering" are still widely held.

B. The Northern Yorkshire Wolds

As with the Vale of Pickering until recent years, so also in the Yorkshire Wolds there has been little research, especially in comparison with the number of studies carried out on chalk landscapes in southern England. Indeed many of the geomorphological problems which have been discussed in the past with reference to the Yorkshire Wolds have not been based upon intensive field work in Yorkshire but by drawing analogies with areas in southern England. This has meant that many interesting and difficult problems have remained unresolved or largely neglected.

The first recognisably scientific study of the northern Wolds was carried out by Wood and Rome (1868) who made a reconnaisance survey of several patches of drift. The publication of their work was preceded by some correspondence (part of which has survived and is reproduced in Appendix A), in which several localities were named. Unfortunately no exact details of the sites were given by Wood and Rome but they were recorded on a map produced by R. Mortimer in 1886. (The original and copies of the Mortimer map are now kept in the Hull City Museum archives).

They thought that ice had covered the Wolds during the Ice Age and that consequently sea-levels must have risen by over 650 ft (190 m). Later Geikie(1874) showed that ice could advance over land and that it was not necessary for sea levels to rise before the onset of a glacial period. With the abandonment of floating-ice theories and following the geological survey of the Wolds by Fox-Strangways (1880, 1884), Reid (1885), and Dakyns et. al., (1886), the theories of Wood and Rome and Mortimer were superseded because the geological survey officers were unable to find convincing evidence of boulder clays or outwash sands or gravels. Reid (1885) recognised that the bulk of the soils on the Wolds represented a wind-blown deposit which had probably been derived from the outwash sands and gravel trains of Holderness.

Reid made a more general contribution to the study of chalk landscapes in 1887 with the publication of his theory that the dry valleys of the chalk of southern England were excavated during a period of intense cold (i.e. under peri-glacial conditions) when the ground was frozen, and so caused an increase in runoff in the spring and early summer thaw periods when local snow patches would have been melting rapidly. With the amelioration of the climate in post-glacial times percolation rates into the chalk would have increased to such an extent that surface runoff would cease except under exceptional circumstanstances. The processes postulated by Reid had actually operated in January of that year (1887) on the Yorkshire Wolds and had caused some flooding and soil erosion (Cole 1887). This line of argument has since become one of the major theories of the evolution of chalk dry valleys. Cole (1879, 1887) believed that chemical solution was the most important process operating during the formation of dry valleys in limestone regions; Mortimer (1885) thought that fissuring and cracking of the earth's crust during periods of uplift were responsible for the origin of dry valleys in the Wolds. Although this idea is now generally discredited, nevertheless his excavation showed that structural dislocations were co-incidental with some dry valleys. Cole's ideas are now generally accepted as being an important part of the processes operating during the formation of valleys in limestone areas.

The scattered drift of the Yorkshire Wolds has been studied and discussed by several authors. R. Mortimer (1886) published a map to show rocks of "supposed Tertiary age" which were found on the Wolds near the villages of Fridaythorpe, Fimber, Huggate and Thixendale. (This map was considered unreliable by Lamplugh (1923) and as a result little attention has been paid to them). Subsequently Stather (1900) gave an account of an unusual patch of Oolitic erratics in the area north-west of Luttons village. In a second paper he described a collection of quartzite pebbles from the southern end of the Wolds and showed that the western edge of the Holderness tills was fringed by Cheviot-derived rocks (Stather 1901). Later still he described more quartzite pebbles which he had collected on the Wolds, especially on the interfluve areas(Stather 1903, 1904). Similar quartzitic material was described by Sheppard (1904 from a sand-filled fissure exposed in a chalk pit on Painsthorpe Wold and at the foot of the buried cliff at Hessle. Quartzitic material had also been recorded by Lamplugh (1887) in his excavations of the buried cliff at Sewerby. Later still Sheppard described quartzitic drift underlying boulder clays at North Landing, Flamborough, (Sheppard 1910). Melmore (1931) reported oolitic drift from the Wolds near Pocklington. Versey (1937) analysed the heavy mineral content of the sand-pipes at Thixendale Grange, which had originally been discribed by Wood and Rome, and tried, without success, to correlate them with sands taken from the northern escarpment at Knapton and Heslerton overlooking the Vale of Pickering. Versey believed that the Thixendale sands and the quartzitic drift of Stather and Sheppard represented a late Tertiary remanié deposit. Wright

(1937) disagreed, he thought that deposits were of older drift origin. This view was shared by Bisat who reviewed all of the evidence which was then available and concluded that the drift of the Wolds had a character which was totally different from that found in Holderness (Bisat 1940). He pointed out however, that the oolitic drift of Stather and Melmore must be of "comparatively late" age. Straw (1961) considered that the sands at Thixendale were of Tertiary age. Versey returned to the problem of the Wolds only briefly when he described a thin silty drift which mantled the northern escarpment of the Wolds (Versey 1948). He also stated that much of this escarpment had been affected by landslips, a view originally put forward by Fox-Strangways (1889 - Sheet 93 Scarborough). The re-recognition (after Reid) of blown sandy silts on the Wolds was extended into Lincolnshire by Straw (1963) and back on to the Yorkshire Wolds by Catt et. al., (1974) who described isolated pockets of material in some detail and assigned a Devensian age to them. Catt et. al., further claimed that these deposits were of loessic origin. Bray et. al., (1981) also found loess in a deep fissure at Westfield Farm, Fimber, which had close mineralogical affinities to the sediments described by Catt et. al. Although Bray et. al., discussed the possibilities of a pre-Devensian origin for the Westfield Farm, they concluded that these loesses were of Devensian age.

The most recent account of the geomorphological evolution of the Wold is the study of Lewin (1969). In this work he took a dual approach to tackling the problems presented by the Wolds landscape, using an analysis of erosion surfaces to try to establish an overall denudational chronology, and a statistical approach towards the development of valley pattern and slope evolution. He was able to show that the degree of control of jointing in the chalk over the development of dry valley patterns is very high. He also thought, in contrast to Reid, that spring-sapping and headward erosion were the main processes responsible for the formation of dry valleys. Lewin followed Reed's early suggestion that the Wintringham col was originally cut by the lower reaches of the proto-Ure which was believed to have flowed via the Ampleforth gap and the Great Wold Valley to the sea before it was beheaded by the river Ouse. Lewin also thought that the northern escarpment of the Wolds was strongly affected by major landslips.

Walbank (1970) studied the major joint patterns of the Yorkshire chalk and concluded that these were related to stress fields which operated during the period of uplift and warping of the chalk in Tertiary times; preferred opening and closing of joint systems was also thought to have occurred during Quaternary times in response to glacial loading and unloading. He also remarked upon the parallelism of the northern flank of the Great Wold Valley with that of a major shatter-zone in the chalk, but drew no conclusion from this.

C. Conclusions

The Vale of Pickering is still accepted as representing the site of a major glacial-dammed lake during the Devensian period. The Yorkshire Wolds are considered to have remained "ice-free" during the Devensian except at their eastern and western margins. The origin of the dry valleys is still a topic of discussion and some lack of agreement. The lack of agreement on this subject and the dearth of more recent observations to support the "Lake Pickering" hypothesis which is based on assessments of evidence which are now 70 years old warrants more detailed studies of both these areas.

CHAPTER II

THE GEOLOGY AND STRUCTURE OF THE VALE OF PICKERING AND ASSOCIATED AREAS

The solid geology of the Vale of Pickering and its surrounding hills consists entirely of Mesozoic rocks of Jurassic and Cretaceous age. The solid geology is fairly well known, although the stratigraphy of the chalk has recently been revised (Wood and Smith 1978). The geology of the Vale of Pickering is now known to be very different from that supposed only a few years ago, although there are still many gaps in our knowledge of this area. Structurally the area is very complex - a fact which has hitherto gone unrecognised, and yet which has very important implications for any study of the region. For these reasons the geology and structure of the area will be described in detail.

A. Stratigraphy of the Jurassic and Cretaceous Rocks

The stratigraphy and outcrop of these rocks was originally established and mapped by Fox-Strangways (1880, 1881, 1892) although the boundaries of the different statigraphical horizons have been revised recently, this work still remains an important foundation (Hem ingway 1974). Two major units of the Jurassic are encountered, Oxfordian and Kimmeridgian, of the upper Jurassic age. The succession is as follows:-

Stage	Strata
Kimmeridgian	Kimmeridge Clay
Upper Oxfordian	(Ampthill Clay (Upper Calcareous grit (Coralline Oolite
Middle Oxfordian	Lower Calcareous grit

The Lower Calcareous Grit consists of a variable unit ranging from

Fig. 5 Geological map of the Vale of Pickering and adjoining areas (based upon British Geological Survey maps + additional sources).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F.H.
B.F.
M
Se
W.L.
K
R
T.G.
miles
0
5
km
0
8
SOLID
Chalk
Speeton Clay
Kimmeridge Clay
Lower & Middle Jurassic Rocks
DRIFT
Alluvium
Glacial outwash (sand & gravel)
Erratics on weathered Kimmeridge Clay
Boulder Clay

massive yellow sandstones to sandy oolites. The sandstones are generally well graded, with over 30% of carbonates present, although the lower parts have a lower silica content. The thickness varies from 15 m to 36 m with approximately 27 m in the area around Pickering village.

<u>Coralline Oolite</u>. This is a grey limestone with wedges of calcareous sandstones of varying thickness. Most of the beds of limestone are oolitic or pseudo-oolitic - local micritic facies are found. The maximum thickness of this member reaches approximately 50 m but like the other beds in the succession, it is of highly variable thickness. It has been sub-divided into 5 units as follows:-

Passage Beds - these mark the change from the Lower Calcareous Grit to the Hambleton Oolite. They are highly variable rocks and range from thin bedded limestone in the east, through massive medium grained sandstones to alterations of limestones and sandstones and finally oolites in the west. This is a relatively thin unit which in the Howardian Hills is known as the Birdsall Calcareous Grit, where it consists of a buff sandstone.

Hambleton Oolite - is represented by bio-oosparites (bioclastic limestones) with lenses of calcareous sandstones. It is basically a lenticular unit with diachronous boundaries which reaches a maximum thickness of 30 m near Pickering. In the Howardian Hills it is represented by 10 m of limestones which pass laterally into the Birdsall Calcareous Grit.

Middle Calcareous Grit - this consists of up to 12 m of highly calcareous sandstones and sandy limestones. It is again lenticular in nature, being thickest in the Pickering-Kirkdale area, but it thins towards the south and is absent south of Malton.

Malton Oolite - this is another variable bed consisting of shelly and oolite limestones approximately 20 m thick. It in part replaces the

Middle Calcareous Grit in the North Yorkshire Moors in the south; it also becomes finer grained in a southerly direction.

Coral Rag - at its maximum thickness it is 9 m thick, consisting of rocks of reef limestones and associated biofacies. In places it passes laterally into oolites. In the Howardian Hills the fore-reef environment was dominant, but to the north in the Hambleton Hills micrites and biomicrites of the back-reef facies occur.

Upper Calcareous Grit. This comprises the greater part of the Oxfordian succession in the hills surrounding the Vale of Pickering. It consists of fine-grained sandstones which are generally more ferruginous than the underlying beds. These beds reach a maximum thickness of 15m and are thought to pass via flaggy beds into the Ampthill and Kimmeridge Clays.

The Ampthill Clay

It was not until very recently that Ampthill Clay type facies of the Corallian was described in the Vale of Pickering Area: in the Birdsall embayment by Wright (1976) and in the Vale of Pickering proper at Marton (Pyrah 1977). It is now know that in fact the Ampthill Clay has quite an extensive outcrop in the Vale of Pickering where it forms part of a fault-bounded mass of deeper water clays and shales, being partly the lateral equivalent of the limestone and sandstone facies of the surrounding hills. In fact many of the low hills fringing the outer margins of the Vale of Pickering at its western end are composed of Ampthill Clay and not Kimmeridge Clay as was mapped by Fox-Strangways (1881), (Richardson, pers. comm.).

The Kimmeridge Clay

This, the highest of the Jurassic strata in Yorkshire, has its outcrop almost entirely obscured by the Quaternary sediments of the Vale of Pickering. The outcrop probably underlies the whole of the floor of the

Vale south of the faulted margin with the Tabular Hills to the north, with the exception of a strip north of the Wolds escarpment where the Speeton Clay is found, and in the west where the Ampthill Clay has been exposed on fault-blocks. The Kimmeridge Clays reach a maximum development of more than 335 metres in the Western Vale (Richardson - pers. comm. 1976). It forms many of the low hills in the more central parts of the Western Vale of Pickering and in the Coxwold-Gilling gap especially south and west of Ampleforth village. The clays which crop out along the Northern Wolds escarpment west of Wintringham village are all thought to be Kimmeridgian, but it is not certain if they extend along the north scarp to at least as far as the Wharram Percy area; at the latter site Oxfordian clays (Ampthill ?) are now known to be present after an ammonite was recovered and identified from the foot of a landslip in the western side of the valley opposite the ruins of the church (SE849642; Hurst pers. comm. 1977). The Kimmeridge Clay consists of hard black pyritous paper shales with beds of impure limestones in the lower parts, the upper horizons are slightly softer and contain few limestone bands (Richarson pers. comm.). Much of the outcrop of the clay is strongly affected by landslip, especially on the flanks of the hills in the Western Vale of Pickering and below the northern escarpment of the Wolds. When weathered the clays are usually mottled blue-greys and browns where they are poorly drained, but are black to very dark grey on a better drained outcrop.

The Speeton Clay

This represents the lower Cretaceous in Yorkshire and consists of a marine clay, the outcrop of which can be traced along the southern margin of the Vale at the base of the Chalk between Ganton and Knapton. Further west it is faulted out and replaced by the Kimmeridge Clay (Neale 1974). Although it has been proved in boreholes beneath shallow drift deposits east of Ganton, no surface exposures are known until the coast is reached at Speeton village. The Speeton Clay consists of a stiff black clay when fresh, which weathers to a greenish-grey plastic clay which is easily distinguishable from the Kimmeridge and Ampthill clays.

The position of the Red Chalk in stratigraphical terms is at present a subject of some dispute. In age it varies from the Albian to the lower Cenomanian and on palaeontológical grounds, should not be included in the same group as the rest of the Chalk; lithostratigraphically however, it can be included with the remainder of the Chalk as it consists of impure limestones (Wood and Smith 1978). The red bands in the Chalk, which are caused by early diagenetic oxidation of iron on the sea bed, form very useful marker horizons for mapping the base of the Chalk (Jeans 1973). It is also easily recognised as an erratic in certain glacial sections on the Wolds escarpment, and, in the tills south of Seamer. The Red Chalk consists of a series of different coloured impure limestones varying from white to brick-red. The thickness of this horizon varies from place to place, but at West Heslerton it reaches 5.5 m.

The White Chalk

In terms of both thickness and physiography the White Chalk is the most important Cretaceous rock in Yorkshire. It has a thickness of 420 m and is divided into 3 major units, the Cenomanian, Turonian and Senonian which are roughly equivalent to the Lower, Middle and Upper Chalk respectively.

The Lower Chalk is a flintless greyish-white micritic limestone of exceptional purity (as is all the chalk) with up to 92% calcium carbonate in the lower horizons. The Lower Chalk crops out along the base of the Northern Wolds escarpment and along the lower slopes of the dip-slope dry valleys in the north-west part of the region. Its total area of outcrop is rather limited, but it is found over the Rowgate and Thorpe Bassett promontories.

The Middle Chalk is generally a hard white limestone which is flintless at the base. The upper horizons of the Middle Chalk contain flints, nodular at first but tabular beds become increasingly important at higher stratigraphical horizons. The tabular flints may vary in thickness from 1 inch to 15 inches (2.5 to 37 cm) and extend over large distances almost without variation. (Wood and Smith 1978 report that flint beds found at Flamborough can be traced as far as Lincoln and possibly Louth in Lincolnshire). The Middle Chalk forms an important part of the Northern Wolds escarpment and is believed to crop out over much of the Northern Wolds. Physiographically this is the most important division of the Chalk.

The Upper Chalk appears to crop out in two outliers in the south-eastern corner of Sherburn Wold (SE 9974) and the southern edge of Ganton Wold (TA 0174). Like the Middle Chalk, the Upper Chalk contains both tabular and nodular flints in its lower horizons and it is thus not possible to distinguish between the Middle and Upper Chalk in the area under consideration, except on palaeontological evidence.

B. Structure

The geological structure of the Northern Yorkshire Wolds and parts of the Vale of Pickering has had a important influence upon the physiographical evolution of these areas to a degree which has hitherto not been properly recognised. Much new evidence has been brought to light during the course of this author's researches which show that there exists a fairly close relationship between the tectonic framework of the Vale of Pickering and Northern Yorkshire Wolds and landscape development. In addition new evidence concerning the number and courses of faults in the Vale of Pickering and disturbances in the Yorkshire Wolds, together with their relationship to one another and to the structure in the Howardian Hills enables us to obtain a clearer picture of what is turning out to be a far

Fig. 6 Section across the Vale of Pickering after Fox-Strangways (1892) showing the postulated existence of a single fault in the Vale of Pickering.

Section across the eastern portion of the Vale of Pickering.

Vertical Scale, Six inches to a Mile; 880 feet to an inch. Horizontal Scale, one inch to a Mile.

Diagram to illustrate the arrangement of the water-bearing strata and the different positions of the artesian wells.

SD. Sandy Drift.
CH. White Chalk.
NEO. Neocomian Clay.
KI. Kimeridge Clay.
C. Calcareous Grit.
OXF. Oxford Clay.
KEL. Kellaways Rock.
EST. Estuarine Shale and Sandstones.

I. The relative position of the Irton artesian well.

G. The relative position of one of the numerous artesian wells sunk at the railway stations and farm-houses throughout this valley.

F. The approximate position of the great Pickering-Brompton fault.

The broken lines crossing the bedding of the strata indicate the position of the saturated rock.

from simple tectonic province. The known details of the structures and their relationships to surrounding structures are given here and will be published in a shortened form in the near future.

Fox-Strangways recognised that the western half of the Vale of Pickering consisted of a graben which was bounded on its northern edge by the Helmsley-Pickering Fault and on its southern margin by the Gilling-Malton Fault. The eastern half of the Vale was not considered to be structurally controlled however, as his section from Wykeham to Ganton shows (fig. 5, Fox-Strangways 1881, 1892). Kendall described the Vale as being a simple faulted synclinal trough (Kendall 1902, p. 499).

Versey thought that the east-west disturbances which cross the chalk of the Northern Wolds, which had been previously recorded by many authors (see below), were due to faulting in the underlying Jurassic strata which had caused buckling and contortion in the overlying Cretaceous strata, and could thus be said to form the eastern continuation of the Howardian Hills structures, and the Vale of Pickering Graben, (Versey 1929). Then and later he considered that faults in the Howardian Hills and Vale of Pickering could be aligned with the major disturbance zones of the chalk (Versey 1929, 1948); although he was able to prove continuity from the Howardian Hills (in 1928); he never proved continuity from the Vale.

Dingle (1971) showed that the contortions exposed in the cliffs of Flamborough Head continued as a series of faults into the western edge of the southern North Sea until they reached, but did not cross, the Dowsing Fault. This latter structure has a long history of both vertical and lateral movements which go as far back as at least the Permian and possibly even further (Brunstrom and Walmsley 1969, Ziegler 1975). This fault marks the eastern limit of the East Midland Shelf - an important region in terms of Mesozoic and Tertiary sedimentation histories (Kent 1974, 1975, 1980). The northern edge of this shelf (or block) is formed by the North Craven Shatter Belt - an east-west line of complex faulting which passes through the area under consideration. To the north of the shatter-belt are the trough areas of Cleveland (on land) and the Sole Pit (in the North Sea). The Market Weighton block forms the tilted northern edge of the East Midland Shelf region and is thought to have been brought into existence by tilting of the granite basement of the latter structural unit (Bott in press).

It can therefore be seen that a complicated structural pattern has begun to emerge whereby a zone of faulting and shattering of the rocks has occurred along the line of junction between two major structural units, and that the Vale of Pickering, North Yorkshire Wolds and Howardian Hills straddle it. However, a glance at any structural map of these areas will show that except for the Howardian Hills, this critical area is almost blank. It is now time to fill in some of the empty spaces.

i. The Vale of Pickering

The northern edge of the Vale of Pickering was originally thought to be bounded by a single continuous major fault which extended from Helmsley via Pickering and Brompton to the coast at Filey, (Fox-Strangways 1880, 1881, 1892, Versey 1948, Wilson 1948, Kent 1974). Richardson has now demonstrated that this is not the case, but in the area between Helmsley and Pickering three major faults form the northern boundary of the Pickering Graben (fig. 7). The Pickering Fault is still thought to be a continuous single structure as far west as Brompton and probably as far as the coast at Filey. The average southerly downthrow of these faults is approximately 170 m (500 feet) but this varies locally and it may be considerably more than the average in some places.

The north western corner of the Vale of Pickering (i.e. between Caulkley's Bank in the south, and Hambleton Hills in the west and a line Helmsley-Pickering in the north) has been recently investigated by

Fig. 7 Map of the major faults and disturbances in the Vale of Pickering and Northern Wolds areas. (Information for western Vale of Pickering was kindly supplied by Mr. G. Richardson of the British Geological Survey).

HELMSLEY
PICKERING
BROMPTON
AMPLEFORTH
NORTH SEA
FOLKTON
STAXTON
GANTON
EAST HESLERTON
KNAPTON
HUNMANBY
MALTON
FOXHOLES
OLD DOR
SETTRINGTON
SELWICKS BAY
RUDSTON
LANGTOFT
SLEDMERE
THIXENDALE
FIMBER
miles 0 5
km 0 8
Disturbances in Chalk
Faults
exposed
course uncertain
Edge of exposed Jurassic outcrop
Edge of exposed Cretaceous outcrop
Edge of concealed Cretaceous outcrop
Craven Shatter Belt
Dowsing Fault

Richardson, who has been able to show that the solid geology of this part of the Vale consists of a series of tilted, twisted and rotated fault-controlled blocks which have been uplifted or depressed by varying amounts. Furthermore he has also shown that this area forms part of a broad anticlinal feature and not a syncline as has so often been believed in the past, (Richardson pers. comm.). Three major structural trends are present in this area: an east-west trend which is found in the extreme west and which passes laterally into the second north-west to south-east pattern. The third major unit is a series of south-west to north-east trending faults. These have caused the area to be intensely block faulted and form a pattern which closely resembles that of the Howardian Hills to the south (fig. 7). This completely vindicates Versey who wrote: "it is not possible to separate the Vale of Pickering faults from those of the Howardian Hills" (Versey 1947). The north-west to south-east fault pattern can be traced further south to the area north and north-west of Malton where it joins a second very important set of faults - the east-west line of the Coxwold-Gilling to Old Dor-Selwicks Bay structures. These latter faults form part of the north Craven Fault system which in turn forms the northern margin of the East Midland Shelf (Kent op. cit.). The southerly continuation of the Pickering Faults and the easterly continuation of the Coxwold-Gilling system (together with a third smaller but parallel fault just north of the Gilling Fault) into the region north and north-east of Malton where the two trends cross one another is impossible to trace accurately. The relationship between the faults in the Vale of Pickering and the disturbance zones in the chalk will be discussed more fully below.

Having shown that the western parts of the Vale of Pickering are broken up into a series of fault-blocks and in view of the tectonic pattern of the Northern Wolds (discussed below) it would not seem unreasonable to assume that the eastern parts of the Vale of Pickering are similarly affected. However, apart from the possible courses of 2 groups of faults, one extending in a north-north-easterly direction from Knapton Wood and a second in a north-north-westerly direction from Binnington to Staxton Brow, the positions or presence of any faults in this area must remain speculative for the time being until more stratigraphical information gained from borehole data is published. It is expected that a complex fault-block system will be shown to be present however.

Cauckley's Bank is a fault-controlled northwards tilted block bounded on its northern, eastern and southern margins by faults. The fault on the southern margin is especially important because it forms part of the Kilburn-Stonegrave fault which in turn is a length of the northern fault of the North Craven Fault Shatter belt. The Kilburn-Stonegrave fault forms the northern margin of the Ampleforth Graben, a structural feature which is reflected in the topography by a long narrow east-west trending valley. The southern margin of this graben is bounded by the second of the major faults of the North Craven system which is known locally as the Gilling-Malton fault. This latter structure forms the southern margin of the Vale of Pickering between Wintringham and Gilling and has a downthrow to the north of between 240 and 300 m (700 to 1,000 feet: Wilson 1948). The downthrow of the Kilburn-Stonegrave fault was estimated to be between 160 m and 180 m (approx. 500 feet) in the area between the two villages - eastwards of this the amount of displacement is not known (Wilson, ibid.). It was long thought that these two major faults, which run parallel to each other for a remarkably long distance between the Dent Fault in the west and the Dowsing Fault in the east and which retain this consistent downfaulted block between them, were not crossed by any other fault structures, but this can now be shown to be unlikely in the Malton-Wintringham area. Richardson is of the opinion that another fault which runs along the south-eastern margin of Cauckley's Bank may also cross the North Craven Faults and join a small fault in the north-western corner of the Howardian Hills near Cawton (fig. 7). Further east in the eastern Wolds around Burton Fleming it would seem that further cross-faulting may also occur (see below).

ii. The Howardian Hills

Little need be written here about the intricate pattern of faulting and folding of this region because this has been more fully and appropriately discussed elsewhere (Versey 1929). It is sufficient to draw attention to the similarity of the pattern of structure with that of the Western Vale of Pickering and the fact that this continues into the North-Western Yorkshire Wolds.

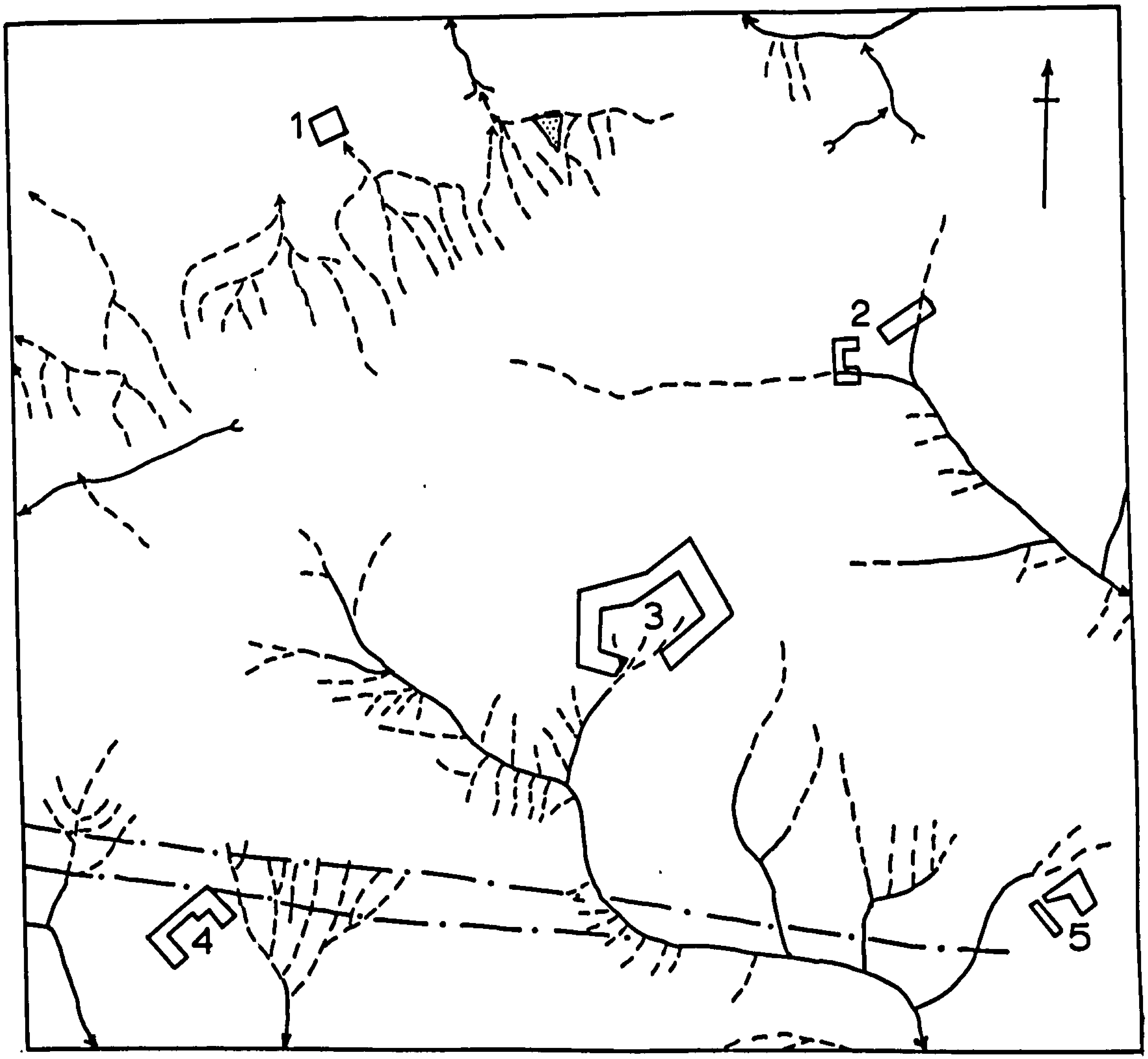
iii. The Northern Wolds

The Chalk of the Northern Wolds forms part of the rim of a south-easterly plunging syncline, the axis of which passes through the escarpment in the area of West Heslerton (Versey 1929, Foster and Milton 1976). Superimposed upon this northern rim is a number of east-west and north-west to south-west trending zones of crushing, contortions, shattering, bulk recrystallization, rotations of blocks and faulting which are related to the North Craven Shatter Belt and its associated faults (Kent 1974, 1980, Foster in prep.). These structures are collectively called "disturbances" and the various results of these earth movements on the macro-petrology of the chalk are illustrated in figs. 12 and 13. Although much has been written about these zones in the past (e.g. Phillips 1875, Fox-Strangways 1880, Davies 1885, Mortimer 1885, Dakyns and Fox-Strangways 1886, Jukes-Browne 1904, Versey 1929, 1948, Walbank 1970, Dingle 1971, Kent 1974, 1975, Neale 1974, Foster and Milton 1976, etc.), very little is known about their nature or courses in the Chalk: they form a "major line (which) is almost invisible on the geological map"

Fig. 8a Air-photograph of Potter Brompton Wold and Ganton Brow (Soil Survey photo).

Fig. 8b Sketch map of the area covered in fig. 8a to show the major features of the area.

1. Dawnay Lodge (SE981767)
2. Ganton Wold Farm (SE995759)
3. Warren House Farm (SE989753)
4. Allison's Wold Farm (SE977744)
5. Cat Babbleton Farm (TA002745)



Line of tectonic disturbance

Dry valley

Dry gullies

Ice-marginal drainage channel

Sub glacial chute

Ganton kame

(Kent 1974, p 27). The fact that the majority of authors since Versey have believed that these structures form part of a continuous line of faulting related to the North Craven Shatter System and faults in the Howardian Hills, did not appear to be reflected in the presence of only three structures shown on the most recent map of the area; this led the authors of the map to write:

"the structure of the East Yorkshire Chalk right across the northern part of the Wolds, could be expected to be much more complex than is indicated" (Foster and Milton 1976, p. 3).

This lack of knowledge concerning the course of the structures in the area is probably due to the incorrect belief that

"the surface of the Wolds for the most part affords very little evidence of the character of the rocks beneath", (Davies1885),

combined with the lack of a proper geological survey of the area since the early 1880's. Instead, it can be shown that by using a combination of evidence derived from air-photographs and ground survey that many disturbance zones are present in the area west of the Hunmanby Monocline, and that more may be present but as yet unproved (fig. 7, table 1, Foster in prep.).

The courses of these disturbances were mapped initially by plotting their positions from 1:25000 and 1:15000 scale air-photographs on to a common 1:25000 scale base map using a Hilger and Watts SB115 Stereosketch. At first only the course of the upturned bedding planes were plotted: later in areas where the courses of the structures were less clear evidence from physiographical features (e.g. gullies, the courses of dry valleys (fig. 8), ridges or knolls (fig. 9) the shape of valley sides (fig. 8)) and angles of dip recorded in various sections by the author and shown on the geological maps in old chalk pits by Fox-Strangways, were all used to trace and locate accurately the courses of the disturbances.

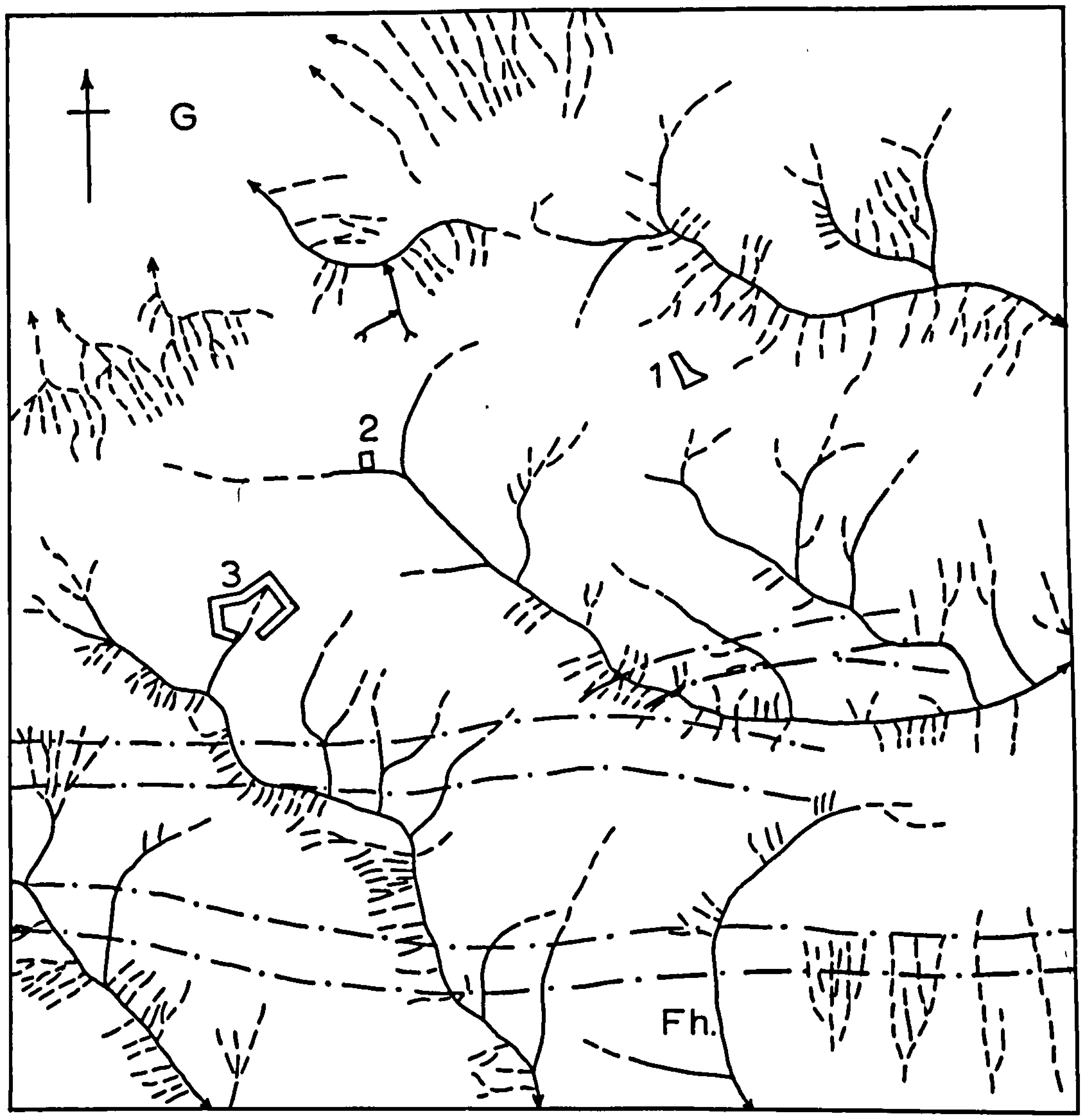
Fig. 9 Structurally controlled linear ridge in the chalk N.W. of Foxholes looking east. Note how the dip slopeof the chalk is broken by the low ridge of disturbed chalk in the centre of the photo. The rough ground (centre-right marks the site of several old chalk pits which are now overgrown. (Photo from SE996734 by Mr. B. Fisher, June 1977).

Fig. 10a Air-photograph of the northern Wolds south and south-east of Ganton. (N.B. north is to the left of this photo). (R.A.F. photograph).


0176

Fig. 10b Sketch map of the area covered in Fig. 10a (N.B. the orientation of this map has been rotated 90°). Fig. 9 was taken from X. The zones of disturbance in the chalk are shown as sub-parallel lines of light/ dark running roughly east-west in the lower part of the photograph. The orientation of Warren Slack and Ganton Dale along lines of disturbance and the presence of many valley-side gullies is noteworthy.

G	Ganton village	
Fh	Foxholes village	
1	Willerby Wold House	(TA012763)
2	Ganton Wold Farm	(SE995759)
3	Warren House Farm	(SE989573)



Line of tectonic disturbance

Dry valley

Dry gullies

Ice - marginal drainage channel

Sub glacial chute

Several independent methods of checking the accuracy of the data obtained from the air-photographs were employed. The first of these was simply to check the angle of dip in an old chalk pit where this coincided with the presence of a structure shown on the air-photographs (e.g. as at Old Dale, SE927717 where the dip of the chalk is 70° and Foxholes TA013734 where the dip is > 70°). It was found that in all cases where a structure as indicated on the air-photograph coincided with a chalk pit the angle of dip of the chalk in the pit (or in some cases temporary or natural sections) was greater than 10° (N.B. the average dip of the chalk in this area is < 5° - Foster and Milton). Most of these data were derived from the geological maps or the author's own field observations, but some useful information concerning the Hunmanby structures was kindly supplied by Dr. D. Chada of the Yorkshire Water Authority. Despite the coincidence of the high angles of dip with disturbances indicated on the air-photographs there were some cases where high angles of dip were found on the ground but there was no corresponding evidence on the photos (e.g. as at Weaverthorpe SE971709, fig. 11, and Langtoft, TA012661). The course of these anomalies was probably due to one of three factors:-

a) the disturbance only affected a very narrow zone of the chalk and therefore was not large enough to be seen on the small scale photographs.

b) the upturned bedding planes were concealed by relatively thick superficial deposits which masked out the courses of the bedding planes.

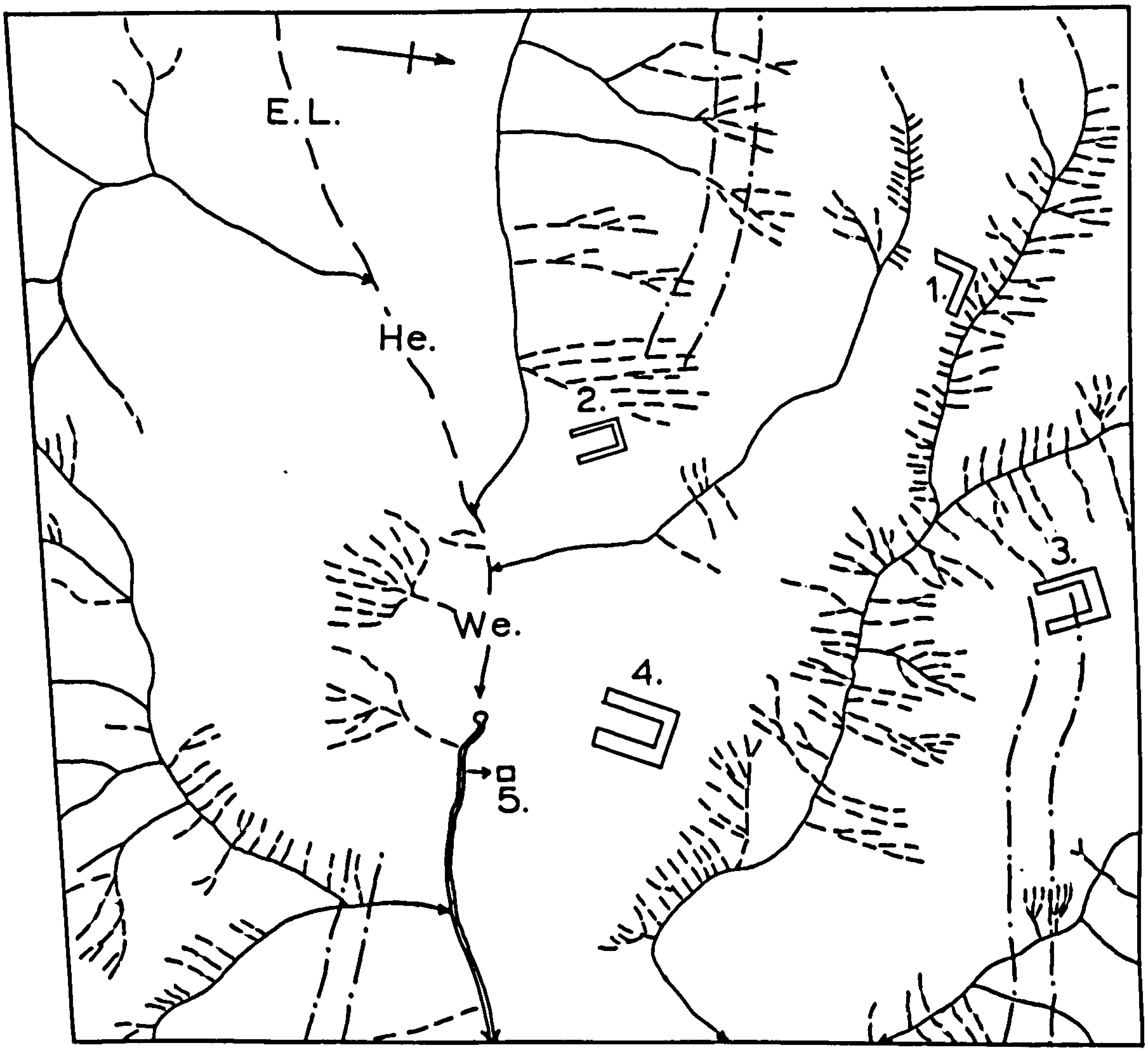
c) the courses of the structures were concealed by a thick vegetation cover - e.g. grass or autumn-sown cereals (the 1:25000 air-photographs were taken in late May and early June 1967, i.e. a time of year when autumn sown crops are up to 45 cm (18 inches) high and quite capable of obscuring underlying small-scale features of the ground surface).

Fig. 11a Air photograph of the Great Wold Valley area around Weaverthorpe. (R.A.F. photograph).


0133

Fig. 11b Sketch map of the area covered in Fig. 11a. Note the absence of data on the photograph to indicate the presence of any disturbances in the chalk in the Weaverthorpe area, even though a disturbance is well displayed in the chalk pit just east of the village (at SE973709).

E.L.	East Lutton village	
He	Helperthorpe village	
We	Weaverthorpe village	
1	Moor Farm	(SE957719)
2	Dotterel Cottage Farm	(SE968713)
3	Dugg leby´s Wold Farm	(SE962738)
4	Gara Farm	(SE971717)



Line of tectonic disturbance

Dry valley

Dry gullies

Gypsey Race

Further ways of checking the validity of the air-photo evidence included the plotting of petrological data characteristics of these structures. This included such features as slickensliding, brecciated and re-cemented gravels, calcite veining, bulk-recrystallisation, etc. It was again found that there was a close coincidence between the presence of the petrological and air-photographic evidence - indeed the former was extensively used to trace the occurrence of the structures where the air-photographs failed to supply adequate information. Topographical features (p. 25) were especially examined for natural or artificial exposures and petrological evidence and again in many cases proof of the existence of structural disturbances were found in the chalk.

The courses of the disturbances are shown on fig. 7 and the details of known exposures are given in table 1. Two major trends are seen to be dominant - a major east-west belt which follows the general line of the Coxwold-Gilling and Ampleforth Faults (i.e. the North Shatter Belt), and a second smaller group of north-west to south-westerly oriented structures.

a) <u>The East-West Trending Group</u>

This forms the most continuous and most numerous group of disturbances in the region, comprising a series of parallel and sub-parallel structures in the area north of a line Thixendale-Sledmere - Langtoft-Rudston. These cross the width of the chalk outcrop, not as single continuous structures as has been hypothesised by some (e.g. Versey 1947), but rather as discontinuous, and in some cases, en-echelon disturbance zones.

Probably the most important are those which follow the general lines of the Coxwold-Gilling and Ampleforth Faults. The line of the latter fault probably crosses the chalk escarpment at Knapton Brow (SE889749) and continues eastwards in an unbroken line to the area around Fordon (TA0274 - i.e. the Sherburn Wold Disturbance - no. 1 on fig. 7).

Fig. 12 Cliffs near Old Dor, Flamborough (TA215732). Normally dipping chalk (just visible on the left of the photo) passes into highly disturbed chalk (in the centre and right of the photo). Height of cliffs circa 95 m.

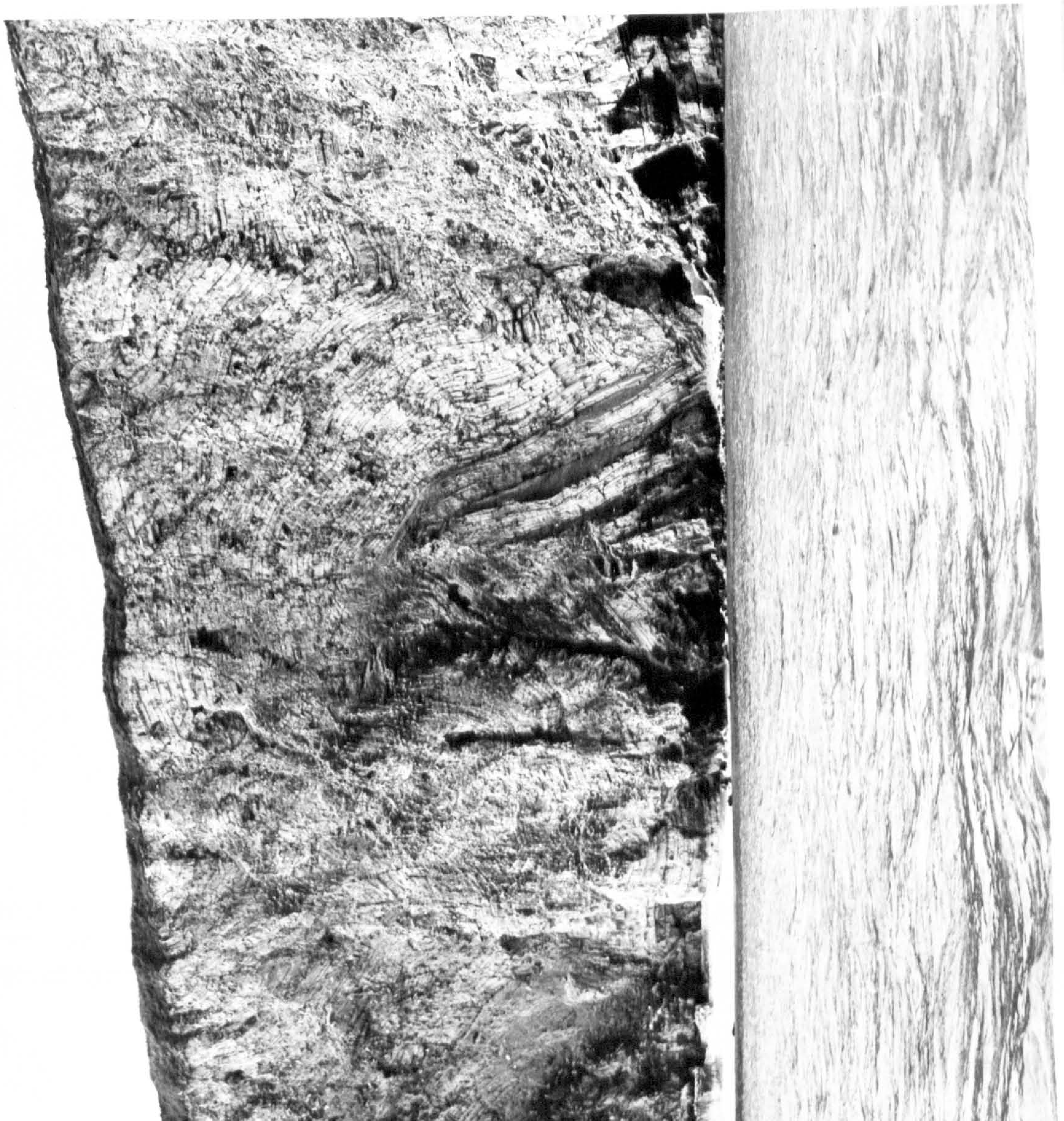


Fig. 13 Detail of folding and disturbance of chalk shown in Fig. 12. N.B. sea-birds give scale. (Photo 12 and 13 kindly supplied by Mr. M. Holliday).

continuation of a fault in the Jurassic rocks to the west (the Leavening Fault). Faults are known to be present here (e.g. the Fairy Dale Fault no. 12, fig. 7), it is possible that part or all of the Vessey Pasture Disturbance may also follow the line of a fault in the chalk. (Mortimer (1885) recorded faulting in Thixendale and Foster and Milton (1976) have reported the presence of a major fault of unknown orientation in this area).

b) The North-West to South-East Trending Group

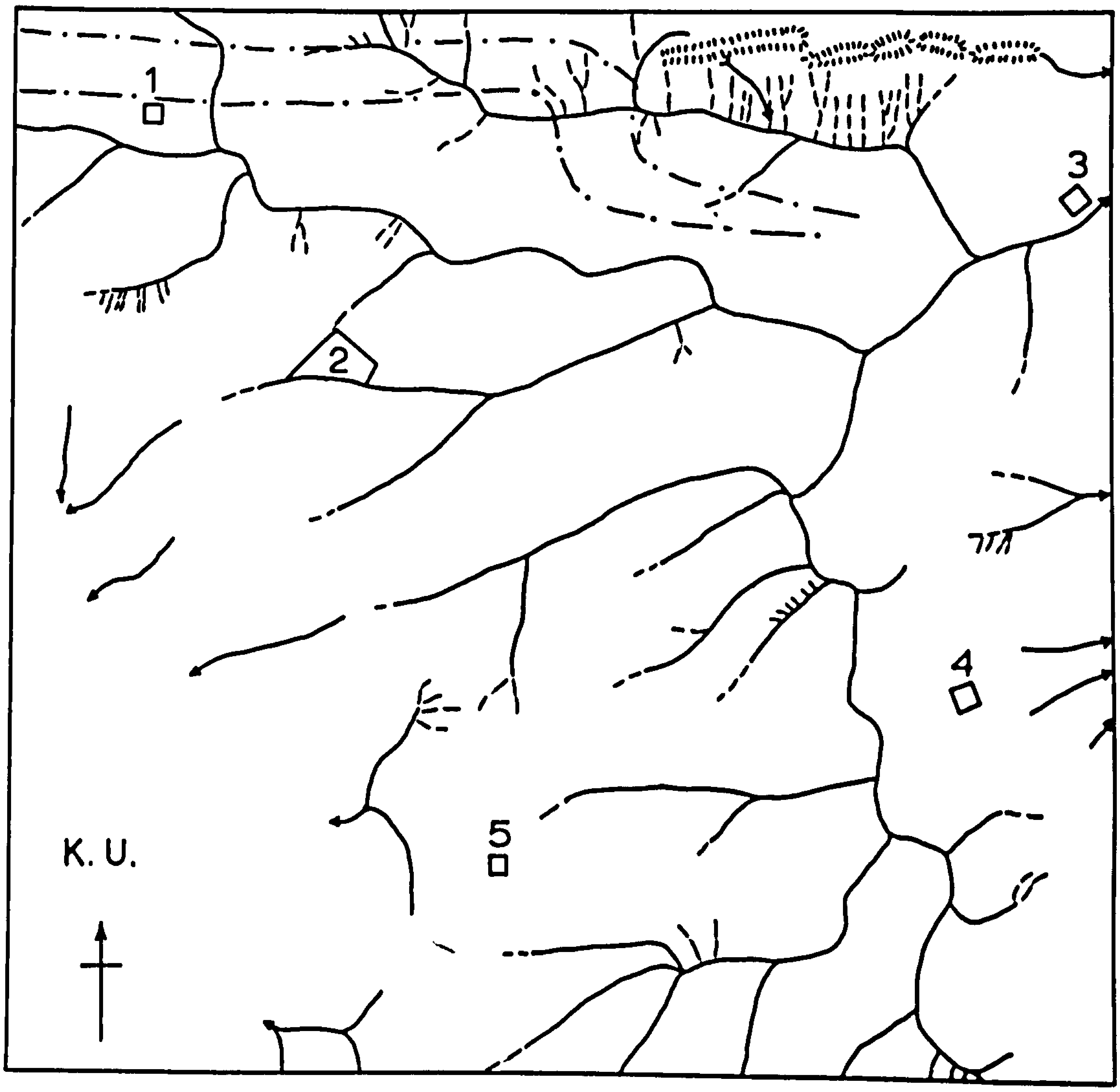
The second important trend of the structures in this region runs from north-west to south-east i.e. a pattern which is similar to that found in the Howardian Hills and Western Vale of Pickering. Structures with this orientation are found in the Hunmanby-Ganton area and in the north-western corner of the Wolds, but they are few in number and shorter than the east-west disturbances.

The most important of the north-west to south-east group is the Hunmanby Fault. (The actual course of this disturbance is N.N.W.-S.S.E. - no. 22, fig. 7). It is interesting to note that the other north-west to south-east trending structures in this area also appear to be folds e.g. the Staxton Anticline and the Binnington Anticline (nos. 18 and 16 respectively, fig. 7). These are probably complementary structures to the Hunmanby Fault, but whether there are synclines between these upfolds or merely stretches of near-flat lying chalk with joints opened preferentially along a N.W.-S.E. axis is still unclear. Woodward and Buckley (1976) found a marked N.W.-S.E. orientation of joints at Flixton Hill chalk pit (TA047778) but no other evidence of disturbance here. In fact Fox-Strangways had recorded abnormally high dips in two chalk pits at Camp Dale (TA058775) approximately 1 km to the south east - this probably marks part of the line of the Flixton Wold Disturbance, no. 20, fig. 7). The severity of the folding in these structures appears to decrease from

Fig. 14a Air photograph of the Wolds south of Leavening (R.A.F. photo).

Fig. 14b Sketch map of the area shown in Fig. 14a. (N.B. the orientation of this map has been rotated 90°). The Raisthorpe Depressions are visible in the top left corner of the photo (top right of map). The angular nature of the meanders in the dry valleys suggests possible structural control in this area. The Burdale Disturbance crosses the left of the photo (top of map).

K.U.	Kirby Underdale village	
1	Brown Moor Farm	(SE809622)
2	Thixendale Grange	(SE819609)
3	Raisthorpe Farm	(SE856617)
4	Uncleby Wold Farm	(SE823595)
5	Gill's Farm	(SE849593)



Line of tectonic disturbance

Dry valley

Dry gullies

Sub glacial chute

Ralsthorpe Depressions

east to west, as does the length of individual fold axes. In addition the orientation also changes (from N.N.W.-S.S.E. on the Hunmanby Monocline to N.W.-S.E. at Binnington Brow). This implies a major movement along a fault underlying the Hunmanby Monocline accompanied by lesser movements along smaller faults which appear to focus on a point at the southern end of the above structure.

In the north-western corner of the Wolds similarly orientated structures have been found. Here faulting has almost certainly occurred in the chalk.

One isolated structure which follows this trend is found at Langtoft (TA0166). Little is known about this disturbance except its orientation, and no adequate explanation is apparent for its anomalous position.

One important conclusion which can be drawn from the study so far and which concerns the scope of this thesis, is the relationship of these structures to the landscape in the Northern Yorkshire Wolds. Although this relationship will be described and discussed in more detail in Chapter V, it is apparent that in some parts of the Wolds the orientation of dry valleys is in part at least strongly influenced by structural trends in the chalk. This applies to both valleys which appear to be oriented parallel to structures for most of their courses, or which change direction as they cross a line of disturbance. The peculiar junction of the three valleys at TA0476 near Flixton Wold is almost certainly unique to chalk landscapes and is very probably a result of the crossing of two disturbance zones in this area. The occurrence of topographical ridges and knolls along parts of the disturbance zones is also noteworthy. Finally there is the possibility (as yet unproved) that in some parts of the Wolds the angle of slope of the valley sides may be affected by the presence of chalk which has been caught-up and altered by these disturbance zones.

Discussion

The first and most important factor to arise from this part of the study is the extreme complexity of the tectonic framework of the Vale of Pickering and Northern Yorkshire Wolds. These areas, together with the Howardian Hills, form a tectonically unified area, to paraphrase Versey: "It is not possible to separate the Vale of Pickering faults from those of the Howardian Hills or the disturbances and faults in the Northern Wolds". The second major feature which requires attention is the different manner in which the Jurassic and Lower Cretaceous strata have reacted to stress by relatively simple, clean faults with relatively little distortion of the surrounding rocks, while the bulk of the Chalk has been severely disrupted in the areas on each side of the faults. Unfortunately it is not known to what degree faulting has occurred in the chalk - faults are certainly present (viz. Versey 1929, Mortimer 1885, Foster and Milton 1976, Jeans et. al., 1978) but equally some of the chalk has clearly reacted by folding (e.g. the Staxton Anticline and the associated structures). Just why a competent rock such as the chalk should react in such a fashion is probably related to the rocks immediately underlying it - over 100 m of Speeton Clay in the Fordon and West Heslerton boreholes, and possibly another 300 m of Kimmeridge Clay beneath that. It is a common phenomenon in coal mines that seams of coal and sandstones (i.e. competent strata) frequently react to faulting in exactly the same fashion as the chalk of the Northern Wolds (i.e. by crushing, rotating of blocks, brecciation, etc.) while intervening shales (incompetent strata) simply react by straightforward faulting. The causes of these differences are not known at present but the presence of thick clays beneath the Chalk in the Northern Wolds does seem to have had a strong influence on the nature of the structures in the latter.

The age of the faulting in this area has been the subject of much previous discussion (see Kent 1974). However, recent evidence (largely unpublished) from the North Sea and the Vale of Pickering shows that this particular line of faulting has been a line of weakness since Carboniferous times and may possibly be older (it has long been known that the western end of the Craven Fault was active in Carboniferous times in the Pennine area). It would appear that sporadic movements have occurred along the North Craven Shatter Belt throughout much of geological time in response to movements between the East Midland Block to the south and the Cleveland and Sole Pit Troughs to the north. Movements on the Dowsing Fault in the North Sea are also related to this activity (Kent 1974, 1975, Zeigler 1975). That these faults were active during the Jurassic is evident from the patterns of sedimentation and during Lower Cretaceous times it seems fairly certain that a narrow east-west trending fault-bounded trough opened up in this area which allowed thick marine clays to develop, (Neale 1974). The sudden disappearance of the Speeton Clay to the west of Wintringham, south of Fordon and east of Hunmanby can all be explained by a fault-bounded trough in this area. The faults were still active during the deposition of the Red Chalk and the lower part of the Upper Chalk as has been described by Jeans (1973) and there appears to be evidence that the Chalk north of Flamborough was deposited in a different basin to that south of the Craven Faults (Wood and Smith 1978). The main movements on thse faults which have affected the chalk must have occurred after the rock had lithified because the nature of the slicken-sliding, brecciation and in places faulting all suggest compact strata (Walbank 1970, Kent 1974). This author supports Kent's suggestion that the most recent movements were quite late - he suggests Pliocene, this author would agree or place them even later, perhaps early to mid-Pleistocene. The reason for this is that Mortimer found two pebbles of Jurassic sandstone in the Fairey Stones which suggests that some form of till cover was probably present when the breccias formed. Another line of evidence may be found in the drainage pattern which is only partly adjusted to structure and is therefore probably antecedent in parts. (There is also the possibility that the drainage formed on a Tertiary cover which has since been entirely stripped away - there is little evidence to support this but see also Chapter IV).

C. Conclusion

The nature of sedimentation in much of the area under discussion in Mesozoic times was dominated by block-fault movements related to the North Craven Shatter Belt and the Dowsing Fault.

The extent and complexity of the structure in this area is only just beginning to be understood however; much more work is required, especially in the Wolds, before it will be fully known. However, the northern margin of the East Midland Shelf can now be clearly defined. It is also clear that a block faulted graben lies between the East Midland and Cleveland Blocks and that tectonic movements in this area have been occurring for a long period of geological time. Some interesting questions still remain unanswered however, such as why the northern edge of the graben should be so clearly defined while the southern edge appears to consist of a series of stepped blocks (Kent 1974); why the main trends of the structures appear to change direction in the Knapton area ?; why do the faults suddenly die out in the Hambleton Hills ?, etc.

It is now clear that the structure of this area is far more complex than hitherto supposed. The relationship between these structures and landforms in the Vale of Pickering is largely obscured by thick drift deposits, but in the northern Wolds there is some evidence which suggests that the courses of some dry valleys may be controlled by structure - this will be returned to in Chapter V.

CHAPTER III

THE DRIFTS AND PHYSIOGRAPHY OF THE VALE OF PICKERING

A. Introduction

The evidence used by Kendall to support his glacier-dammed lake theory has been reviewed in Chapter I and will be discussed further only where this impinges upon the descriptions of new or old material. Little work has been carried out in the Vale of Pickering since the turn of the century and since then a better understanding of glacial processes and processes of peri-glacial environments has been gained; therefore an attempt is made in this chapter to review Kendall's original evidence together with new material gathered from various parts of the Vale. There are however large areas of the Vale of Pickering which have not been properly studied and which may yet yield much information. A shortage of time and resources has precluded a more detailed study of these areas. Despite this however, new evidence has been brought to light which it is hoped will lead a better and more complete understanding of the late Pleistocene history of the area. It is not proposed to give a detailed interpretation of the events of the late Pleistocene in this chapter as some of the evidence submitted may be considered to be ambiguous and of doubtful age. Arguments for and against certain hypotheses will therefore be deferred until Chapter VI when the evidence from both the Vale of Pickering and the Northern Wolds will be jointly analysed and discussed.

The evidence presented below has been divided into the following units: the erratics of the Western Vale of Pickering, the drifts of the northern fringe of the Vale east of Pickering, the southern outwash train, the buried valley, the sedimentary infill of the buried valley, the Seamer-Flixton lake, the post-glacial history of the natural drainage of the Vale, the marginal and lateral glacial drainage channels of the Vale, and the Settrington dry valley.

B. The Erratics of the Western Vale of Pickering

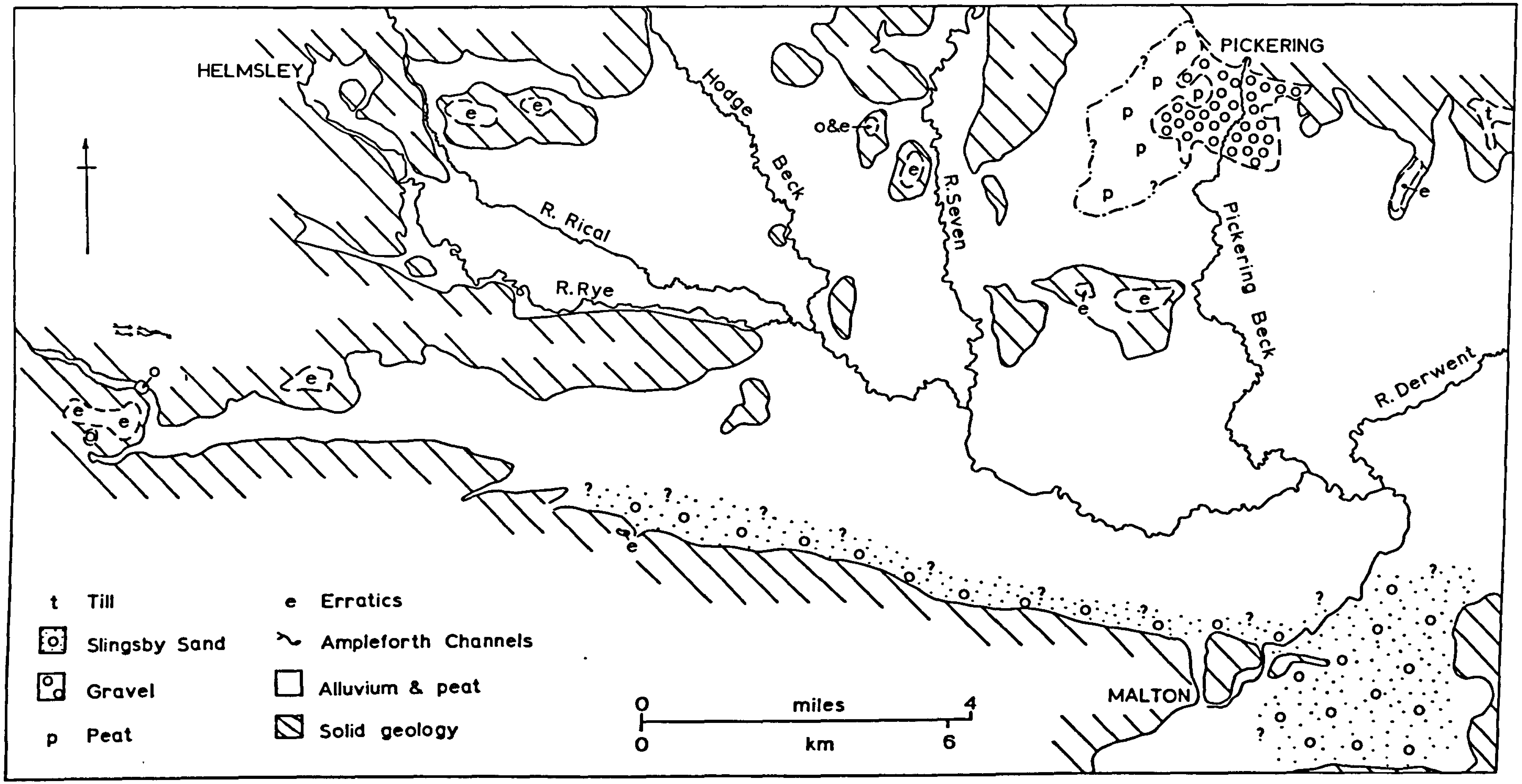
Erratic pebbles and boulders have long been known in the soils and gravels which cap the low hills of the western end of the Vale of Pickering (Fox-Strangways 1880). Indeed the very nature of the soils in some areas is supposed to have influenced the village names - Harome is derived from the O.E. "Harum" - among the stones (Shepherd 1956). Fox-Strangways mapped these erratics as scattered gravels but unfortunately, owing to a cartographical error, they were published as boulder clays or areas of till, thus giving a completely false impression of their nature (fig. 15). In reality the soils in these areas are simply very gravelly in some places and less so in others, especially on the flanks of the hills where pebbles are rare. Kendall knew of the existence of these deposits but paid little attention to them - he was only partly correct when he claimed that the deposits consist solely of locally derived material.

The following details of these deposits have since been established:

i) The deposits described by Gayner and Melmore (1936) - these authors provided the first petrological evidence that pebbles derived from rocks other than those in the surrounding areas were present on the low hills of the western Vale. Quartzites and igneous (dolerite) pebbles up to 5 cm (2 ins) across were recorded. In the area south of Mossburn Bank, near Hovingham, they also recorded the presence of "opaline chert, quartzite of the coarse yellow sort and a small dolerite pebble". (op. cit.).

ii) Marton (SE733838) - in the brick pit of Golden Hill an exposure showed two saucer-shaped lenses of very coarse boulder-gravel set in a matrix of finer pebbly gravel and clay (fig. 16). The larger of the lenses was 11 m wide and 2 m deep, the smaller was 1.1 m wide and 45 cm deep. Both lenses were asymmetrical in shape with the deepest part of the

Fig. 15 Drift map of the western Vale of Pickering showing the revised drift outcrops (after Fox-Strangways (1878), Harrison (1936), Gayner and Melmore (1936), Edwards (1978) and author's mapping. N.B. lack of "morainic" material in the Ampleforth area in the east.


HELMSLEY
PICKERING
MALTON
R. Rical
R. Rye
Hodge Beck
R. Seven
Pickering Beck
R. Derwent
o&e
t Till
Slingsby Sand
Gravel
p Peat
e Erratics
Ampleforth Channels
Alluvium & peat
Solid geology
0 miles 4
0 km 6

saucer lying to the north-west. The infill consisted of large (up to 45 cm long) loosely packed boulders and cobbles of sub-rounded, locally derived fine-grained sandstones, some of which were split and showed that weathering and discolouration extended to a depth of 1 to 1.5 cm below the surface. Boulders which had been deposited near the base of the lenses were hardly affected by discolouration of the surfaces by weathering. The smaller cobbles and pebbles of the matrix were composed of fine-grained sandstones, coarse-grained sandstones (many of which had been bleached to an off-white colour by weathering: the "fresh" colour was of a dark yellow), rare quartzite pebbles and some very rare oolite limestone. Ferruginous sandstone pebbles, ironstones and cherts were also recovered. The matrix of the deposit consisted of a dark orangy-yellow gritty clay. The troughs of gravel rested on between 30 and 45 cm of black, sticky tenaceous weathered upper Oxfordian or lower Kimmeridgian clay which in the unweathered state consisted of hard black paper shales. The course of the gravel-filled hollows could be traced along part of the north-western flank of the hill for approximately 150 m after which the trough-shaped nature of the deposit disappeared and the gravels become a loose collection of scattered groups of pebbles and isolated larger boulders.

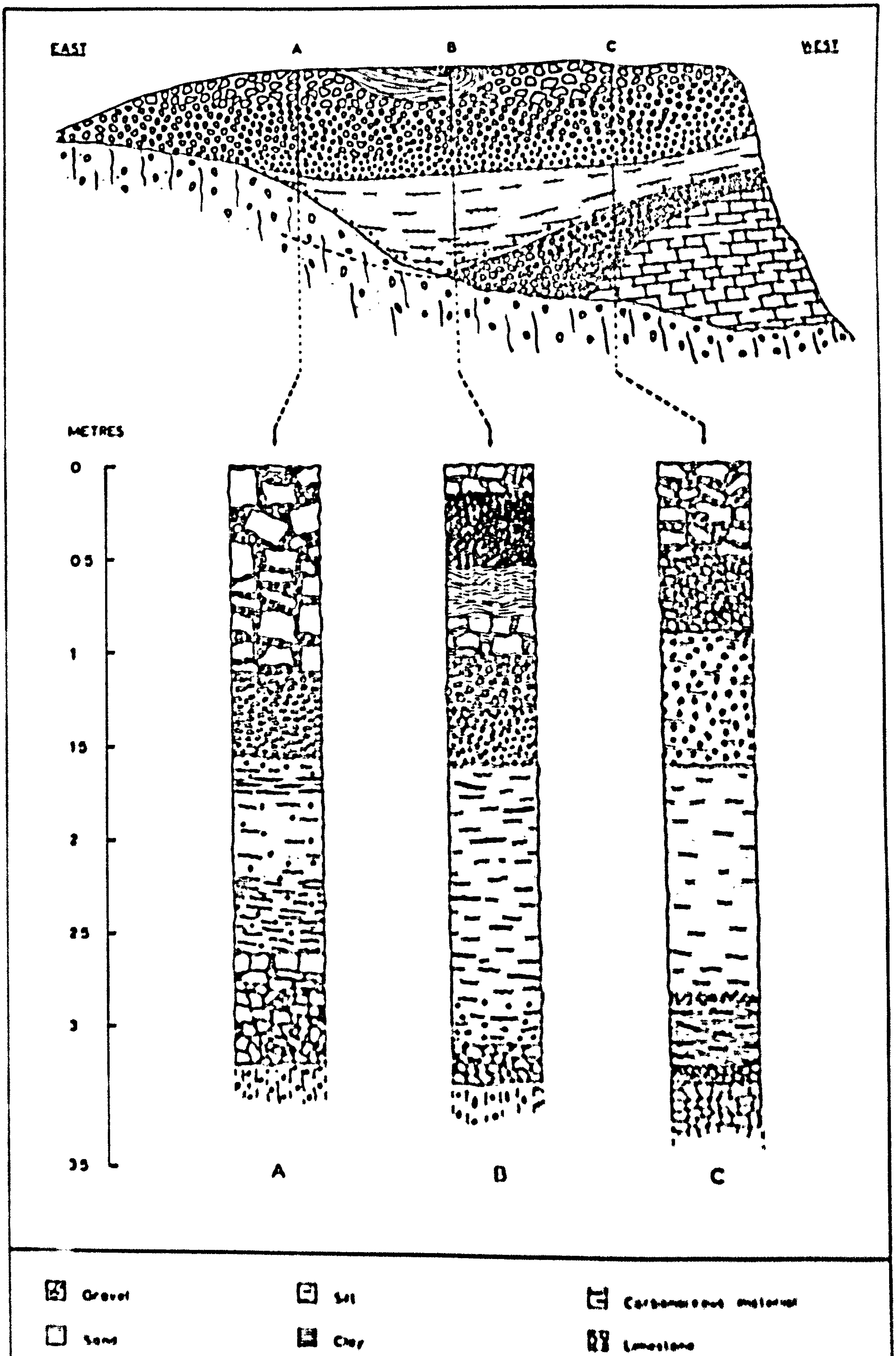
iii) Wath (SE6757500)- in the south-western end of the Vale of Pickering, at the site of the stone-quarries at Wath just east of Hovingham Village a large clay erratic was found. This was found lying upon the limestones in the entrance to the old workings on the western side of Wath Beck behind (i.e. south of) the weighbridge. The following was recorded (fig. 17):

Fig. 16 Section at Marton clay pit, Golden Hill. For details see text.


NORTH
SOUTH
Coarse gravel
Fine gravel
Sandy gravel
Silty clay
Paper shale (weathered)
Paper shale
Length of section approx 13·5m.
Depth of section approx 3·3m.

	Section	Depth to:
A.	Large angular blocks of shelly oolite limestone in a matrix of smaller frost-shattered fragments found in a matrix of fine sand and angular gravel. (Large blocks were up to 38 cm x 35 cm x 21 cm).	1.1 Metres
	Small (5 cm x 2 cm x 1 cm) angular gravel composed of shelly oolitic limestone. Matrix of fine sand and rare driekanter pebbles (Jurassic gritstones). This gravel showed crude horizontal bedding.	1.5 Metres
	Dark yellowish brown fine-grained sand with possible cross or laminar bed-structures. Within the sand lens were scattered small rounded pebbles of quart zite and oolitic limestone. Near the top of this horizon, thin (up to 3 cm) beds of silt were interbedded with sand; the silt became progressively more important towards the base until 40 cm above the bottom of the deposit the sands became a mixture of fine sand and coarse silt. Small discrete fragments and thin streaks of finely comminuted carbonaceous material (? coal) below the top of the sands.	2.6 Metres
	Well cemented, coarse angular rubble composed of local shelly oolitic sandy limestone.	3.2 Metres (base not seen)
B.	Coarse angular shelly oolitic limestone gravel (up to 10 cm x 15 cm x 3 cm) set in a grey fine silty sand matrix.	0.15 Metres
	Grey fine sandy gravel (1 cm) composed of angular fragments of oolitic limestone.	0.22 Metres
	Dark yellowish brown fine gravel (2 cm) composed of angular fragments of oolitic limestone.	0.53 Metres
	Black to very dark grey platy shaly clay; very disturbed and distorted. No fossils.	0.82 Metres
	Coarse blocky angular gravel composed of shelly oolitic limestone set in a matrix of dark brown fine silt (loess ?). This gravel showed fining upwards sequence.	1.05 Metres

Fig. 17 Section at entrance to Wath Stone Quarry as recorded in January 1975. For details see text.



EAST
A
B
C
WEST
METRES
0
0.5
1
1.5
2
2.5
3
3.5
A
B
C
Gravel
Silt
Carbonaceous material
Sand
Clay
Limestone

Section	Depth to:
Medium gravel (8 cm x 3 cm x 5 cm) composed of angular shelly oolitic limestone set in a matrix of fine sandy silt.	1.3 Metres
Fine-grained (5 cm) horizontally bedded, angular shelly oolite gravel with a fine silty sand matrix.	1.6 Metres
Alternating beds of fine sand and coarse silt with no sedimentary structures. Carbonaceous material (? coal) present as streaks of finely comminùted fragments. Small pieces of limestone (3 cm) were found approxmately 20 cm above the base of the sand, these become more common below this level.	3.1 Metres
Coarse grained shelly oolitic limestone gravel - well cemented.	3.3 Metres (base not seen)
C. Large (15 cm) angular blocky limestone gravel with a matrix of sandy silt.	0.5 Metres
Medium grained (8-15 cm) angular blocky limestone gravel with a matrix of sandy silt.	0.9 Metres
Fine (5 cm) angular limestone gravel with much sandy silt matrix.	1.4 Metres
Alternating beds of fine sand and coarse silt with silts becoming increasingly dominant toward the base. A small bed of gravel 7.5 cm thick was found approximately 35 cm above the base of this deposit, and was underlain by very silty sand with streaks of finely comminùted carbonaceous material (? coal). Small pockets (3 cm dia.) of ferruginous sandstone were also present in the lower horizons.	2.9 Metres
Medium (8 cm x 6 cm x 2 cm) angular blocky oolitic limestone gravel, poorly cemented with secondary calcite.	1.8 Metres
Shattered oolitic limestone, in places disturbed by cryoturbation.	2.1 Metres (base not seen)

The pocket of clay in section B varied in thickness from 15-8 cm and was 2 m wide. It was markedly thicker at its western end (where it was 15 cm thick) where overturning had occurred (fig. 17). At the eastern end a small raft of clay had become detached from the main body and was found overlying the latter; the small pocket measured 110 cm x 10 cm and was surrounded by a layer of reddish-brown silt with much angular fine oolitic limestone fragments.

Although this erratic is small by comparison with the size of material which can be transported by ice, it is thought that the relatively compact and undisturbed nature of the clay strongly suggests that it had been rafted on to the limestones by a glacier. Such disturbance as had affected this clay would be accounted for by very limited downslope movement after deposition.

iv) The "Ampleforth Moraine" - Kendall believed that the long ridge of ground south of Ampleforth village was composed of till and comprised a terminal moraine of the Vale of York glacier (Kendall 1902, p. 501). This was shown by Harrison (1936) to be incorrect and that the ridge consisted of Kimmeridge Clay capped with scattered boulders and patches of gravel (N.B. Fox-Strangways had mapped this ridge as Kimmeridge Clay but due to the cartographical mistake mentioned above this was wrongly marked as "boulder clay" on the Geological Survey map). Harrison also described some of the erratic material which he found in the vicinity: at Water Gate Bridge (SE580779) he recorded 0.9 m (3 ft.) of gravel over-lying Kimmeridge Clay but gave no details of the petrology of the deposit. A second body of gravel was recorded by him on Ellis Hill (SE570770) - south-west of Ampleforth village, which contained pebbles of Carboniferous Limestone, Millstone Grit, Chiastolite slate from Skiddaw, various Borrowdale volcanic pebbles and half-a-dozen other unidentified igneous rock types.

Re-investigation of the low hills of the western Vale of Pickering and the Ampleforth area has shown that little can be added to the findings of Fox-Strangways and his successors. Almost all the erratic material is of local Jurassic origin, usually weathered and bleached sandstone and gritstone blocks which may be up to 0.1 m long and sometimes more. Rarely small fragments of weathered oolitic and chert pebbles are found, and quartzites have also been recorded. However, this scattered and somewhat poor collection of material may be of some significance as will be discussed later (see Chapter VI).

C. The Drifts of the Vale of Pickering north of the River Derwent and East of Pickering

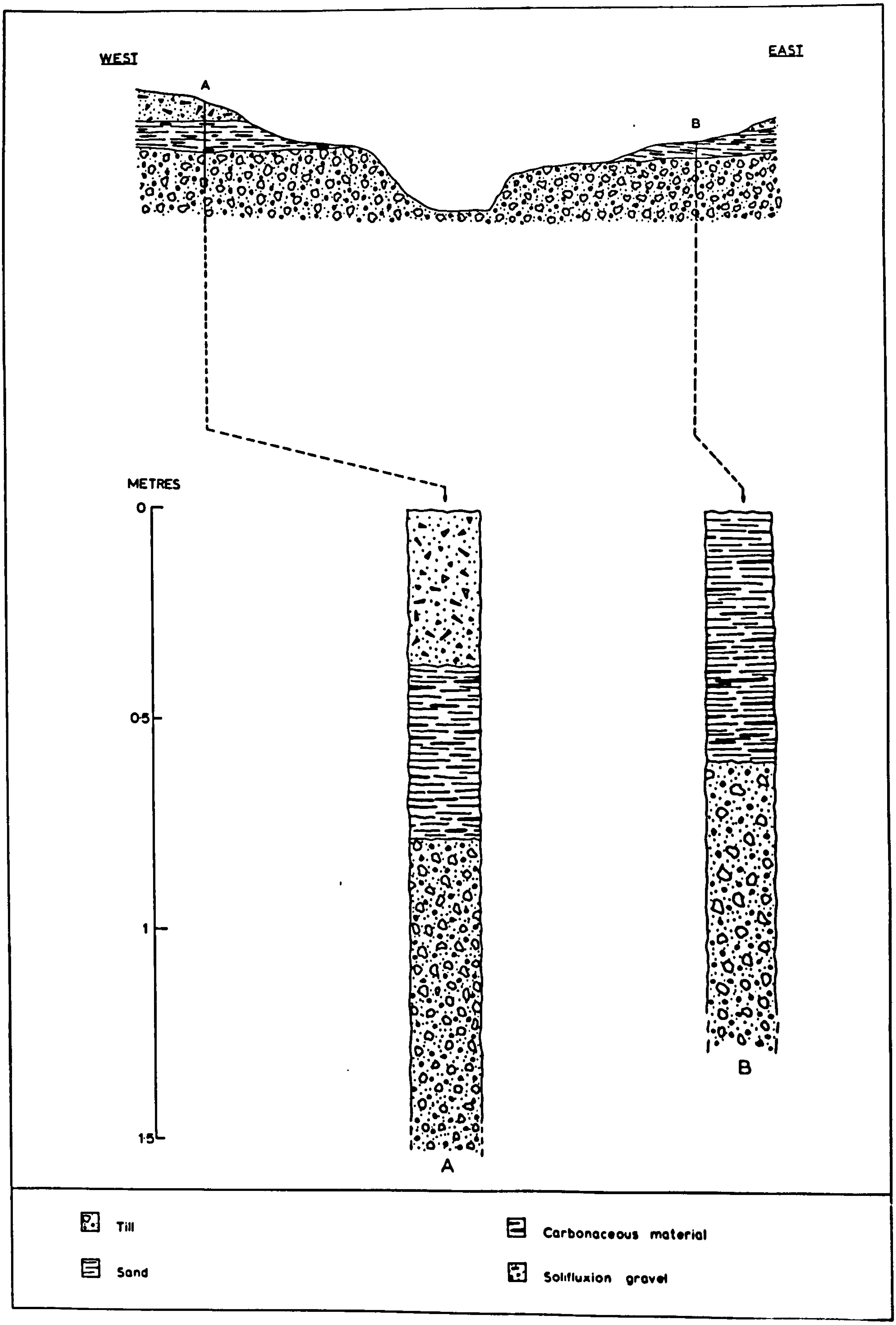
Although there is a large variety of sediments in the eastern end of the Vale, the bulk of them can only be studied from surface exposures - those buried beneath younger, more recent deposits are known only from the results of drilling. The fluvial deposits of the rivers are, or at least appear to be, largely derived from the Jurassic material of the Cleveland Hills and these fill a series of poorly defined channels and hollows in the underlying superficial deposits.

The sediments in the area under study in this section have been sub-divided into the following: the glacial and fluvioglacial deposits of the southern fringe of the North Yorkshire Moors and the northern edge of the Vale; the Carrs; and the alluvial deposits of the River Derwent and its northern tributaries.

i. The glacial and fluvioglacial deposits of the northern fringe of the Vale:

Boulder clays were originally mapped by Fox-Strangways (1880, 1881) capping the low hills of Jurassic clay at several localities on the northern edge of the Vale including Thornton-le-Dale, Wilton and

Fig. 18 Section in till at Church Lane, Thornton-le-Dale (as recorded in April 1976). For details see text.


WEST
EAST
A
B
METRES
0
0·5
1
1·5
A
B
Till
Sand
Carbonaceous material
Solifluxion gravel

Ebberston. Little is known about these deposits: they may be genuine tills but equally they may represent disturbed solifluxion deposits (fig. 15).

Thornton-le-Dale: In the geological survey memoir Fox-Strangways recorded 8.5 m (30 ft.) of clay packed with "doggers" (calcareous concretions) in the railway cutting of the village (SE832822 - Fox-Strangways 1880). A survey of the fields around the cutting only proved the presence of weathered and scattered blocks of Jurassic gritstones and sandstones. According to Fox-Strangways no far-travelled material was found in the cutting, certainly none was found on the surface of the ground in this area.

In the village two sections which were separately cut in till were found: at the junction of Church Lane and Hugh's Street (SE843833) and in the front garden of a house at SE839831. The latter section exposed a mass of dark reddish-brown to reddish-brown heavy clay with scattered pebbles of locally derived sandstones, gritstones and oolitic fragments. The former section was larger and more informative and showed the following (fig. 18):

Section	Thickness
Yellow to dark yellow plane-bedded quartzitic sand with thin streaks and seams of finely comminuted coal.	0.6 Metres
Reddish-brown to dark reddish-brown tenacious sandy clay with many pebbles scattered throughout. Oolitic limestone fragments were the most common rock present, but the fragments were small and very weathered. Rare larger blocks of limestone were grooved (? striated): grooves 0.5 mm - 1 mm deep x 4 cm long. Other rocks included well rounded quartzite pebbles, gritstones, (98% Jurassic remainder Carboniferous), porphyry (provenance unknown), dark fine grained igneous (probably Whin Sill dolerite) and possibly one pebble of Shap granite.	1.2 Metres

The sands described at the top of the section were confined to two depressions at the eastern and western ends of the section. No sedimentary structures other than plane bedding were observed. Overlying the western sand-filled depression was a mass of very sandy clay with much angular oolitic gravel - this almost certainly represents a solifluction deposit as it apparently lacked clear structures: overgrowth of this part of the section by trees and shrubs made detailed study of this section impossible. The estimated thickness of this horizon was 0.35 m. North of the village it was not possible to find traces of these deposits.

Roadworks carried out along the A171 between SE844832 and SE849831 showed that a very similar deposit to that found overlying the till and sand at Thornton-le-Dale was present at the ground surface. The material in the road excavations was very much sandier than that found in the Hugh's Street section; there was also much less oolite and a higher ratio of (poorly cemented) quartzitic sandstone pebbles to gritstones than in the village section. The lack of oolitic material may be a reflection of either weathering or original low concentration or a combination of these.

Wilton Bank (SE65824): According to Mr. S. King (of the Soil Survey of England and Wales) very sandy clays were excavated at Wilton Bank in October 1977 which superficially appeared much like the till at Thornton-le-Dale. However until minerological analyses have been carried out it cannot be known whether they are tills or solifluction-derived deposits. Although tills were mapped in this area by Fox-Strangways (1881) this could have been another example of a cartographical error of the type described in the western Vale above. If the Wilton "till" is only a locally derived solifluction deposit it would have to be assumed that the Thornton-le-Dale material is also of solifluction origin. If however, they are true tills, the presence of much easily weathered oolitic material would suggest a Newer Drift (i.e. Devensian) rather than Older Drift (pre-Devensian) age.

Tills in the Vale east of Wykeham: Tills of probable Withernsea type are found in a wide area across the north-eastern and south-eastern edges of the Vale of Pickering. The outcrop of the till as mapped by Fox-Strangways (1880) does not represent the western limit of till in the Vale however, as exposures in the banks of the River Hertford and possibly borehole data further to the west indicate the presence of tills there.

The section in the bank of the River Hertford was found at the base of the low partially buried hill on which the Star Carr Mesolithic site was established, and can still be seen beneath and a few metres east of the Star Carr footbridge (fig. 19). The upper surface of the till was very uneven and in many places disappeared below river level, but sufficient was exposed to show a very dark chocolate-brown tenacious clay including oolitic limestone, Carboniferous Limestone (with brachiopods, corals including Lithostrotion sp.), gritstones of Jurassic and Carboniferous provence, red sandstones (? Triassic), various porphyries including Cheviot materials, dark fine grained igneous pebbles (including Whin dolerite ?), gneiss, micaceous schists, small ferruginous sandstone pebbles (Jurassic-Estuarine series), etc. Some of the softer pebbles were clearly striated with grooves 1 mm deep x 6 cm long. Two fragments of Oxfordian or Kimmeridgian septarian nodule were recovered from this site. Many of the erratics were of a considerable size - blocks of gritstones from the Cleveland Hills measuring 60 cm x 40 cm x 30 cm were found and material measuring 20 cm long x 15 cm wide was common. Searches in the banks of the river east and west of the above site failed to reveal more exposures. These tills are almost certainly of Devensian age as they pass laterally and apparently without a break into the tills exposed on the coast in Filey Bay, as shown by the borehole evidence.

The fluvio-glacial and peri-glacial deposits of the Northern Vale of Pickering:

These were not differentiated by Fox-Strangways from the sands and gravels which are found on the southern side of the Vale, even though on textural, petrological (in terms of origin of the gravels) and possibly mineralogical grounds the two deposits are quite distinct. Fox-Strangways did make a distinction between the fluvio-glacial gravels which formed the Ayton Terrace-Wykeham ridge complex and the Seamer ridge, which he described as "glacial", and the large spread of gravels which cover the low-lying ground to the south and which were considered to be "post-glacial" in age. In fact it is not possible to separate these deposits - they are petrologically similar and where they are exposed they are seen to overlie or are interbedded with tills. Although they underlie much of the area of the northern Vale west of Wykeham and may in part be of late-glacial (Zone III) or even early post-glacial origin, at present there is no way in which any division of these gravels may be made based on age. The spread of these deposits is extensive - they probably underlie large tracts of the Seamer-Flixton and Wykeham Lakes (see below); they are known to cover the bulk of the area between Wykeham and Thornton-le-Dale north of the River Derwent. However, it has not proved possible to map accurately the limits of these gravels - the southern margin is especially difficult because in the east it is overlain by thick lacustrine peats and clays. Further to the west the River Derwent has so mixed the different sediments of the northern and southern Vale that the outcrops of both become lost in a broad zone of "alluvial" deposits. It is possible that this mixing of sediments from the two edges of the Vale continues at depth below the flood plains of the River Derwent and Hertford.

The clast size of the northern drift is extremely varied - in the gravel pit excavated in the Hutton Buscel terrace for example, boulders over a metre in diameter may be found, while nearby beds of fine silty sand may be present. It would seem that as general rule the coarsest material is found in the Ayton-Hutton Buscel terrace and that the further away one moves into the Vale the finer the material becomes. The average cobble size in the Hutton Buscel area is in the order of 10-15 cm; at Seamer Carr and in the gravel pits to the north it is smaller (5-10 cm). The gravels observed in the banks of the River Hertford at Star Carr were slightly smaller again than the material at Seamer (i.e. circa 5 cm).

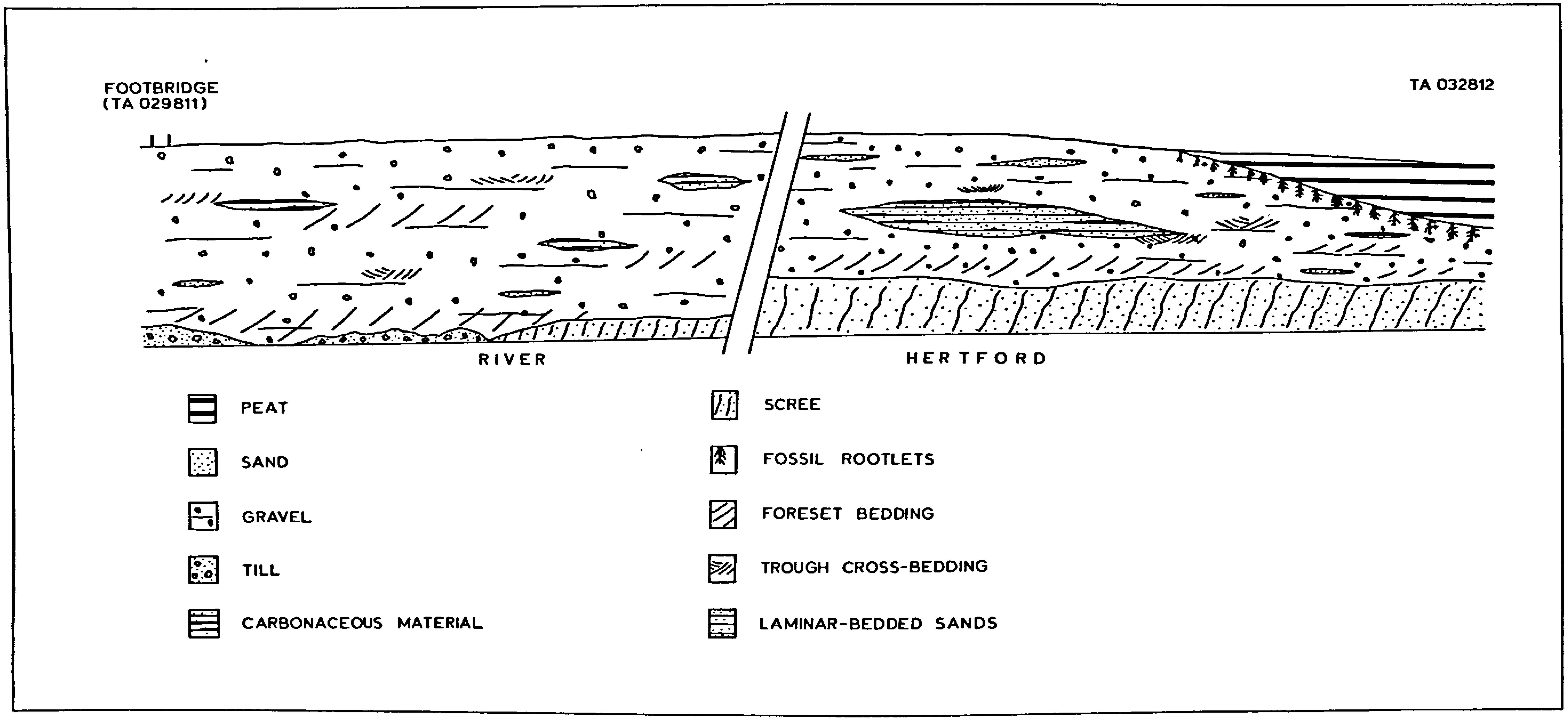
Over much of the area between Wykeham and Thornton-le-Dale a general southwards fining sequence into the Vale was observed i.e. from circa .5cm in the northern fringe to circa .1 cm in the area just north of the flood plain of the River Derwent.

The sources of this material are two-fold - the bulk is derived from local Jurassic rocks (sandstones, limestones and some shales) and farther-travelled glacial erratics. The further west one penetrates into the Vale away from Wykeham the less important becomes the glacial content and the greater the proportion of locally derived material.

Although these gravels occur over an extensive area of the Vale of Pickering, there are disappointingly few exposures. Poor exposures were observed in the gravel pits in the type area at Seamer (TA032833), various pits near West Ayton (SE982745) and a single exposure in the banks of the River Hertford (TA028810). No exposures were observed in the wide spread of gravel over the northern central parts of the Vale. Despite this the following sedimentary structures were recorded:

i) Imbrication: this was most easily recognisable in the coarse gravels at Seamer, West Ayton and Star Carr. (River Hertford). Current directional data (based upon measuring the orientation of the long axes

Fig. 19 Sketch sections of gravels and tills exposed in the north bank of the river Hertford at Star Carr footbridge (TA028810) and the bank to the east. The sectionlies just to the east of the Mesolithic dwelling and probably formed an island in the post-glacial lake.


FOOTBRIDGE
(TA 029811)
TA 032812
RIVER
HERTFORD
PEAT
SAND
GRAVEL
TILL
CARBONACEOUS MATERIAL
SCREE
FOSSIL ROOTLETS
FORESET BEDDING
TROUGH CROSS-BEDDING
LAMINAR-BEDDED SANDS

of pebbles) showed that the dominant flow directions were east-west to south-south-east to north-north-west (fig. 20). Certain of the gravel beds at West Ayton were notable in that they had little or no fine sand matrix (Kendall 1902) but were well imbricated. Directions there showed a wide variation (Franks pers. comm.).

ii) Trough-cross lamination: This was fairly common in the sand lenses at West Ayton but rare at Seamer. The trough-structures were most common in the saucer-shaped sand lenses which were interbedded with the gravels - larger or flatter beds of sand usually contained ripple-drift or laminar bedding. Troughs varied considerably in size from 20 cm deep x 60 cm wide to 2-3 cm deep x 10 cm wide.

iii) Ripple-drift-lamination: this was found in the section at Ayton, Seamer and Star Carr. The ripples were up to 6 cm high x 20 cm long.

iv) Laminar-bedding: this was by far the most common sedimentary structure observed in the sands, and crude laminar structures were also observed in the coarse gravels. Laminar bedded sands had a marked tendency towards fining upwards sequences. In the basal horizons of many of the graded sandy units were found platy fragments of rounded shale and finely comminuted coal fragments - in places this material gave the sand an almost black colour. Occasionally fragments of shale 2 - 3 cm across were recovered in the sands exposed in pits around Ayton; at Star Carr a lens of this material yielded plates up to 1 cm across. Further work on the sedimentology and petrology of the Ayton and Seamer gravels is still in progress (A. Franks, pers. comm.) which it is hoped will become available in the near future.

The current-direction data so far obtained suggest that the bulk of the upper horizons of the Seamer Gravels were derived by high discharge streams, almost certainly of glacial meltwater origin, derived from areas to the north, north-east and east. The sourceof this was probably the rapidly melting and retreating North Sea Glacier. It seems likely that much meltwater passed down the Forge Valley and was then deflected west-wards along the site of the modern Ayton terrace, by a branch of the decaying and stagnant North Sea Glacier which was blocking the eastern end of the Vale of Pickering at this time, (Kendall 1902, 1903, Edwards 1978). The Wykeham ridge may have been built up from meltwater deposits in a crevasse which opened in the northern flank of the decaying ice, but more current-direction data is needed from this area before this hypothesis can be properly tested. Further south at Star Carr the evidence of current-direction data suggest that a south-easterly source was responsible for the upper gravels at least, but it is possible that within the environment of a rapidly melting glacier and an associated rapidly changing topography, this data does not give an accurate picture of the major events at that time. It should be noted here that "Sherburn" facies outwash was found interbedded with "Seamer" drifts at Star Carr and that this could be used as evidence to support the south-east to north-west current direction data.

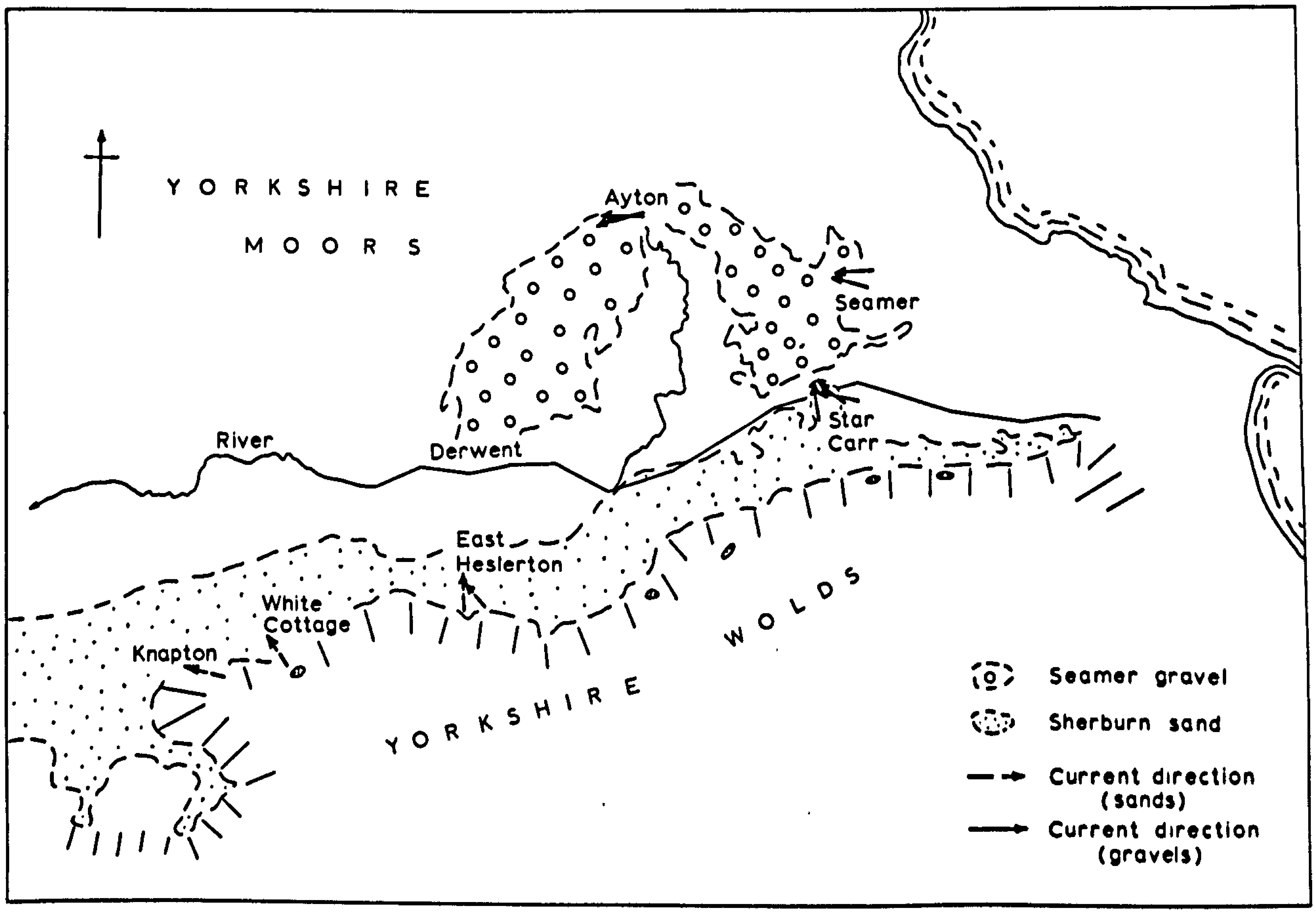
D. The Southern Outwash Train: The Sherburn and Slingsby Sands

The southern outwash train extends along the foot of the Wolds escarpment from Flotmanby in the east to Malton and along the northern edge of the Howardian Hills to Hovingham in the west. This group of sands and gravels were sub-divided by Fox-Strangways (1880, 1881) into the Slingsby Sands (those between Malton and Hovingham); and the Sherburn Sands (between Malton and Flotmanby - fig. 20).

a) The Sherburn Sands

The Sherburn Sands consist of mixed fine, medium and coarse grained quartzitic sands with lenses and beds of chalk and flint gravels. The northern edge of this group of deposits grades into the alluvial material of the flood plain of the River Derwent or disappears under the peats of

Fig. 20 Outcrop of the Sherburn Sands (south) and Seamer Gravels (north) in the eastern Vale of Pickering. Current direction data shown by arrows.



YORKSHIRE
MOORS
Ayton
Seamer
Star
Carr
River
Derwent
East
Heslerton
White
Cottage
Knapton
YORKSHIRE WOLDS
Seamer gravel
Sherburn sand
Current direction
(sands)
Current direction
(gravels)

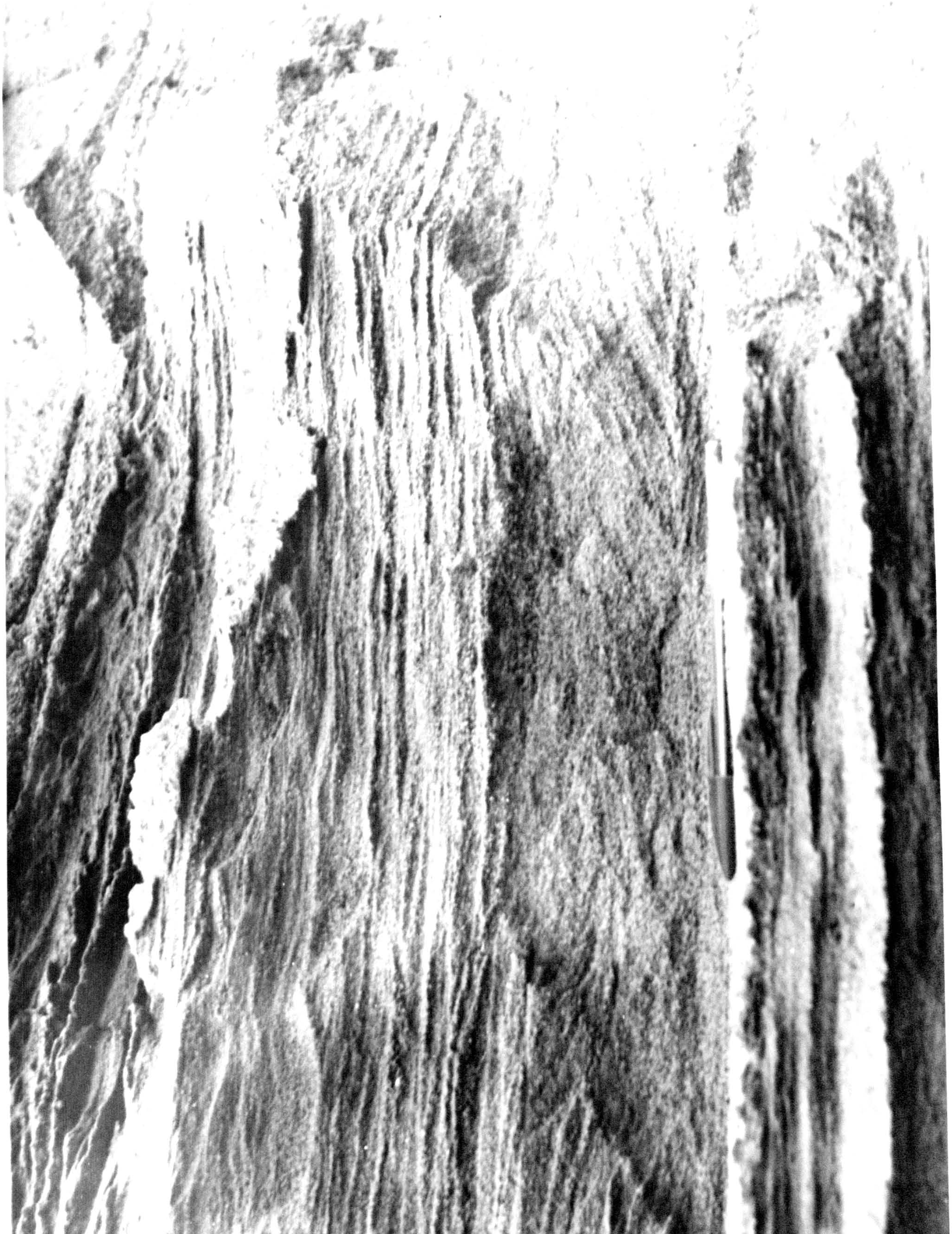
the carrs in the eastern end of the Vale. The rather vague northern limit of the sands mapped by Fox-Strangways (1880) is not particularly accurate but it does broadly reflect what is in fact an almost impossible boundary to define. This author has redefined the boundary using aerial-photographs and drawn the limits of the Sherburn Sands along the southern edge of the flood plain deposits of the River Derwent (fig. 20). The southern margin of the sands is equally difficult to define as much of the thin sandy deposit which fringes the footslopes of the Northern Wolds scarp is probably derived from the Sherburn Sands. Small discrete patches of sand have been found both near the base of the scarp and in positions near the scarp-crest (see Chapter IV for details) which are certainly water laid, so it is possible that some of the sandy fringe at the scarp foot may have been derived from the south at the same stage in the history of these deposits.

Sections in these sands were recorded at the following sites in the Vale of Pickering:

i) East Heslerton: The sand pit at East Heslerton (SE918767) provided much information about these deposits. The sands were observed in the south end of the pit where up to 4.5 m of material was exposed without the base being reached. Sedimentary structures were abundant and dominated by trough-cross bedded units with interbedded lenses of laminar or planar bedded sand (fig. 21). Ripple-drift lamination was rare. The latter were used for current direction analysis and showed an almost consistent south-south-east to north-north-west direction (of a total of 11 readings, 9 were oriented in this direction - fig. 20).

The trough-bedded units varied in size from 10-12 cm deep x 35-40 cm wide (small scale) to 20 cm deep x 70-80 cm wide (larger scale). Graded bedding of the sands was common in the trough-bedded units, and large pebbles of chalk and flint and finely comminuted coal and small (<1 cm)

Fig. 21 Laminar and trough cross bedding in Sherburn Sands at East Heslerton sand pit (SE918767). These bedforms were characteristics in all faces in the sand pit here and at White Cottage (SE901753). Thin seams and streaks of finely comminuted coal were also characteristic. Biro pen gives scale.



platy fragments of dark grey shale were also found. Local evidence of small scale erosion of underlying sedimentary structures was commonly found at the base of the trough-bedded units.

Laminar-bedding (or planar bedding) was found in sequence from only a few millimetres thick to 5-6 cm thick. These too showed evidence of erosion by the overlying trough-bedded sands and were occasionally found to truncate the underlying trough-bedded sands. Lag deposits of coal and shale were also occasionally found on bed surfaces within the laminar sands.

The uppermost 1.5-2m of sands exposed in the southern end of the pit were darker in colour than the underlying material and lacked any signs of sedimentary structures. During a phase of expansion of the pit in early 1977 a Saxon cemetery was discovered which had been buried beneath between 0.5 and 1 m of blown sand (Brewster 1978 pers. comm.). Roman remains at Staxton and a mediaeval farmstead at Sherburn were also buried under blown sand until they were excavated in recent years and this probably shows that most if not all of the structureless surface deposits observed at East Heslerton and elsewhere in the Vale have been redistributed by the wind. (see also Fox-Strangways, 1880).

ii) <u>White Cottage, West Heslerton</u> (SE901753): In this pit, which is now abandoned and partly overgrown, up to 3.5 m of sand were once exposed. Trough-cross bedding and laminar bedding were again recorded, the structures being very similar in size to those of East Heslerton. Comminuted coal and shale fragments were again present in the form of lag deposits. Scattered pebbles of angular flint were found in the upper 1.5 m of sand; the nature of the distribution of these pebbles suggested that they may have once formed near-horizontal beds which have been disrupted either by the collapse of animal burrows (rabbits are particularly common in the southern Vale of Pickering) or to the effects of cryoturbation. Gravel-sized material was almost entirely absent from the lower exposed parts of the sands.

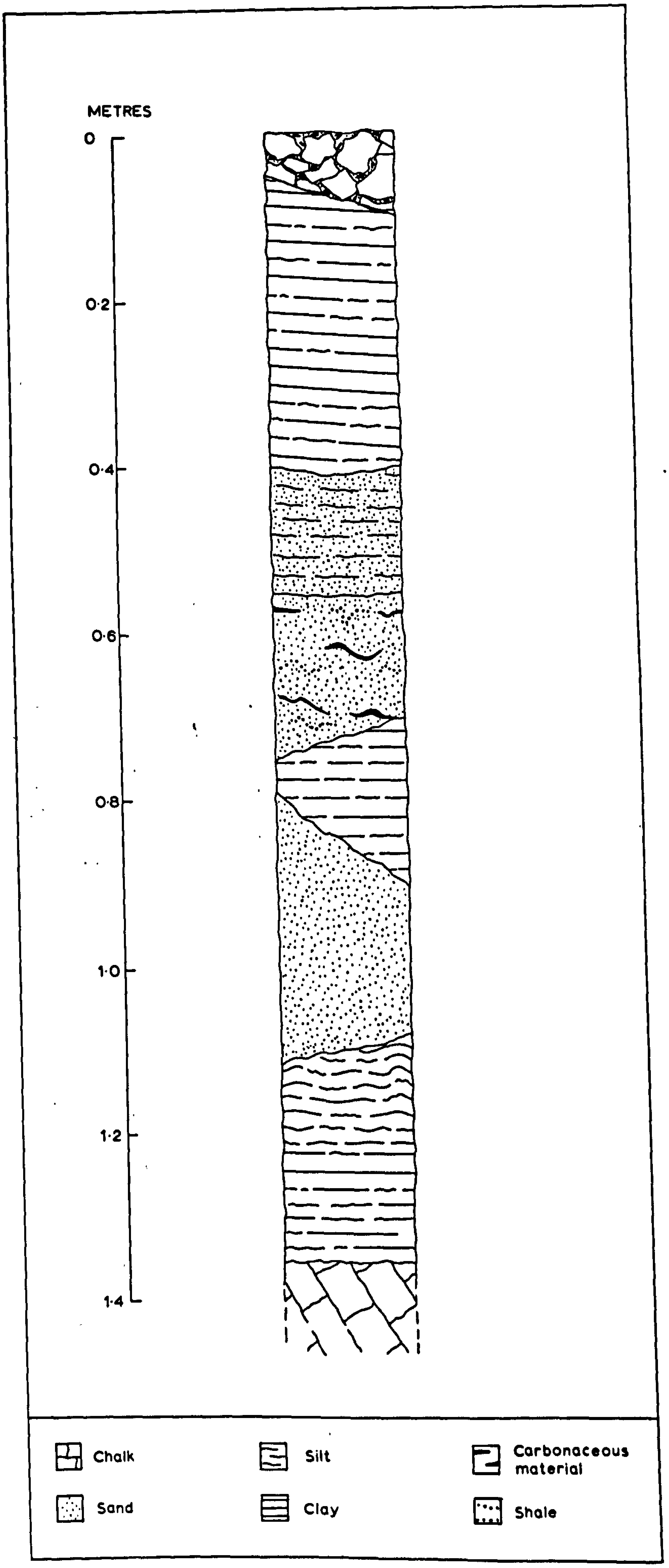
iii) Knapton Plantation (SE897751): In sections in the wood up to two metres of structureless sand with thin (< 5 cm) pebble beds (composed of angular flint) overlaid up to two metres of well bedded stone-free sands. Streaks of comminuted coal and shale were less numerous here than further east but they were thicker (up to two cm thick) and wider (up to 30 cm wide). The upper sand beds, which were structureless, contained between three and five discontinuous pebble beds. The succeeding 0.7 m of sands were laminar bedded and devoid of carbonaceous and shaly material (this is the thickest known sequence of continuously laminated sands recorded in the southern drift train): the basal sands contained trough-cross bedding, planar bedding and a 12 cm thick single bed of ripple-drift laminated sand. The bottom of the sands rested upon an uneven surface which was cut into chalk and flint gravels of solifluction origin and at the base of the sands some local reworking and incorporation of this gravel bed occurred. The sands exposed here appeared to occupy a steep-sided hollow which had been excavated into the underlying solifluction deposits, but slipping on many of the faces obscured the boundary of the sands and gravels so that relationships were almost impossible to determine accurately.

In the northern face of this section a small pocket of dirty yellow sand which was overlain by a bed of red to reddish brown clay (similar to the sandy clays found on the Wolds) was found in a hollow in the chalk (fig. 22). The following was recorded:

Section	Thickness
A. Angular coarse (6 cm) densely packed chalk rubble with scattered fragments of angular flint in a matrix of dark brownish-grey silt.	5-10 cm
B. Blocky dark reddish brown stoneless silty clay.	30 cm
C. Mottled red and pale creamy-yellow densely packed silty sand.	15 cm
D. Medium grained bedded dark yellow, light yellow and off-white highly quartzitic sands with thin streaks of finely comminuted coal and shale. This sand was laminar bedded but the bedding was highly disturbed and distorted, probably during the period when the sand fell or collapsed into the hollow in the chalk. The darker colours in the sand were concentrated near the top of the deposit with the lighter colours in the lower part of the profile.	15-20 cm
E. Dark reddish brown blocky stoneless silty clay. This formed a lining on the sides of the hollow and a horizon across the sands in the fissure.	3-15 cm
F. Medium to fine-grained dark yellow to reddish yellow sand.	17-20 cm
G. Mottled pale-brown and yellowish brown stoneless silty clay, much less blocky than horizon E. There was some microfolding of the upper layers of this horizon.	34 cm
H. White hard blocky chalk dipping at approximately 80° x 227° (south of west).	

Microfolding in horizons D and F (sands) and G (clay) and the inward dipping nature of the plane-bedding in the sands of horizon D suggest that some adjustment by either collapse or pressure from above must have occurred after the sands had been deposited. The sides of the fissure were lined with a variable thickness (between 5 and 30 cm) of red to dark reddish brown clay. Where contact between the clay and sands occurred the sands were stained a dark brown due to the concentration of

Fig. 22 Infill of fissure found in chalk at Knapton Plantation gravel pit (SE897751). For details see text.


METRES
0
0·2
0·4
0·6
0·8
1·0
1·2
1·4
Chalk
Silt
Carbonaceous material
Sand
Clay
Shale

iron-oxide. The fissure was of constant width (45 cm) throughout its depth and the sides of the fissure showed no signs of solution. Because the width of the hollow was the same as the underlying block of chalk it is considered that the original block of chalk which occupied this fissure was probably removed (by glacial plucking ?) and replaced by the sands and clays by the same agency. Texturally the sands in the hollow appear to be similar to those in other parts of the pit. The presence of carbonaceous material in the sands further suggests that these deposits represent a small body of local material which in this instance has been deposited and sealed in a local hollow. The clays were indistinguishable from similar material which can commonly be found on the dip slope of the Wolds (see Chapter IV).

iv) Knapton Gravel Pit (SE889751). The only other sections with recognisable sedimentary structures were exposed in this pit. In the south-east corner of the workings up to 0.8 m of laminar and trough cross-bedded sands were exposed, overlying a lobe of soliflucted angular chalk/flint rubble (figs. 23 and 24). The sands had incorporated locally derived fine chalk (flint gravels in the base) but the bulk of the deposit was pebble free. Overlying the well bedded sands were up to 0.5 m of structureless, weathered, dark brown sands which were rather gravelly near the top (figs. 23 and 24). The lower bedded sands were preserved in an asymmetrical hollow in the underlying chalk and flint gravels, but the uppper structureless sand horizons overstepped the bedded sands and passed on to the underlying gravels. Where the unbedded sands rested directly upon the underlying gravels the thickness varied from 20 cm to 50 cm. No current direction data were obtainable from the sands but the hollow which they occupied appeared to be orientated south-east to north-west. Imbrication in the lower gravels also indicated a south-east to north-west direction of flow.

Fig. 23 Steeply dipping, alternating coarse and fine grained chalk/flint solifluction gravels (grèze s litées) exposed in the east face of Knapton gravel pit (SE889751) in March 1977. The alternating light and dark bands help reveal micro-faulting in the steeply dipping gravels which are turned over towards the south (left) and the whole is overlain by a mixed cover of blown sand and angular chalk/flint gravel which is cryoturbated into the surface of the underlying gravels, (right side of photo). Holes in the face are birds' nests. (Photo by Mr. B. Fisher).

Fig. 24 Sherburn Sands (laminar bedded) overlying solifluction chalk gravel in the east face of Knapton gravel pit (SE889751) exposed in March 1977. The distal coarsening of the noses of the solifluction lobes is clearly shown on the left of the photo. Between 6 and 8 lobes were recorded here filling a hollow in the underlying, steeply dipping finer grain ed grize s litées gravels. The whole section is overlain by blown sands with scattered chalk and flint gravels (the blown sands are probably derived from Sherburn Sands). The hole in the sands are birds' nests. (Photo by Mr. B. Fisher).

A section in the north-east face of the pit observed in 1975 (since destroyed) showed over 2 m of mixed sand and chalk/flint gravel which had probably been deposited in a north-westerly continuation of the hollow described above. The sand lenses were up to 0.2 m thick and the gravels up to 0.4 m - these units were interbedded. Only rarely could examples of planar bedding be found in the sands - other sedimentary structures were not recorded.

v) Other sites: Exposures in the Sherburn Sands were recorded in two abandoned and overgrown pits at Staxton (TA023793). All the faces were badly slipped and overgrown and no sedimentary structures were recorded. The presence of irregular slightly wavy bands of ferruginous sand was noted however. Seven of these ferruginous horizons were present at Staxton, each varied considerably between 5 cm and 15 cm thick and were concentrated in the upper 1.6 m of sands. Similar ferruginous beds were recorded in the southern end of the East Heslerton Pit and in a poor exposure in the sands near Ganton golf course (at SE987778) in 1974. The ferruginous bands at East Heslerton and Staxton lay parallel to the surface of the ground and at the former site appeared to pass laterally into a mass of chalk and flint gravels (see below) where the ferruginous beds died out. The origin of these ferruginous concentrations is obscure but it seems that they are of pedological origin. They are certainly not sedimentological as they were observed to cross bed-structures in the East Heslerton pit, and suggestions that they represent a form of lamination associated with a former Lake Pickering can be discounted (Clark et. al., 1954, Shepherd 1956).

The gravel content of the sands at Staxton was rather greater than further west: there were many more thin seams of chalk and flint gravel and occasionally pebbles of Jurassic grit and sandstone were found. Fragments of chert and quartzite were also recorded, as was Carboniferous gritstone. Further details of the chalk and flint gravels are described below.

Attention has already been drawn to the presence of Sherburn-like sands in the banks of the River Hertford at Star Carr. Walker & Godwin (in Clark et. al., 1954) reported extensive spreads of silty sands and angular chalk gravel interbedded with calcareous muds over much of the old lake bottom south and east of Star Carr. These deposits were thought to have been derived by solifluction during Zone III times from the sands and gravels (i.e. Sherburn Sands) which fringe the northern margin of the Northern Yorkshire Wolds.

In the western end of the Sherburn Sands outcrop only three sections were observed, all of them being in drainage ditches. The old sand pit at Knapton (SE877741) only showed blown sand lying at the surface - replanting of the pit with trees prevented further excavations from being carried out. A drainage ditch at Spring Farm (SE859727) revealed 80 cm of wind-blown, dark brown medium to fine-grained sands with scattered angular pebbles of chalk and flint. This overlaid 20 cm of yellowish brown gravelly medium-grained sands. Below this a further 1 m of gravelly yellow sand was augered. Rare fragments of Red Chalk were found in the gravels in this section but Jurassic, Carboniferous or other far-travelled erratics were absent. A badly overgrown and much disturbed section at Mill Bank House, Thorpe Bassett (SE864729) revealed 2.5 m of weathered (and possibly partly reworked) sandy chalk gravel.

The fields between Thorpe Bassett, Wintringham and Knapton were all very sandy with many scattered pebbles of angular flint and chalk. Many of the fields showed evidence of deflation and redistribution of the sands (in the form of banked hedgerows and field boundaries: such evidence is present over the bulk of the Sherburn Sands outcrop). This blowing of the surface sand deposits made the mapping of the southern limit of the sands in the Wintringham embayment an almost impossible task. However, it could be shown by augering that in the valleys of Wintringham and Thorpe Bassett Becks the sands were thicker than in the surrounding areas under-lain by the chalk.

On the western side of Thorpe Bassett Wold a few hundred metres west of Ebor House Farm (SE837716) yellow sandy gravels were found underlying a variable thickness (0.2-6 m) of slipped and weathered black clay (Kimmeridge Clay). Small platy fragments of black shale and Red Chalk were also found in these gravels. In sections exposed in a pipe-trench to the south of the stream section the Kimmeridge Clay horizon was overlain by sandy gravels which may have been of wind-blown origin, or may have been derived from soil-creep or slip from above.

vi) The chalk and flint gravel facies

Within the Sherburn Sands which are found at the foot of the northern Wolds scarp and on the southern flank of the Vale of Pickering there is a coarse-grained facies which has not been described so far. This consists of mixed sub-angular chalk and angular flint gravel which is mixed with considerable quantities of sand. These gravels are described here as a separate unit but the relationships between the sand and gravel facies shows that they were deposited contemporaneously.

a) East Heslerton Pit (SE918767): gravels were confined to the northern half of this pit where approximately 2.5 m of gravel composed of mixed chalk (85-90% of total gravel fraction) and angular grey and white flints were exposed. The gravels were relatively loosely packed and had a high proportion of sand matrix (circa 60% fig. 25). The gravels were overlain by circa 1-1.5 m of dark brown blown sands so no indication of their presence was visible at the surface. The presence of this thick blown sand cover made mapping of the lateral extent of the gravel body into the Vale impossible. No bed-structures were visible in these gravels

Fig. 25 Particle-size distribution curves for Sherburn Sands from the Vale of Pickering.

Lines on graph are numbered as follows:-

______________ 1
___ ___ ___ 2
_ _ _ _ _ _ 3
__ .. __ .. 4
.... 5

For original data see table 5 e.g. to read graph C4 look up line 4 (__ .. __ ..) on graph C. Then find "graph_C4" in table 5.

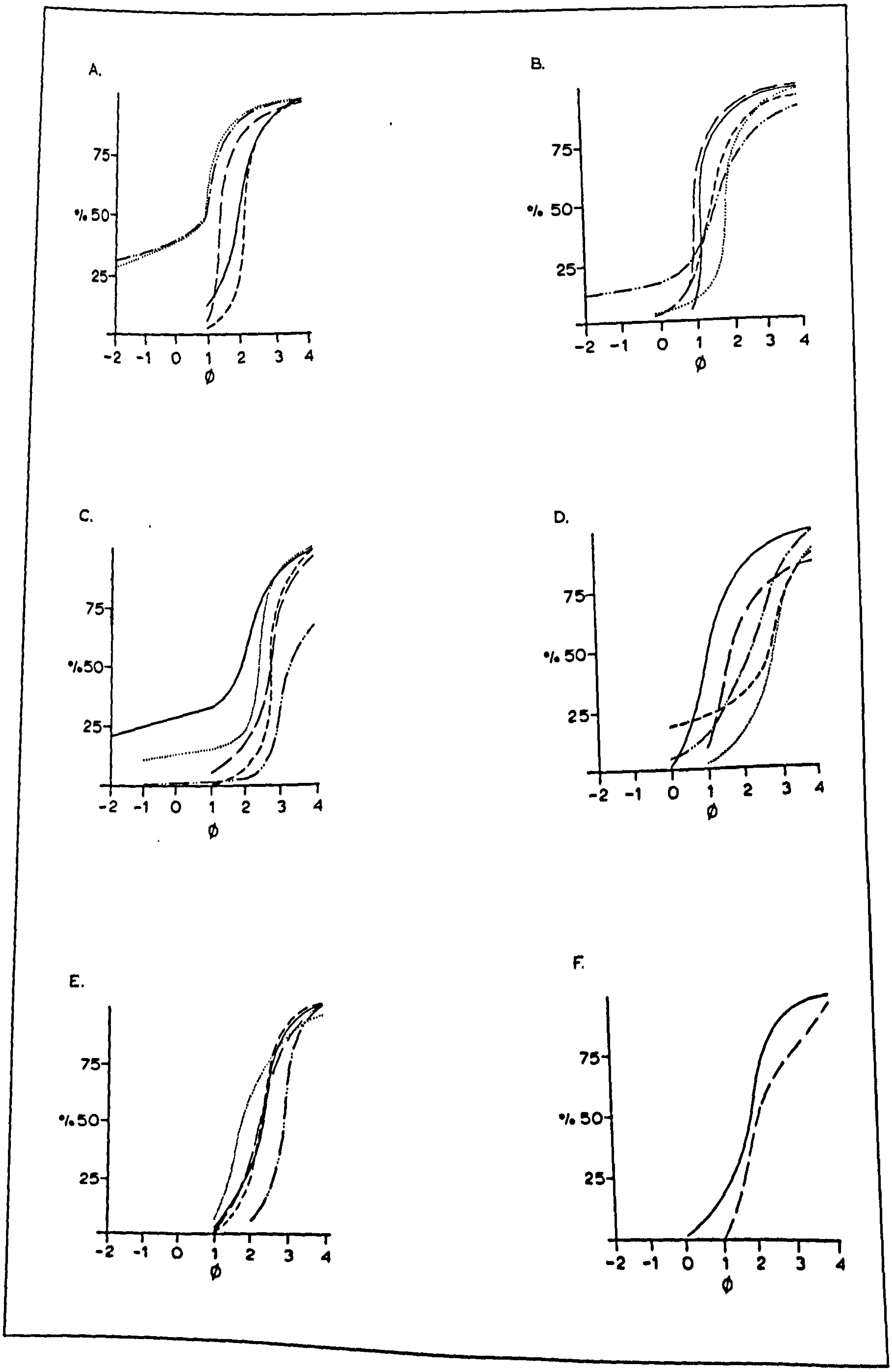

A.
75
% 50
25
-2 -1 0 1 2 3 4
ø
B.
75
% 50
25
-2 -1 0 1 2 3 4
ø
C.
75
%50
25
-2 -1 0 1 2 3 4
ø
D.
75
% 50
25
-2 -1 0 1 2 3 4
ø
E.
75
%50
25
-2 -1 0 1 2 3 4
ø
F.
75
% 50
25
-2 -1 0 1 2 3 4
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Fig. 26 Involuted chalk/flint gravels with Sherburn Sand matrix, East Heslerton sand pit (SE918767). Photo taken at the north end of the pit in May 1975 by Mr. B. Fisher.

as they had been severely disturbed by ground-ice and frozen ground activity (see Chapter V for details and fig. 26). It has not proved possible to determine the thickness of the gravels in the pit - they are thought to be not very thick (probably no more than 5 m) as borehole data from other parts of the Vale suggest that surface gravel lenses are generally poorly developed (see below). Scattered in the gravels were rare pebbles of Jurassic sandstones and gritstones and even rarer dreikanter pebbles.

The junction between the gravels in the north end of the pit and the sands in the south (see above) was unfortunately largely obscured by backfill but appeared to consist of a series of interfingering lenses of sand and gravel which extended over a horizontal distance of circa 100 m. Thus the gravels thinned and became progressively more sandy to the south while the sand lenses thinned and become more gravelly to the north.

b) Knapton Plantation (SE901751) and Knapton Gravel Pit (SE889751): the gravels at these sites have been described in passing above - suffice to say that the coarse clastic material appears to have been derived from locally reworked chalk and flint solifluction gravels, into which considerable quantities of sand have been incorporated.

c) Sutton Grange (SE80357065) The western extension of the sands and gravels into the Settrington embayment was only indicated by the nature of the soils of the area which remained very sandy, albeit with local pockets of chalk and flint and Jurassic-derived gravels. A section in a gas-main trench at the entrance to a new housing estate on the old site of Sutton Grange (SE80357065) showed the following:

Section	Thickness
A. North Side of the Entrance	
Very compact yellow sands, medium to fine grained, structureless	60 cm
Fine (<4 cm) yellow sandy angular chalk gravel	53 cm (base not seen)

Where the section of the trench turned through 90° (to a line east-west) the section showed:

Section	Thickness
Very compact medium to coarse grained yellow sand	30-50 cm
Blue-grey tenacious clay with gastropod remains (see faunal list below). In the upper horizons several blocks of shelly oolitic limestone were found; at the base several fragments of coal and shale.	variable from 0-95 cm
Very sandy angular chalk gravel (< 4 cm).	10 cm (base not seen)
B. South Side of the Estate Entrance	
Dark grey to black, organic-rich sandy topsoil	22 cm
Very dark yellowish-brown medium grained sand with small rafts of blue-grey clay scattered throughout. Occasionally small phosphate nodules were found in the clay rafts which suggests that the latter were derived from the Kimmeridge Clay.	85 cm
Very small (0.5-1 cm) sub-angular chalk gravel with much coarse to medium-grained sand matrix. Rare large pieces of chalk (up to 7 cm) scattered throughout. The horizons (upper 22 cm) were a bright orangy-yellow but the lower parts of the profile the gravel became a darker greyish-yellow colour. (Fragments of Red Chalk, coal and large fragments of oolitic limestone were found in the spoil from this trench).	80 cm (base not seen)
C. Section approx. 50 m south of 'B'	
Very dark yellowish-brown sand, slightly coarser than in section 'B'	38 cm

Section	Thickness
Small (<2.5 cm) sub-angular chalk-gravel with yellow sand matrix. The upper surface of this gravel was very uneven and showed evidence of local erosion	25 cm

In the chalk gravel in the lower part of section 'C' a large block of oolitic limestone (27 cm x 18 cm x 15 cm) was found. This block was weathered from between 1 and 1.5 cm below the surface, but below this the processes of weathering do not seem to have penetrated.

The gastropod remains found in the clays of section 'A' were kindly identified by Mr. A. Norris of the City Museum, Leeds, who found:

Species	Number Present
Carychium minimum (Muller)	1
Oxyloma pfeifferi (Rossm)	4 + fragments
Cochlicopa lubrica (Muller)	2 + fragments
Aegopinella nitidula (Drap)	1
Oxchilus cellarius (Muller)	1
Euconulus alderi (Gray)	1
Candidula gigantii (L. pfe)	2
Trichia hispida (L)	4
Cepaea sp. ?	fragments
Lymnaea truncatulata (Muller)	4 + fragments
Anisus leucostoma (Millet)	1
Pisidium personatum (Malm)	1

(nomenclature after Walden and Kerney (1976))

The following comments were supplied by Mr. Norris:

"Most species are represented by single examples so a count of specimens tells us nothing. The occurrence of *Candidula gigantii* suggests that the deposit is very recent indeed, possibly only a few hundred years old. The habitat by this small assemblage is possibly a small marsh formed just below a spring line".

Although no surface springs are found near or on the site at present, the lower gravels in the sections were waterlogged and indicated the presence of a high-standing water-table. A spring at SE799701 to the west of this site is presently found in a very similar situation to that which may have existed on the site of the gastropod-bearing clays and which could be evidence in support of Mr. Norris' suggestion. These springs and possible spring sites appear to be controlled by an east-west fault, (either one of the North Craven faults or one of the parallel minor faults which form part of the Craven Shatter Belt), which throws the Kimmeridge clay down on the northern side against the Corallian oolitic limestone aquifer which lies to the south. If there was a spring-marsh here it appears that inorganic sedimentation was responsible for causing the final sedimentation of the hollow rather than organic materials and peat. The source of the inorganic material may have been sand and silt blown in from the surrounding area, combined with fine-grained material carried in suspension by the rising spring-water. A fall in the local groundwater table, caused either by artificial draining of the land or abstraction of water from local wells may explain the original drying up of this particular spring.

The underlying mixed sands and gravels may be of fluvioglacial origin; the mixture of chalk/flint gravels and blocks of oolitic limestone suggests that some of the material could have been derived through the gap in the Jurassic ridge to the south (at Newstead House: SE810701) or as a mixed deposit which was being moved laterally along the northern edge of the ridge from east to west.

d) <u>The Slingsby Sands</u>

The Slingsby Sands are even more badly exposed and poorly known than the Sherburn Sands. The Slingsby Sands appear to form a lateral continuation of the Sherburn Sands; the former extend along the northern edge of the Jurassic outcrop of the Howardian Hills. Only one exposure has been recorded in these sands at Slingsby Village (SE701748), where 3.2 m of deposits were recorded. The bulk of this material however was slipped and overgrown. Small clean sections showed the presence of trough cross-bedding (the "false-bedding" of Fox-Strangways, 1881) and laminar-bedding. The size of these structures was the same as had been recorded in the sands at East Heslerton. The particle size of the material was also similar to the Sherburn Sands (i.e. between 120 μ and 80 μ : fig. 27). A cover of blown sands and loess between 0.3 and 1.2 m thick which also contained small pebbles of Jurassic gritstones (including a dreikanter pebble) and oolitic limestone was present throughout the exposed parts of the pit.

The northern edge of the Slingsby Sands disappeared in the alluvial deposits of Wath Beck, Slingsby Carr Cut (a natural stream which has now been strictly controlled) and the River Rye. The southern margin consists of a fringe of wind-blown material which overlaps the underlying fluvial sands and passes onto the northern edge of the Howardian Hills. Where the fault-scarp of the Gilling-Malton Fault is particularly well developed (e.g. between Appleton-le-Street: SE734737 and Barton-le-Street: SE744742) the thickness of the blown sands is markedly thicker (over a metre has been augered without the base being found in several places along this scarp). The western limit of the sands is very difficult to define: Fox-Strangways mapped it near Hovingham and recorded a belt of gravel between that village and the southern edge of Caukleys Bank (at SE670780). This author could not find any substantial evidence for either of these conclusions. It would seem from the nature of the soils in the area west of Hovingham that large patches of blown sand and silt are present overlying a clay subsoil, but the possible presence of undisturbed Slingsby Sands, alluvial sands and other fluvio-glacial deposits cannot be ruled out.

Comparison of the Southern drifts of the Vale of Pickering with those of the Northern Outwash Train show some marked differences. Firstly the southern drifts are generally much finer and contain far less gravel than their northern counterparts; they are also much better sorted. Secondly the constituents of the gravel fractions of the two deposits are markedly different: those of the northern drifts consist largely of Jurassic-derived material with a substantial proportion of older rocks derived from areas beyond the North Yorkshire Moors. The Sherburn gravels on the other hand are almost entirely derived from the Chalk to the south, and the few "foreign" pebbles found are almost entirely Jurassic gritstones. The Slingsby gravel component (which forms a very small fraction of the whole outwash deposit) is almost entirely derived from the Jurassic rocks of the Howardian and possibly Hambleton Hills.

Finally both the Northern and Southern Outwash trains have yielded evidence in the form of bed-structures which reveals that these sediments were deposited by streams and not in a lacustrine environment (fig. 21). Some reworking of the surface layers by wind is apparent in the southern drifts but this seems to have been less important in the case of the northern outwash - probably because the latter are generally very much coarser.

e) The Mineralogy and Particle Size of the Southern Outwash Train

i) Mineralogy: The full details of the mineralogy of the Sherburn and Slingsby Sands have yet to be properly described, but three samples were taken from widely separated localities to try to assess any major differences over the combined outcrop. The localities were White Cottage sand pit (SE901753), Slingsby sand pit (SE701748) and a small patch of sand on the northern Wolds scarp at Flixton Brow chalk pit (TA039793). In addition a sample of blown sand was taken from Sewerby Cliff (TA202687) in an attempt to test the hypothesis that the Sherburn and Slingsby sands might have been derived from pre-Devensian sands in the North Sea Basin. The mineralogy of the four samples was studied by Dr. J.A. Catt who kindly compared them with the average of three groups of samples taken from the Holderness tills (table 2). He also made the following observations:

"There are considerable differences between the four samples. Because of the abundance of pink garnet, brown hornblende, augite and a few other minerals I feel that the Sewerby sample is not really related to the others. Although the differences between the other three are quite strong I would say that they are probably best explained in terms of mixing (in varying proportions) of two components. One component (abundant in the Slingsby sample and to a lesser extent in the Flixton Brow sample but much less common in the White Cottage sample) is rich in zircon, colourless garnet, rutile and possibly tourmaline among other non-opaque heavy minerals, which is a fairly resistant assemblage, the sort of assemblage in the south of England I would associate with sediments older than the Pleistocene, The other assemblage is rich in epidote, hornblende, augite, chlorite and biotite and is almost certainly glacial in origin. However, it does not fit terribly well with any of the Holderness till analyses that Paul Madgett did. In the abundance of hornblende, epidote and augite it fits the Basement Till best, but the Basement contains too little chlorite and biotite. In contrast the Devensian tills contain rather more chlorite and biotite, but not enough hornblende; the Skipsea Till probably contains enough augite and epidote but the Withernsea Till does not".

"Probably the best fit is with the Basement Till and the worst with the Withernsea, but if the glacial component of the sands were derived from the Base-ment, say during the Ipswichian or early Devensian, there would probably be winnowing by wind action to increase the proportion of the flaky minerals chlorite and biotite".

Two major points arise from Dr. Catt's analysis and discussion. The first of these is that he associates parts of the mineral assemblage with suites derived from Tertiary sediments in southern England. It will be shown later (in Chapter IV) that Matthews (1977) has independently suggested that late Tertiary remanié deposits may exist in solution fissures on the northern Wolds: Versey (1937) had earlier suggested that possible Tertiary sediments were preserved in solution pipes in the north-western area of the Wolds around Thixendale and Fimber. Comparison with Miocene deposits preserved in solution hollows in the limestones of the Derbyshire Dales (Walsh et. al., 1972) is also tempting. However, unless and until the mineralogical suites of the sands found on the Wolds and in the Vale of Pickering can be shown to have closer affinities to the sand of other inland Tertiary deposits, the North Sea Basin must remain the most likely source of these sediments.

The second major point which was not discussed by Dr. Catt is that the sands may not represent a Withernsea, Skipsea or Basement assemblage because they may have been derived from tills and sediments in addition to the above. That some mixing of the mineral suites occurred during the Ipswichian-early Devensian is beyond proof, but mixing may also have occurred during the advance of the late Devensian glaciers and continued as the meltwater streams reworked and redistributed the sediments as outwash both on the Wolds scarp and in the Vale of Pickering. Post-glacial reworking by snow-meltwater may also have occurred. More light can only be shed upon this problem by a more detailed study of all the tills and outwash sediments in the eastern and southern margin of the Vale, and of the scattered sands on the Wolds.

ii) <u>Particle Size</u>: An analysis of the particle size characteristics of the sandy deposits at the base of the Wolds escarpment and within the Vale of Pickering (the Sherburn Sands - Group A), on the crest of the escarpment (Sherburn Sands - Group B) and from the dip slope of the Wolds and in Warren Slack (Sherburn Sands - Group C, - for details of the latter deposit see Chapter IV), was carried out. Determination of the age of the different groups of sediments is not possible using particle-size characteristics alone, as these may be influenced by different agencies and environments of deposition, but if there appear to be good grounds for supposing that different groups of sediments may have a common source (as is the case with these sands), these techniques may be a useful determining factor (Greenwood 1972, Briggs 1975).

The mineralogical evidence discussed above suggested a possible link between the Sherburn Sands in the Vale of Pickering (Group A) and the Sherburn Sands found on the Wolds escarpment (Group B). No evidence for links between groups A and C (the latter are the Sherburn Sands found on the Wolds dip slope) or groups B and C were found. Therefore statistical analyses were carried out to test the null hypothesis that no similarity exists between combinations of the sediment groups A, B and C i.e., that no combination of sediment groups could have been derived from the same source.

The tests used were as follows:-

a) <u>Student's t Test</u>

A null hypothesis was set up that given any pair of the three groups A, B and C, there are no significant differences between their means:this was tested for the three groups of pairs A B, A C and B C and the result are shown in table 7.

The results showed that the null hypothesis was rejected at the 5% significance level for groups A B (Vale of Pickering and Scarp sands) and

Fig. 27 Particle size distribution curves for the Slingsby Sand pit (SE 701748). Lines on graph are numbered as follows;-

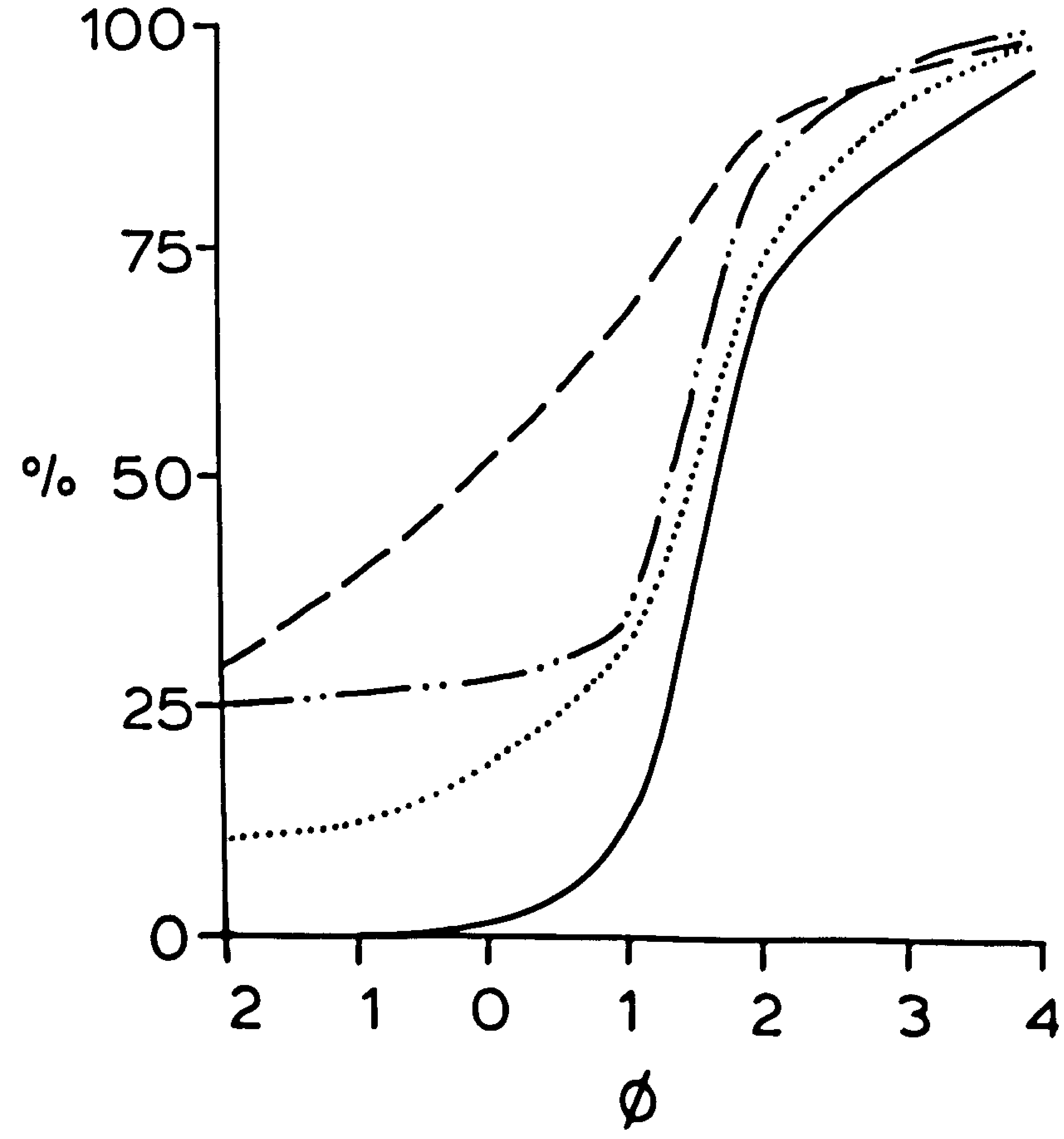
____________ 1

___ ___ ___ 2

__ •• __ •• 3

•••••••••••• 4

For original data see table 5. To read graph look up line (e.g. ______), and then read data from "graph 1" under "Slingsby Sands" on table 5.


100
75
% 50
25
0
2
1
0
1
2
3
4
Ø

A C (Vale of Pickering and dip slope deposits), indicating a common source of sediment supply. However the null hypothesis was accepted at > 10% significance level for group B C (scarp vs. dip slope sediments) which indicates that there must have been other significant sources of material which were being mixed with the sediments from the Vale of Pickering to give two discrete groups of sands on the Wolds.

b) Analysis of Variance

This test involves a more sophisticated analysis of the same parameters as the t test, but in addition to testing of groups, it can also test the three groups at the same time. Further individual means and standard deviations are tested against each other and may thus reveal more strongly connections between the groups than the t test is able to do.

The means and standard deviations of all samples were calculated, followed by the mean of the means, the mean of the standard deviations, the standard deviation of the means and the standard deviation of the standard deviations. These data were then used in an analysis of variance and a table of variance constructed (table 8). From this there were found to be significant variations between the means of groups A and B and A and C, but no significant variations when groups B and C and A, B, C were tested. There were found to be significant variations between groups A and B, and A and C, and the group A, B, C when the standard deviations were compared. With both means and standard deviations there were no significant variations between B and C. When means were tested against standard deviations for the three groups A B, A C and B C there were found to be no significant variations between them, whereas when the larger group A, B, C was compared, significant differences were found (fig. 28).

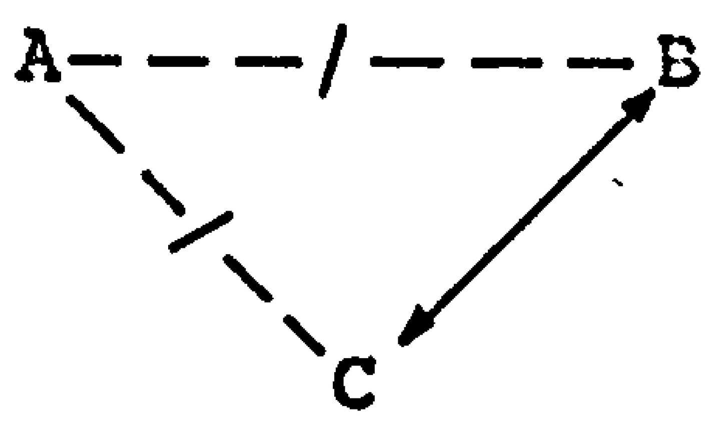
c) Bivariate Scattergrams

Although not a statistical test, a series of bivariate scattergrams were constructed (fig. 29) for environment sensitive parameters (Friedman

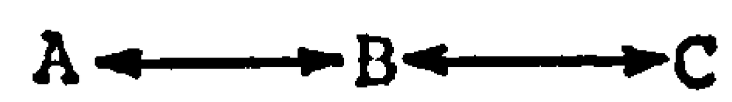
Fig. 28 Diagram to show results of analysis of variance of Sherburn sands found in the Vale of Pickering (group A), Wolds scarp (group B) and Wolds dip slope (group C) when means and standard deviations were compared. For explanation see text.

a. MEANS

SINGLE UNITS

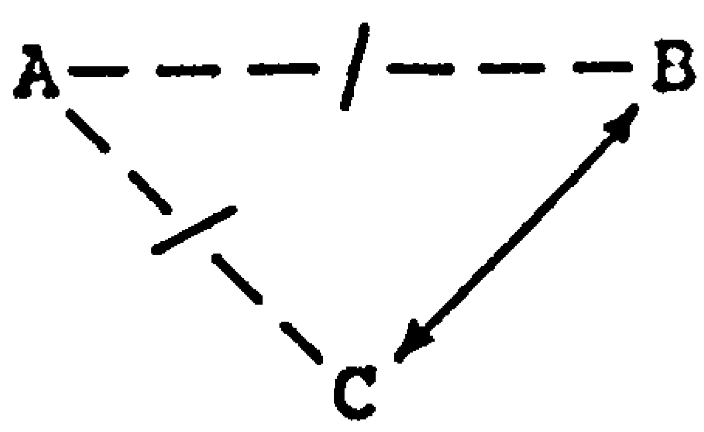


GROUPED DATA

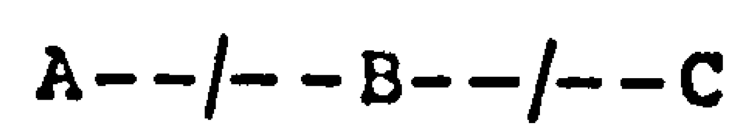


b. STANDARD DEVIATIONS

SINGLE UNITS

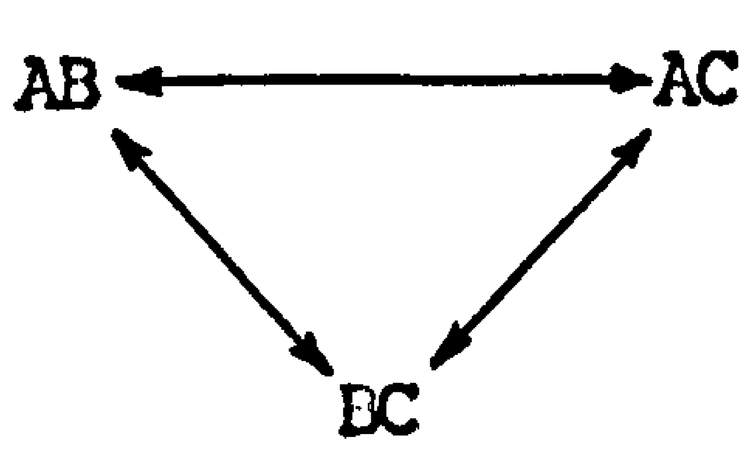


GROUPED DATA

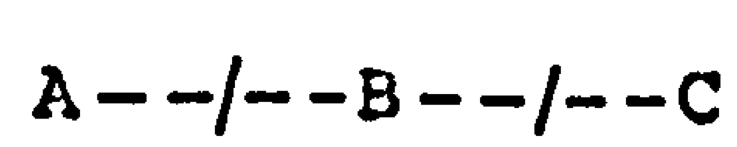


c. MEANS VS. STANDARD DEVIATIONS

SINGLE UNITS



GROUPED DATA



NO SIGNIFICANT VARIATION ←——→
SIGNIFICANT VARIATION ——/——

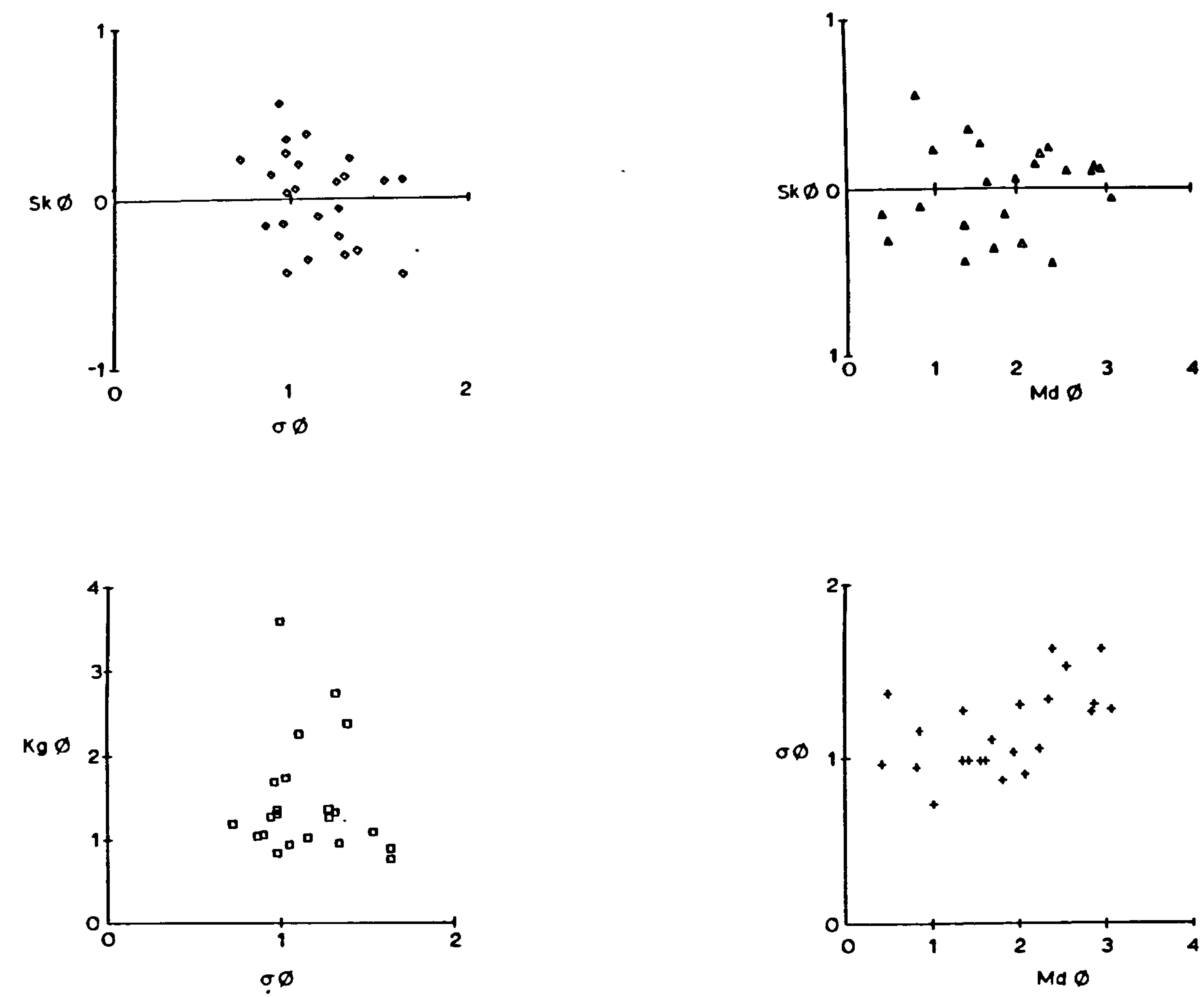
1961) - a technique which has been used with some success by Greenwood (1972) and Briggs (1975). These showed that the bulk of the Sherburn Sands from the Vale of Pickering generally tended to be strongly clustered with just a few isolated examples scattered from the main group. For the scarp and dip slope groups however, there was a much wider scatter and less tendency to cluster. On all four graphs the degree of overlap of the scatter between the three sediment groups was quite high, which implies that the three groups of sediments were laid down under broadly similar conditions and could initially have been derived from a similar source. The scarp and dip slope groups of sediments seem to have less variation between them, but this may be a reflection of their lack of clustering rather than a true causal correlation.

iii) Discussion

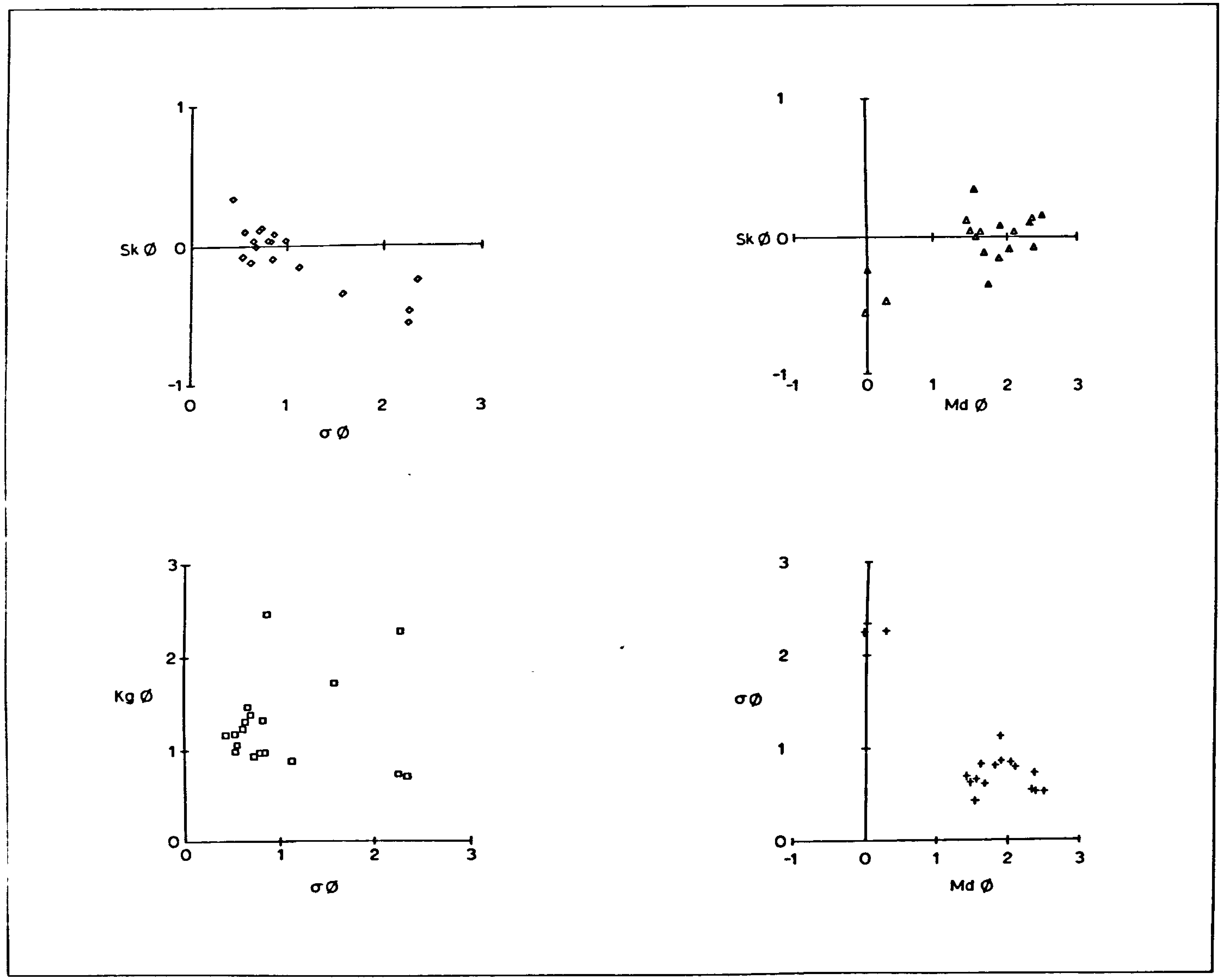
From the combined mineralogical and statistical tests there seems to be a significant link between the Sherburn Sands in the Vale of Pickering and those on both the escarpment and dip slopes. However, there has not been shown to be any similarity between the deposits on the Wolds scarp and dip slopes. Weight is added to these conclusions by the presence of small amounts of finely comminuted coal or shale fragments, or both, and although this alone is inadequate to draw conclusions about age or origin, it can be used in conjunction with the data above to support a relationship between the three sediment groups. Further, on geomorphological evidence it would seem that the Devensian ice in the Vale of Pickering overtopped the northern Wolds escarpment for much of its length and may well have extended onto the dip slope and drained southwards in the early stages of melting. The overall source of the deposits indicated by the statistical analysis of the sediments and the mineralogy is the Vale of Pickering or the immediately adjacent North Sea basin. However during the course of transport across the Wolds escarpment and dip

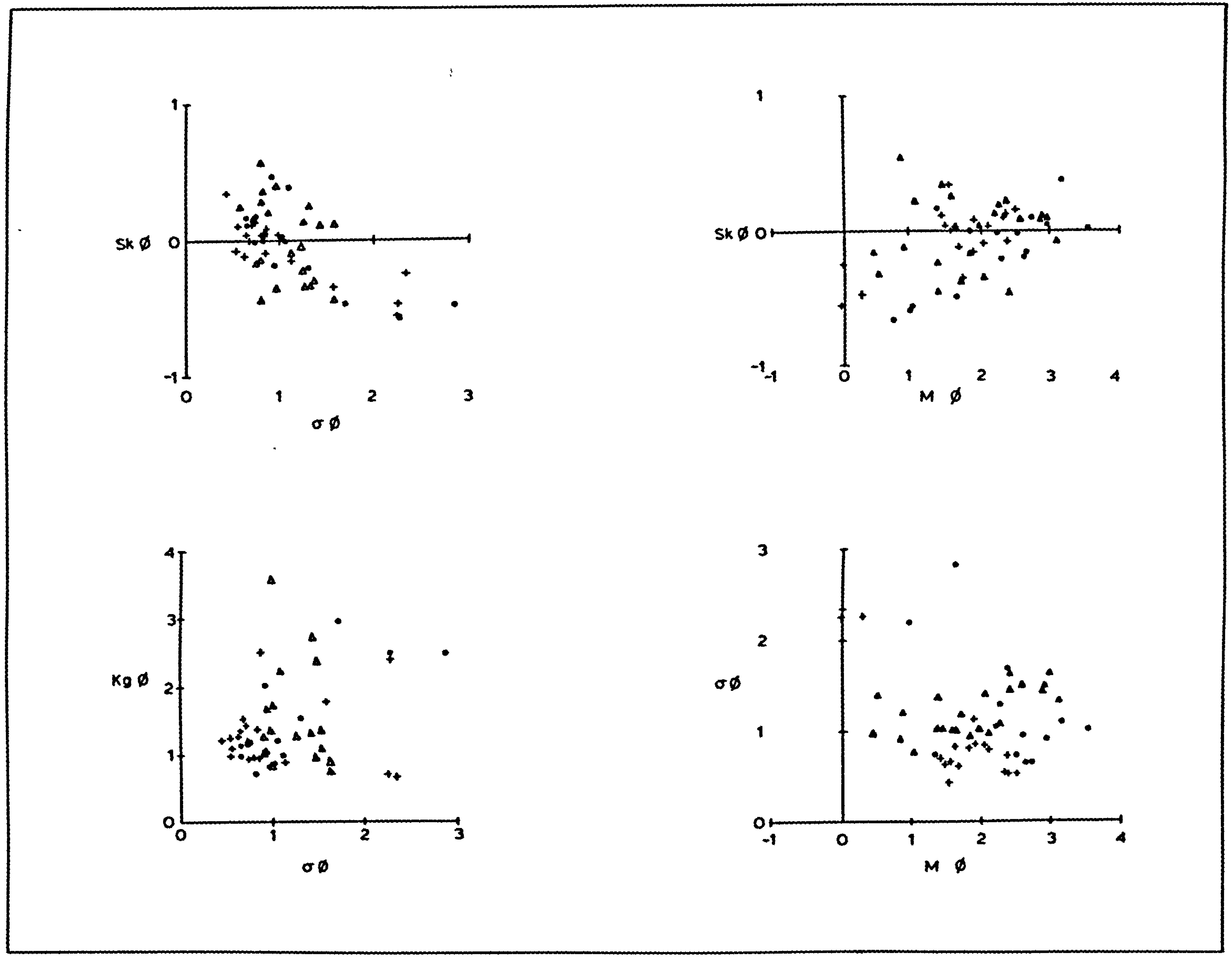
Fig. 29 Bivariate co-efficient graphs for the Sherburn sands in the Vale of Pickering, escarpment sands, and dry valley deposits, (for details see text).

+ = Vale of Pickering deposits
o = escarpment sands
△ = dip slope deposits



Sk Ø
σ Ø
Sk Ø
Md Ø
Kg Ø
σ Ø
σ Ø
Md Ø


Sk Ø
σ Ø
Sk Ø
Md Ø
Kg Ø
σ Ø
σ Ø
Md Ø


Sk Ø
1
0
-1
0
1
2
3
σ Ø
Sk Ø O
1
-1
-1
0
1
2
3
4
M Ø
Kg Ø
4
3
2
1
0
0
1
2
3
σ Ø
σ Ø
3
2
1
0
-1
0
1
2
3
4
M Ø

slope, some mixing of material occurred so that 3 distinct sub-groups can now be recognised. Thus although the scarp and dip-slope sub-groups were derived from the material found in the Vale of Pickering and have certain affinities with the latter, the scarp and dip-slope sediments have no links with each other. These variations can probably be best explained as a consequence of being deposited in different environments - those in the Vale of Pickering being left by large braided outwash rivers which derived their material from the bulk of the glacier, those on the escarpment representing slightly and locally reworked ground moraine or ice-contact deposits and those on the dip slope were probably derived by fluvio-glacial outwash streams from the fringes and upper-most parts of the glacier, together with any other loose material which happened to be lying around on the Wolds dip slope at that time.

E. The Buried Valleys of the Vale of Pickering

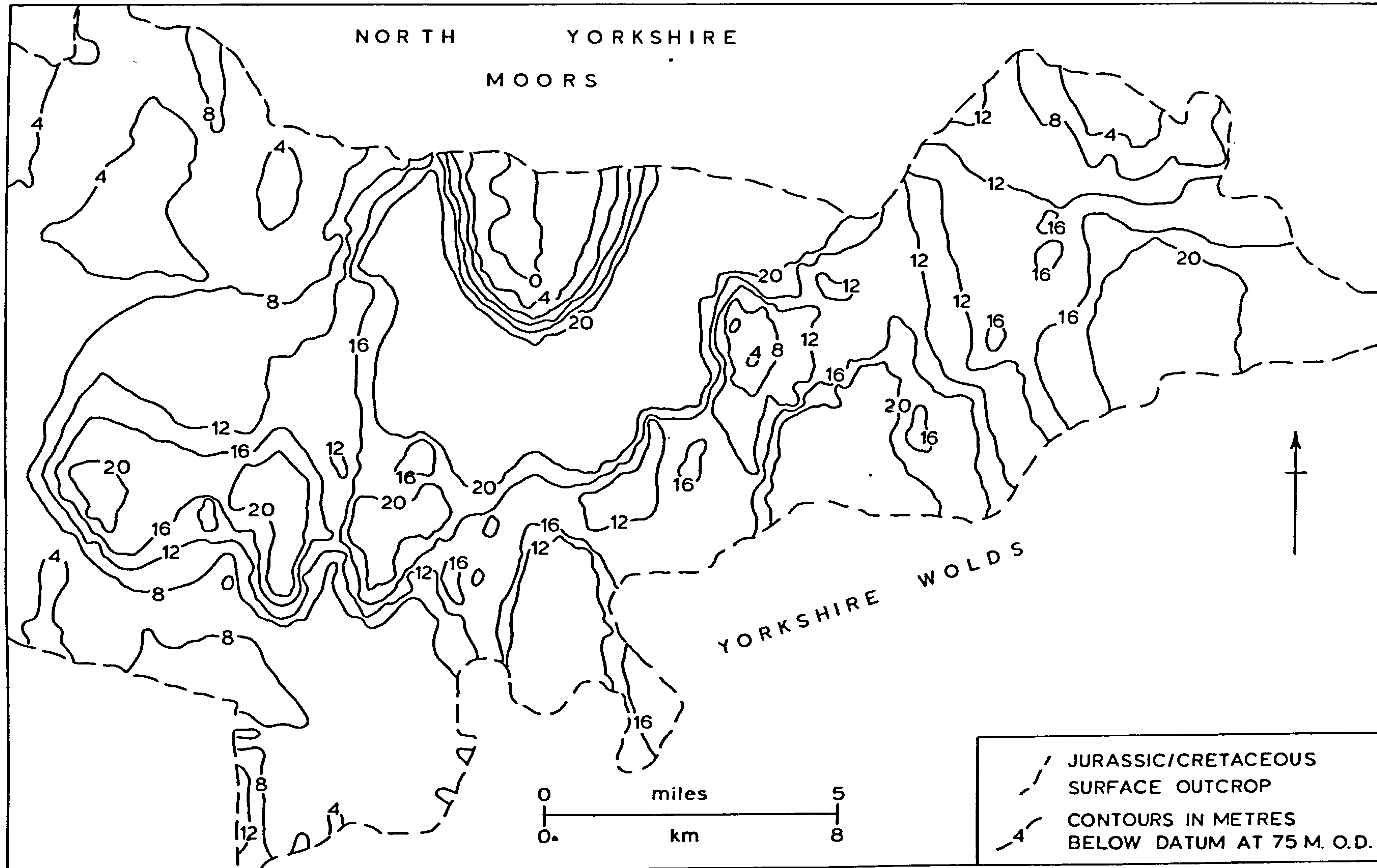
It has long been known that a deep buried channel underlies the central and eastern parts of the Vale of Pickering (Fox-Strangways, 1880, 1881, 1892; Kendall, 1902, 1903; Gayner and Melmore, 1936; Oakley et al., 1942, 1944; Shepherd 1956). A sub-drift contour-map was contructed by Shepherd but this has been modified and redrawn using the more recently published borehole data supplied by the Central Electricity Generating Board and more recent well data.

Two methods of drawing the contour maps - one the interpolation of contours by hand from the available borehole data (as in fig. 30), the other using a SYMAP computer programme (fig. 31) - were utilised in the study. The latter unfortunately did not give very good results because of an inherent weakness in the nature of the data which was used as the basis for the programme. The SYMAP programme works by calculating the distance between adjacent data points and determining the differences in value between them. Contours are then drawn at the appropriate distances

Fig. 30 Sub-drift contour map of the central and western Vale of Pickering, based on borehole records shown on Fig. 32. Map produced by interpolating contours by hand.


NORTH YORKSHIRE MOORS
YORKSHIRE WOLDS
22
19
16
13
10
7
?
0 miles 5
0 km. 8
Contours in metres OD
Jurassic / Cretaceous surface outcrop

Fig. 31 Sub-drift contour map of the central and western Vale of Pickering produced by SYMAP computer programme, based on borehole records shown on Fig. 32.


NORTH YORKSHIRE
MOORS
YORKSHIRE WOLDS
0 miles 5
0 km 8
JURASSIC/CRETACEOUS
SURFACE OUTCROP
CONTOURS IN METRES
BELOW DATUM AT 75 M. O.D.

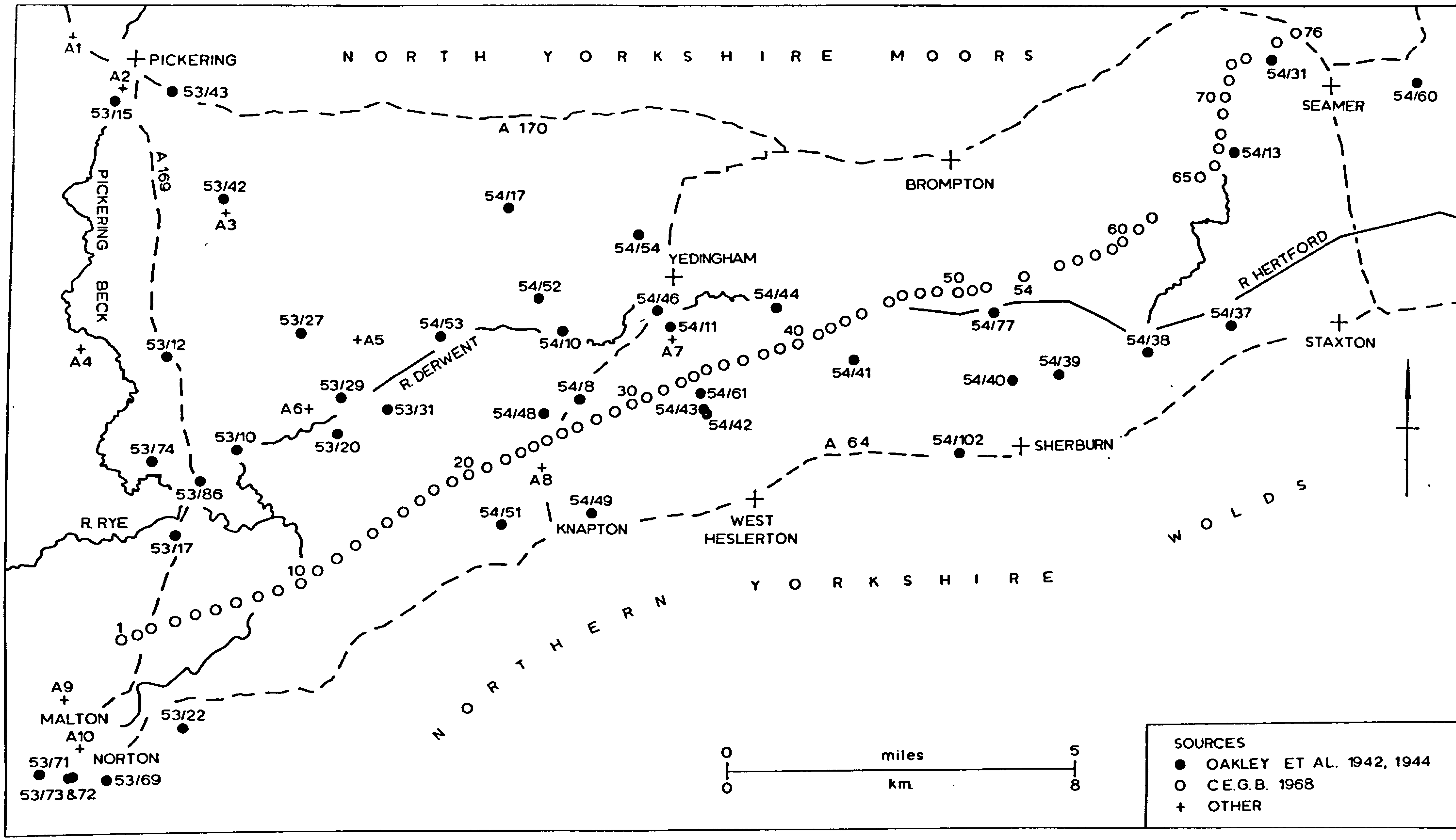
between the data points. Unfortunately the data base points with large values (i.e. boreholes which have penetrated large thicknesses of drift to reach the rock floor) have a group of data points with smaller values between them. The programme calculated and drew contours between points of different value without regard to possible topographic features such as a continuous valley, with the result that the map shows a series of buried ridges and basins which tend to reflect the clustering of borehole data and the relative value recorded at each borehole rather than an accurate picture of the nature of the buried valley. It would be possible to reduce this distortion by adding fictitious boreholes to fill gaps between high value points at the eastern and western ends of the buried valley, but these would have to be based on some form of interpolation and thus seriously reduce the accuracy and objectivity of the SYMAP programme and therefore seriously impair its value.

For these reasons the contour map produced in fig. 30 which was drawn by hand is used here as a basis for further discussion. It is fully appreciated that this map is of questionable accuracy, but it is probably as accurate as any interpretation of the data will allow at this stage.

The valley can be divided into two unequal segments - a smaller section lying west of a north-south line from Sinnington, via Great Barugh and south-eastwards to Malton, and a larger deeper section lying to the east of this.

i) <u>The western section of the buried valley system</u>: The evidence for the position of the buried valleys west of the Sinnington-Malton line is poor, with only a handful of boreholes in the extreme east of the area showing the existence of at least two separate valleys which reach a maximum depth of 27 m O.D. (fig. 30). More than this is not known at present except that the courses of the modern rivers do not follow the line of the buried valleys in all areas (e.g. Hodge Beck at Bowforth (SE691838) and the River

Fig. 32 Location of boreholes used to produce the sub-drift contour maps in Figs. 30 and 31.


NORTH YORKSHIRE MOORS
NORTHERN YORKSHIRE WOLDS
PICKERING
SEAMER
BROMPTON
YEDINGHAM
STAXTON
SHERBURN
WEST HESLERTON
KNAPTON
MALTON
NORTON
PICKERING BECK
R. DERWENT
R. HERTFORD
R. RYE
A 170
A 169
A 64
A1
A2
A3
A4
A5
A6
A7
A8
A9
A10
53/15
53/43
53/42
53/12
53/27
53/74
53/86
53/17
53/10
53/20
53/29
53/31
53/22
53/71
53/73&72
53/69
54/17
54/54
54/52
54/53
54/10
54/46
54/11
54/44
54/8
54/48
54/61
54/43
54/42
54/51
54/49
54/41
54/40
54/39
54/77
54/38
54/37
54/102
54/13
54/31
54/60
1
10
20
30
40
50
54
60
65
70
76
0 miles 5
0 km 8
SOURCES
● OAKLEY ET AL. 1942, 1944
O C.E.G.B. 1968
+ OTHER

Rye west-north-west of Nunnington (SE6579) are known to have their beds cut into Oxfordian or Kimmeridgian shales: cf. Fox-Strangways field slips of the area; (G. Richardson 1977, pers. comm.). The possibility that other sections of river courses may be incised into "solid" strata is difficult to test in areas where weathering of the shales and clays has removed the fossil evidence.

A deeper valley than the above must pass into the eastern portion of this area (i.e. the western half of the Vale) because the western extension of the deep trunk valley can be traced as far as Great Barugh after which a lack of data make further determination of the course of the valley impossible (fig. 30). A tributary valley from this deep trunk valley may branch in the area south of Great Barugh and pass between the lower hills upon which the villages of Great and Little Barugh stand.

ii) <u>The eastern section of the buried valley system</u>: The details of the buried valley in the eastern portion of the Vale are better known than those of the valleys in the west, but the concentration of a large proportion of the boreholes and wells in the Marishes-Yedingham area means that the details of the valley in the area east of East Heslerton Carr are rather more obscure (fig. 30 and 32). In the area between Knapton and East Heslerton Carr the central buried valley splits into two major branches, the southern branch being considerably deeper than that to the north. The southern branch heads into the Malton embayment and may lead into the Kirkham valley (see below). The northern branch of the valley heads into the more central and northern parts of the Vale and splits into a number of smaller shallower heads which appear to extend into the western and north-western parts of the Vale (fig. 30).

The southern branch of the valley is between 10 and 15 m O.D. in the area south of Knapton. In this region it is divided from the northern branch of the valley system by a buried west-south-west to east-north-east

Fig. 33 Transect of the drift deposits in the Vale of Pickering as revealed by the C.E.G.B., borehole data. N.B. the irregular clay lenses in the upper 7 m of the outwash sands near the surfaces of the sections and the isolated ridges of Kimmeridge Clay in the west.


SE 797735
METRES O. D.
R. DERWENT
RAILWAY
KNAPTON ROAD
R. DERWENT
BROMPTON BECK
R. DERWENT
TA 008845
METRES O. D
25
20
15
10
5
Kimmeridge Clay
Sand
Peat
Gravel
Laminated clay
Silt
Length of section: 22·5 km.

trending, partially dissected ridge of Kimmeridge Clay (fig. 30). The northern tributary of the valley system then rejoins the southern branch to the west of this ridge, although the floor of the southern branch of the valley is still deeper than that of the northern branch. The southern branch of the valley also turns away from the main west-east trend of the Vale of Pickering and instead passes south-westwards into the Malton embayment. Lack of good quality recent borehole data from this area precludes any determination of the nature or course of the head of the southern tributary once it has entered the Malton embayment - the presence of one well-log from the south-eastern part of the area is insufficient evidence to support much speculation. However if the deep valley head passes into the Kirkham Valley (and there is no evidence at present to prove or refute this) the theory of the latter having been cut by lake or ice-meltwater draining from north to south will have to be radically revised. A possible alternative explanation for this deep buried valley head is that its excavation was caused by snow-meltwater draining into this area from the hills to the south and south-west during periods of peri-glacial climate. Rapid incision of a deep valley system may have been facilitated by faulting in the area which brought Kimmeridge Clay to the surface here. (No such deep valleys are thought to exist at Thorpe Bassett or Wintringham for example, where the Chalk would have provided a more resistant stratum to erosion). Rapid incision of the valley in the area between the buried ridge of clay at Knapton and the escarpment to the south is implied by the steep sided nature of the valley in this area.

The northern branch of the valley has two major heads, the deepest leads back into a relatively deep and narrow extension which passes south of Great Barugh and may send a tritutary between Great and Little Barugh villages (see above). The second major head leads back towards Pickering village and Newtondale - this appears to be much wider and shallower valley than those described so far, although it is possible that a deeper narrower valley has been incised into the floor of the large valley but has not been revealed by boreholes yet. Below the confluence of the two trunk head-valleys described above, the major buried valley passes eastwards towards the coast, narrowing as it does so. On the northern side of the valley the ridge which extends southwards from Thornton-le-Dale causes the valley to narrow, but east of this the trunk valley broadens again as a relatively steep slope has been found in the area south of Allerston and Ebberston. Further east from Ebberston the gradient of the northern edge of the buried valley decreases somewhat, although this may be a reflection of the lack of borehole data for this area. The apparent lack of northern tributary valleys between Thornton-le-Dale and Seamer may also be due to the lack of data rather than a genuine absence of such features. A buried tributary valley does extend southwards from the site of Forge Valley, but the dimensions of this feature are still to be discovered fully.

The only known tributary on the south side of the trunk valley downstream from the confluence of Knapton lies approximately midway between Sherburn and Ganton at the site of Sherburn Ings and the modern confluence of the rivers Derwent and Hertford. It is not known whether this tributary splits and heads into the Ganton and Sherburn scarp valleys, or whether these latter features have their own direct but buried connections with the trunk valley to the north. It is possible that the deep gravel-filled depression now being exhumed at Knapton Gravel pit, (SE888749: for details of this see the descriptons in section D of this Chapter, and Section A of Chapter V), may be part of another undiscovered southern tributary valley, but as yet no further details are known about this feature, if its exists at all.

Where the buried valley crosses the modern coastline (under the site of Filey) the rock floor is at least -30 m O.D. However, two boreholes which were sited within 15 m and 115 m of the borehole which recorded the maximum depth of the valley floor, revealed the rock-floor to be at only -22 m O.D. Two explanations for this are possible: either the deep channel revealed by the borehole which reached to slightly more than -30 m O.D. had penetrated a sub-glacially cut tunnel valley, or this deeply incised section represents a very late phase of rather rapid incision which occurred just prior to the advance of the North Sea Glacier. Examples of tunnel valleys of considerable size have been recorded in East Anglia by Woodland (1970) and it is possible that during the melting of the ice during either the Devensian or an earlier period of glaciation such a valley was cut in the floor of the pre-existing valley at Filey. If on the other hand the valley was cut by sub-aerial processes it would seem that the incision was relatively rapid as slippage or collapse of the valley sides incised into the Kimmeridge Clay has not occurred.

The average gradient of the deeper (i.e. southern) branch of the buried valley is approximately 1 in 1440 or a fall of 0.65 m per km. The gradients in the northern branch of the valley is slightly greater, 1 in 1350 to 1 in 1400 or a fall of 0.7 m per km. The gradients in the Malton embayment and in the area north and south of Kirby Misperton area are considerably steeper. The cause of this increase in gradient may be due to one of two factors - a change in the lithology of the Kimmeridge Clay from a shale to impure shaly limestone (i.e. from Upper Kimmerigian in the east to Lower Kimmeridgian in the west), or the result of headward recession of the rejuvenation effects into this area after which the mouth of the valley was invaded and blocked by ice.

iii) Discussion: The buried valley in the Vale of Pickering is comparable with other overdeepened buried valleys in Eastern England, e.g. the Tees (Smith and Francis 1968), the Humber (Versey 1948, Gaunt 1976a) and the Tyne (Richardson 1976, pers. comm.). The Pickering Valley is at approximately the same level as the Tyne (-29 m O.D.). This latter correlation of levels could indicate that sub-aerial erosion was responsible for the last phase of deep excavations at Filey and thus the sub-glacial option could be dismissed.

More information is needed from this area before this problem can be resolved.

The incision of the buried valley may have been the result of more than one period of prolonged low sea level; in the the Vale of York for example Gaunt has found evidence of buried Ipswichian deposits at -13 m O.D., (which implies a low sea-level phase at the end of Wolstonian period), but further records that the period of greater incision (to -24 m O.D.) occurred later during the low sea level phases of the early and middle Devensian (Gaunt 1976 a, b). So far no Ipswichian deposits have been found in the Vale of Pickering although an Ipswichian fauna was described in the Kirkdale cave near Kirkby Moorside (Buckland 1822, 1823; Boylan 1972, 1977). If incision of the river valleys occurred in the Vale of York during early Ipswichian times a similar phase of downcutting very probably occurred in the Vale of Pickering. According to Gaunt the successive fall in sea level during the early and middle Devensian was probably an uneven event with minor oscillations on the generally falling trend but, in the Vale of York, so in the Vale of Pickering there is no evidence known to indicate any of these fluctuations. The fall in sea-level is attributed to the abstraction of sea-water from the oceans and its gradual accumulation as ice at the polar regions. This period of prolonged cold and falling sea-level lasted for circa 50,000 years (i.e. from 70,000 to 20,000 years B.P. - Shotton et. al., 1974), prior to the major advance of the Devensian glaciers into this part of England circa 20,000-18,000 years ago (Penny et. al., 1969).

F. The Sedimentary Infill of the Vale of Pickering Buried Valley

The blockage of the eastern end of the Vale of Pickering by ice and sediment in the late Devensian resulted in a marked change in the environmental conditions of the area. The most important consequence was the change from an erosional to a depositional environment which has apparently continued, albeit with changes and possible erosional breaks, (or phases of non-deposition), to the present day. Deposition within the valley started in the eastern central area with sands and gravels, rapidly passed into thick laminated lacustrine clays and finally a phase of mixed laminated clays with sands and gravels. An alluvial phase succeeded this and is apparently still in progress today.

a) The basal sands and gravels: These deposits are of variable thickness (up to 6 m) and very patchy in their distribution - in many parts of the Vale they are absent. The nature of the distribution does not appear to be related to valley depth, (i.e. the thickest deposits are not found in the deepest parts of the valley): it could be related to local sediment supply or to the local conditions which prevailed at the time of deposition. Chalk is known to be present in some of the gravels, but in the majority of the well-logs no petrographical details are given. It is not known if coarse clastics underlie the tills and outwash deposits in the east end of the Vale and even if they did it seems that they would probably have been derived from local glacial sources.

b) The lower laminated clays: In the area between Ruston Carr (i.e. along a rough north-south line from Wykeham to Sherburn) in the east to the line Sinnington-Barugh-Malton in the west the sediments of the buried valley are dominated by a variable thickness (from 2.7 m to 33 m) of grey, greyish-brown and brown laminated silts, silty-clays and clays. These have often been referred to as the "lake clays" or "laminated clays" by previous authors (e.g. Fox-Strangways 1880, 1881; Kendall 1902, 1903; Oakley et. al., 1942, 1944; Penny and Rawson 1969, Penny 1974). The thickest development of these sediments is in the area around and to the north-west of Knapton: 30 m of "clays" were recorded at Howe Farm, Wykeham on Old Malton Moor (53/17 fig. 32) and 33 m of "clays" broken by a seam of gravel 5 cm thick at Scampston Hall (54/51 fig. 32). In the north-eastern part of the area at Derwentdale Farm near Seamer, 22 m of "laminated clays" were recorded (54/13). The accumulations appear to be rather thicker in the deeper parts of the buried valley generally, with a tendency for the upper horizon to fall towards the east more rapidly than the gradient of the valley floor (fig. 33). On the southern fringe of the valley these deposits seem to have been replaced in part by sands and gravels, e.g. at Ganton railway station 6.5 m of "lake clays" were overlaid by 12.5 m of sand and gravel (53/38), and at Binnington railway cottages 4.6 m of "lake clays" were overlain by 13.7 m of sand and gravel (54/37).

The origin of this thick and apparently nearly uniform material is problematical. Parts of the "laminated clay" sequence are almost certainly derived from slipped masses of Kimmeridge Clay derived from the unstable sides of the valley or from rafts brought in by ice. C. E. G. B. borehole 21, where "blue clay" was reported is a good case of this, as it has been found by the author that the Kimmeridge Clays in the Vale of Pickering area weather to a characteristically blue-grey colour, especially in poorly drained or frequently waterlogged areas. (Speeton Clay by contrast turns to a much more distinctive greenish-grey under similar circumstances). In C. E. G. B. borehole 10 a band of "firm red laminated clay" suggests that Red Chalk was somehow being brought in and deposited, and at Selley Bridge Farm, Marishes a well-log recorded 17 m of Kimmeridge clay overlying the basal sands and gravels. The bulk of these laminated sediments are remarkably uniform in their composition however and with the few exceptions noted above and the rare occurrence of sand and gravel seams around Marishes and Yedingham the sequence appears to have been dominated by fine-grained and very fine-grained sediments.

The uniformity of sedimentation is in contrast to the sequence of lacustrine deposits found in the mouth of the Tees by Smith and Francis (1968) who recorded large boulders and patches of gravel in their borehole logs. These coarser clastics were believed to represent ice-rafted material which was deposited in a glacial-dammed lake. The records in the Vale of Pickering are more similar to those in the southern part of the Vale of York which were described and discussed by Gaunt (1976a) who attributed the thick sequence of laminated deposits to deposition in a sub-glacial lake. The implications of these theories will be discussed more fully in Chapter VI.

c) The upper mixed laminated "clays", sands and gravels: It has already been stated that the upper horizon of the lower laminated clays tends to fall towards the east. However the upper surface of the clays is far from being an even plane surface, but contains many low rises with intervening depressions, which are filled with a mixed group of gravel and sands (fig. 33). These coarser sediments are interbedded with variable thicknesses of laminated fine grained silts and clays; the whole group of these mixed sediments are collectively referred to here as the "Upper Mixed Sediments".

A typical succession of these sediments was found in borehole 19 which revealed:

Section		Thickness
Topsoil		0.45 M (1′ 6″)
Medium dense brown silty fine sand	Upper mixed deposits	2.3 M (7′ 6″)
Firm brown laminated clay with fine silty partings		1.5 M (5′)
Medium dense brown silty fine sand		3.35 M (11′)
Firm brown laminated clay		0.6 M (2′)
Medium dense brown silty fine sand		1.3 M (4′)
Firm brown laminated clay with occasional fine silty partings - Lower Laminated Clays		6.1 M (20′) (base not seen)

The succession is fairly typical and shows the development of three lenses of brown silty sands with two lenses of laminated clays interbedded in the sands. Lack of lateral continuity in these deposits means that only one laminated clay horizon may be present in some areas, and in others only two sand horizons. Towards the east the surface horizon of sand tends to be replaced by gravel (chalky in the south; northern glacial drift type material in the north). The sands and gravels in the southern part of the valley are thought to be of the Sherburn type because where these have been traced into the Vale from the Sherburn Sand outcrop near the foot of the Wolds scarp there has been a complete continuity across the surface. In some borehole logs comminuted coaly fragments have been recorded in these sands from all horizons - this too tends to support the suggestion that the sands and gravels in the south are of the Sherburn facies. At the north-eastern end of the line of C. E. G. B. boreholes (i.e. from borehole 56 in Wykeham Carr onwards) the basal laminated clays virtually disappear and are replaced by coarse and medium grained gravels and sands. However as the borehole at Derwentdale Farm showed, not all of the laminated clays had been replaced and it is possible that the shallow depth of the C. E. G. B. boreholes in this area means that the basal clays were not penetrated. The highest level which the laminated clays of the Upper Mixed (group of) Sediments reached is circa 29.3 m (at borehole 53/15) in the area south-west of Pickering. The highest level of the clays elsewhere was at Derwentdale Farm (27.5 m at 54/13) and at Knapton (22.8 m at C. E. G. B. 20). Generally the level of the clays increases towards the central and western parts of the Vale of Pickering (the borehole at Derwentdale Farm excepted), with four boreholes recording such clays at heights above 20 m O. D. in the area south and south-west of Pickering (boreholes 53/48, 53/46, 53/28 and 53/15: fig. 32). The heights of these clays are significant because the modern level of the River Derwent where it enters the northern end of the Kirkham Valley is approximately 17.3 m O. D. Thus either the Kirkham Valley must have been temporarily blocked during the phase of deposition of the upper laminated clays or over 12 m of rock must have been eroded in the Kirkham Valley. This problem may be resolved in one of two ways:

either a) the sediments in the Pickering area and the "Pickering delta" (which consists of a fan-shaped mass of gravel which lies at the southern end of Newtondale) were deposited in an ice-marginal lake which stood at a level in excess of 33 m O. D.,

or b) the sediments formed in an open lake which filled the bulk of the modern Vale of Pickering (as was suggested by Kendall in 1902), and the higher levels of the sands and clays represent the uneroded remnants of deposits which were originally much more extensive. This would mean that the Kirkham Valley would have been blocked during the period when these sediments were deposited.

G. The Seamer-Flixton Lake Site

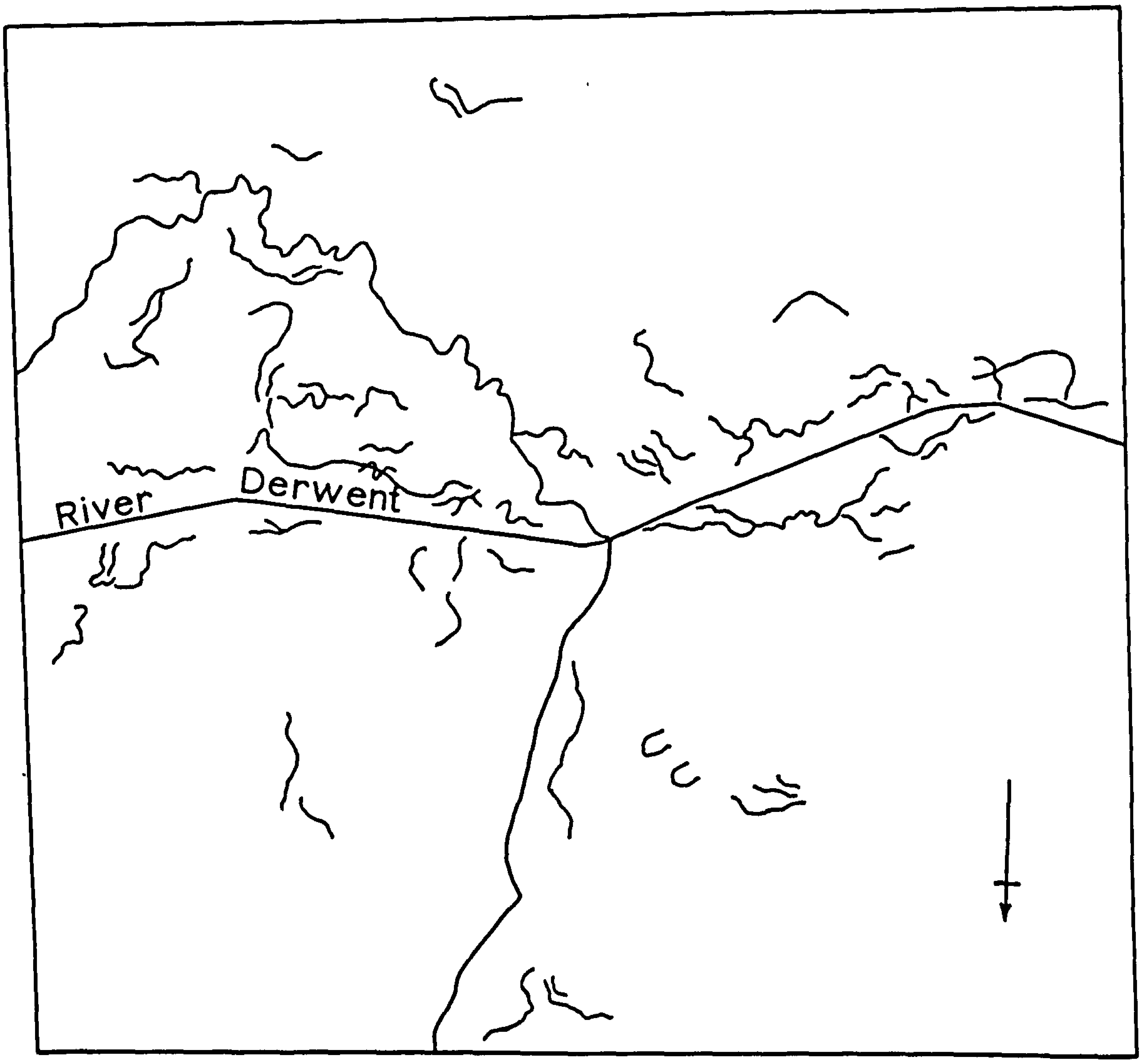
Lying to the south and west of the outcrop of the Seamer gravels and the tills of the eastern Vale and occupying a depression in these sediments is the site of the best documented of the late-glacial and early post-glacial lakes of the Vale of Pickering. These lakes are completely filled with peats and are now the sites of the carrlands of the eastern Vale. The Seamer-Flixton Lake once occupied a hollow which is approximately bounded by the rough line Seamer-Cayton-Ebberston-Muston-Flixton. The old lake site has been divided into two unequal parts by the alluvial deposits of the River Derwent and by a semi-buried ridge of fluvio-glacial gravels which extend southwards from the southern end of Forge Valley. A small segment of the old lake lay to the west of the River Derwent but was bounded on its western edge by the ridge of fluvio-glacial material at Wykeham; a larger segment of the old lake lay to the east of the River Derwent and was bounded on its northern and eastern edges by the emergent tills of the eastern Vale. The southern margin of both segments of the lake was bounded by the outcrop of the Sherburn sands and gravels at the foot of the Wolds escarpment. In the southern part of the Vale the two segments of the Vale join ed to form a continuous sheet of water which at its maximum extent must have been circa 8 km long x 5 km wide. The lake appears to have been relatively shallow over most of its area, although hollows, some up to 12 m deep, have been recorded (Clark et. al., 1954). Influxes of clastic sediment from the River Derwent in the north and probably by snow-meltwater from the margins of the lake during Zone III times may have helped to even out some of the undulations on the lake floor, but most of the more recent sediments appear to consist largely of peats and other organic debris. In places the higher parts of the lake floor broke the surface of the lake and caused small islands - these are still visible in the field and on air-photographs of the area (fig. 34).

The pollen stratigraphy of the peats of the Star Carr and Seamer Carr areas have been intensely studied by Walker and Godwin (in Clark et. al., 1954). Their studies showed a typical vegetational succession from birch-scrub and birch-woodland in Pollen Zones I and II respectively through birch-scrub in Zone III (due to the degeneration of the climate in the Younder Dryas) back to birch-woodland, pine woodland and finally oak-elm-beech woodland in Zone VI times onwards. The above authors were also able to show that the lake was as open sheet of water until approximately Zone V when reedswamp, which had initially been confined to the margins of the lake, rapidly extended across the shallower parts of the lake floor leaving only the deeper hollows an open water. Finally even the deep hollows were filled with organic material and the whole area was colonised by plants. The last dated plant deposits were of Zone VII age - oxidation and erosion have removed any younger peats which may have been deposited. Walker and Godwin showed that the level of the lake rose erratically during the period of its existence and attributed this to blockage of the outlet of the lake at the western and by the growth of marginal reedswamps and the accumulation of organic debris in the outlet area. According to Walker and Godwin, Seamer Meads (TA0382), was not flooded until late Zone IV - early Zone V times. However more recent palynological evidence obtained by students at Hull University showed that the pollen spectra was complete for Zone I - early VII in this area and that part of the spectra for Zones I-III indicated the presence of open water during these times (J. R. Flenley pers. comm. 1978).

The evidence for the climatic deterioration in Zone III times is twofold: there is the palynological data described above which clearly indicate that a decline in the vegetation occurred at this time, and secondly there is sedimentological evidence. Walker and Godwin found that

Fig. 34a Air photograph of part of the Seamer-Flixton lake site and the confluence of the River Hertford and River Derwent (Soil Survey photo).

Fig. 34b Sketch map of the area covered in Fig. 34a. (Brompton and Sherburn Ings). The former courses of old river channels can be clearly seen traversing the peaty areas which probably represent deeper water sections of this former lake.



Course of present rivers

Former river courses

over the bulk of the area of the lake site which they studied fine clastic sediments were deposited in Zones I and II, but that during Zone III this was interrupted by coarser sands and gravels which were spread unevenly over the lake floor. In the south these gravels consisted largely of angular chalk debris. Penny believed that these mixed deposits represnted material which had been soliflucted from the Wolds scarp during the winter months and had extended as solifluction sheets over the frozen surface of the lake: during the spring thaw the sediments had dropped to the bottom of the lake. An alternative hypothesis is that these deposits were brought down the scarp by snow-meltwater streams and carried into the shallow lake in small deltas and by turbidity currents. Either hypothesis requires cold conditions however.

The effects of the Zone III climatic deterioration continued into Zone IV, during which period a fine blue or buff-coloured calcareous mud was deposited over much of the lake floor. Walker and Godwin reported that in most of the sites which they augered this mud contained gastropod remains, but no details were given. A small sample of this mud was obtained by the author from the spoil of a drainage ditch 200 m ENE of the footbridge at Star Carr. This was sent to Mr. A. Norris for examination, and the following was recorded:

Species	
Valvata cristata (Muller)	Common
Valvata piscinalis (Muller)	Fairly common
Bithvia tentaculata (Linne)	Common
Lymnaea peregra (Muller)	Common
Hippeutis complanatus (Linne)	Fairly common
Armiger cristata (Linne)	Fairly common
Pisidium micium	Held-scarce
Pisidium sp.	Fairly common

This assemblage was considered to be rather poor when compared with samples taken from the bed of the nearby modern River Hertford. The environmental conditions indicated by the assemblage was one of shallow water with very little vegetation and a sandy/muddy bottom (Norris, pers. comm. 1978). This fauna probably shows that the vegetation in the surrounding areas of the lake was still recovering from the effects of the cold in Zone III times - as explained above when the reedswamp finally began to advance across the lake shallows its progress was swift and the results were complete. The decrease and final cessation of gastropod remains higher in Zone IV times probably also indicates the changing environment as a result of the advance of the reedswamp.

It has been stated by authors in the past that the lakes described above were the direct descendents of the Lake Pickering envisaged by Kendall (e.g. Clark et.al., 1954, Shepherd 1956). Shepherd even drew a series of reconstructions of the shrinkage of Lake Pickering to show how it retreated into the eastern Vale of Pickering (Shepherd, op. cit.). However, there is no evidence to support this theory. It seems from the present evidence that in fact there could have been a fluvial phase, which intervened between the filling and draining of Lake Pickering and the formation of Lake Seamer-Flixton when the outwash gravels of the Seamer drifts were deposited in the eastern Vale of Pickering. This is indicated by both field evidence (see section C above) and borehole evidence -(e.g. fig. 33). It is possible that small bodies of standing water did exist in the eastern Vale in kettle holes and other deep hollows in the drifts at this time and that these coalesced into a larger lake on the Seamer-Flixton site in pre-Zone I or early Zone I times. However, the early history of this lake complex is still unclear and further research needs to be carried out to try to unravel the complexities of the late-glacial history of this area.

H. The Post-Glacial Drainage as Mapped from Aerial Photographs

The documented history of the artificial drainage of the Vale of Pickering since the 10th century A.D. has been reviewed and discussed by Shepherd (1956). She found that prior to this, most of the lower-lying areas of the central and eastern parts of the Vale were uninhabited wetlands which were liable to severe winter flooding and sometimes summer flooding too. The restricted outlet of the Kirkham Valley was thought to be largely responsible for causing the ponding back of the floodwaters of the Derwent and Hertford Rivers and their tributaries in the east, and the combined tributaries of the Derwent in the west. However the slightly higher nature of the ground in the west meant that although it flooded during the winter months it was able to drain away more rapidly. (Marshall (1788) wrote that whereas it took 10-14 days for floodwater to pass from Helmsley to Malton it took 21 days for floodwater to travel from Seamer to Malton. However, these very low rates of flow were in part attributable to the interference with the natural flow, especially at Malton, so these prolonged periods of flooding were probably worse during Marshall's time than they had been in earlier centuries). During these periods of flooding small meres and ponds probably formed within the flood-plain of the rivers in the east and in the surrounding poorly drained lowlands too. The meres may not all have formed through the rivers breaking their banks but from the general rise in the level of the groundwater table which was caused by the general flood conditions. The bulk of these meres were probably temporary in nature and likely to drain as the water-table returned to lower summer levels.

i) The Derwent-Hertford Valley: The former extent of the flood plain of the River Derwent and its major tributaries in the eastern part of the Vale of Pickering has been mapped from aerial-photographs. These clearly

Fig. 35 Map of the former drainage channels of the Vale of Pickering as revealed by aerial photographic interpretation. For explanation see text.

85
90
00
99
0
miles
2
0
km
3
80
99
Well drained areas
Poorly drained areas
Peat filled hollows
Carr peat
Modern river courses
Abandoned river courses
Gravel islands
Flood plain
90
76
00

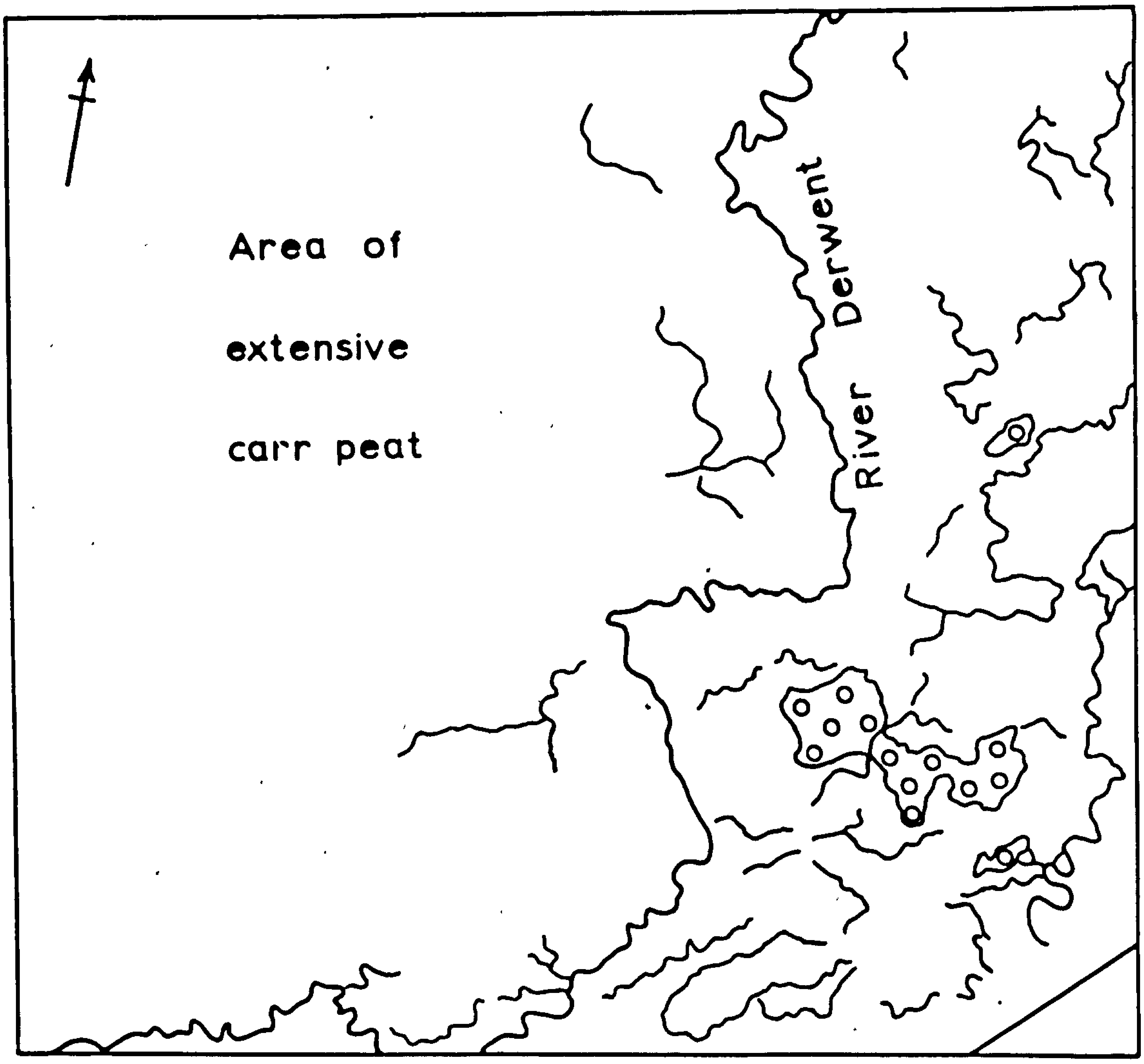
show the importance of the flood plain which extends as a wide belt of land over which the river has migrated, the plain being the widest in the east and showing a tendency to narrow steadily towards the west.

The River Hertford rises as a small stream in the tills at the foot of the Wolds escarpment in the area of Hunmanby, but this is a small stream which does not seem to have accomplished much erosion even during Zone III times. The eastern end of the Flixton Lake site has not yielded evidence of deltaic deposits in the area where the stream now enters the peat-filled hollow, and the air-photographs failed to reveal any evidence of levées in any part of the eastern end of the lake site. It would seem therefore that although the River Hertford rises to the east of the old lake site it must gather a good deal of its discharge from the peats and other sediment-infill of the low-lying hollow once occupied by the Seamer-Flixton Lake.

The River Derwent was (and still is) quite different. Prior to the artificial diversion of the bulk of the discharge and most of the flood-water from the Northern Yorkshire Moors into the sea via Sea Cut at the northern end of Forge Valley, a river of considerable size flowed into the northern edge of the Seamer-Flixton Lake. This can be clearly seen on aerial-photographs where large natural levees have been built up on several occasions into the northern and central parts of the old lake (figs. 34 and 36). It is interesting that a series of levées should have been built up rather than a single large delta complex, for this may give a clue to the age of the old river channels during the period of levée formation. By finding the ages of the peats and other sediments underlying and overlying the levée sediments it should be possible to work out the sequence of levée formation. A tentative scheme has been proposed here based upon the clarity of the different levées which itself is a product of the depth of burial beneath the peats of each of these

Fig. 36a Air photograph of Wykeham Ings on the northern edge of the Flixton-Seamer lake site, showing former courses of the river Derwent and the extent of the "flood plain" in this region (Soil Survey photo).

Fig. 36b Sketch map of the area covered in Fig. 36a. Note that much of the area underlain by carr peats is now planted with trees. The small mounds of gravel may well represent the relics of pitted outwash material left by melting ice at the end of the Devensian.



River Hertford

Former river channels

Gravel islands

features.

The environmental conditions indicated by the levée rather than delta formation suggests that the northern and central parts of the lake must have been very shallow to enable the river to build up a series of banks and associated confined channels through which the river flowed. It is possible that levée formation only started after the shallow lake floor had been invaded by reedswamp in early Zone V times and that prior to this a (now buried) delta complex was built up in the north. However borehole and auger data from Seamer Ings (TA0081 and TA0082) showed that peats were interbedded with sands, silts and clays of probable alluvial origin - they could represent levée deposits or they could equally represent backswamp and overbank flood deposits. Clearly a detailed survey of this area is required to sort out the complex stratigraphy and lake history of this area.

The limits of the former flood plain of the River Derwent in the levée area appear to have extended from Ings Plantation (SE9882) in the west to Seamer Ings (TA005815) in the east. Over this wide belt of ground the old levée systems can be seen on aerial photographs and can be found by the different soil textures in the field. This old flood-plain seems to have extended from north to south right across the site of the Seamer-Flixton lake before joining the River Hertford and turning west to flow across Binnington Carr and Sherburn Ings.

In the central parts of the Vale (i.e. west of the confluence of the Derwent and Hertford to Yedingham) the width of the old flood plain varies considerably. The flood plain is widest where the Derwent swings to the north at Hay Bridge Farm and is narrowest in the area just west of West Heslerton Carr. In some areas (e.g. Ganton) the edge of the flood plain extends to within 0.5 km of the foot of the Wolds escarpment, but farther west it moves away from the scarp until at Knapton it is over 1.3 km from the scarp foot.

In the area between West Heslerton Carr and Yedingham the old flood plain is at its narrowest (0.5 km). Unfortunately the air-photographic evidence in this area is difficult to interpret because the ground here has been artificially drained and this has destroyed the tonal differences in the soils which help to reveal the courses of former channels. Nevertheless there is a marked narrowing of the flood plain which has to be accounted for as this is a wholly unexpected feature. Apparently a belt of slightly higher ground extends from the foot of the Wolds scarp at Knapton into the Vale and it is this which caused the flood plain to narrow. In this belt of ground the C. E. G. B. borehole logs showed that Sherburn-type sands were present with lenses of laminated clays (the Upper Mixed sands and Laminated Clays). It is still not certain why these sediments should be at a higher level here than elsewhere, but the presence of the buried ridge of clays in the area may be partly responsible for this.

West of Yedingham the old flood plain opens out again but the number of former channels is much reduced. The River Derwent turns to the south just after passing the village and extends in a broad sweep towards the gap in the Howardian Hills ridge at Malton before passing on to Kirkham. Before the Derwent reaches Malton however it is joined by its major western tributary, the River Rye. However there is little evidence from aerial-photographs of the history of this confluence except that it has probably been confined to a rather limited area in the past (fig. 34).

On the northern and southern flanks of the flood plain of the River Derwent in the central part of the Vale are found two strips of poorly drained land. The width of these strips of land is variable - on the south side of the river it tends to be narrowest, especially in the Ganton area, but it is also at its widest in the Knapton area further west. On the northern side of the Vale the strip of poorly drained land extends from the edge of the former flood plain to a line roughly followed by the A171. Across the northern belt of land the former flood plains of the northern tributary streams to the River Derwent can be traced. The evidence from both the field and from the air-photographs shows that the soils in the area adjoining the flood plain were poorly drained (and still are so where ground drainage has not been artificially improved); field evidence consists of gleying, mottling of colours and the accumulation in some areas of iron-pan and peaty deposits in small hollows. There is no evidence either on the ground or on the aerial photographs which would indicate the past existence of large bodies of standing water - most of the evidence to date suggest rather that the level of the water-table has fluctuated markedly and that where this has broken the surface in isolated hollows, some peat accumulation has occurred.

The width of the former channel in the levée deposits in the eastern vale and in the numerous channels in the flood plain of the central parts of the Vale, combined with evidence from the wavelength of the abandoned meanders, show that the rivers which flowed in the channels were considerably larger than those of today.

The drainage history of the western Vale of Pickering is more difficult to interpret from aerial-photographs. The widths of the flood-plains of the major rivers appear to be much more restricted than that of the Derwent, and the belts of land on each side of the flood plain which would have been affected by high ground-water levels also appear to be narrower. However because this area has been better drained by artificial means, (e.g. tile drains and drainage ditches), the subtle tonal changes which indicate the presence or former presence of river channels and areas liable to groundwater flooding have been largely obliterated.

ii) <u>Interpretation:</u> The implications of the above evidence from the aerial-photographs, when combined with that from the field and from borehole data, are that the existence of a former lake of late-glacial or post-glacial age in the lower lying parts of the Vale are, with the exception of the Wykeham-Seamer-Flixton area and possibly in the Binnington Carr - Sherburn Ings area, probably unfounded. Shepherd suggested a sequence of falling stages of Kendall's high level (225' - 69 m O. D.) Lake Pickering, with each stage occupying less of the Vale until only the central (i.e. flood plain) area was left submerged. Walker and Godwin suggested that the maximum height of the Seamer-Flixton lake must have been circa 25 m O. D. (78') and suggest that blocking of the local lake outfall by reedswamp was responsible for this. This seems to be a more plausible suggestion than that the whole of the eastern and central parts of the Vale was submerged beneath a lake. It could also help to explain the presence of a former high water-table in the areas marginal to the flood-plain of the river. It seems unlikely that the flood-plain was permanently flooded at this stage, but the shifting channel of the river may have effectively obliterated any evidence of this.

The laminated deposits between 25 and 26.5 m O. D. in the Knapton and Marishes areas are almost certainly not contemporaneous with the peats and other lacustrine sediments in the Seamer-Flixton area for several reasons:

a) There is no evidence of organic deposits in these areas - the hollows have been entirely filled with inorganic sediment, yet the thickness of the latter (up to 4 m) suggests that the hollows were of comparable depth to the lake in the east and presumably would have offered a similar environment. There is also no reason to suppose that the supply of fine-grained clastic sediment should have been any greater in the west than to the east - indeed the converse would seem to have been more likely.

b) There are few or no organic or inorganic lacustrinesediments found over much of the central parts of the Vale to the height required (i.e. circa 26-27 m O. D.) if a lake of the kind proposed by Kendall and Shephard existed in post-glacial times. There is no reason to suppose that the peats and other sediments should have been preferentially preserved in the east and selectively destroyed further west.

c) There may have been a steeper gradient on the water table in pre-historical times before Man started to interfere with the natural drainage system. If this was the case groundwater could have stood at a lower level in the west, near the Kirkham outfall, than in the east where two restrictions, at Yedingham and at the eastern edge of the Seamer-Flixton Lake combined to help dam up the local water table.

Thus the evidence presented so far concerning the existence of late - or post-glacial lakes in the Vale of Pickering is such that except in the east the case does not seem to be a strong one. Further evidence presented below may help to confirm this.

I. <u>The Marginal and Lateral Drainage Channels of the Vale of Pickering</u>

Marginal and lateral drainage channels have freqeuently been described from both modern glacial environments and as fossil features, so they may be fairly easily recognised today (see Chamberlain 1894, Derbyshire 1958, Maag 1969, Mannerfelt 1945, 1949, 1960, Russell 1893, Schytt 1956, Sissons 1960, 1961, 1977, Tarr 1897, 1909, Tarr and Butler 1909, Von Engeln 1912). The main circumstances needed to allow the channels to form are a sufficient supply of meltwater (Schytt), the need for the glacier to be frozen to the rock slope in the case of marginal or sub-lateral channels (Maag) and in some cases the need for the strata on the hillslope to strike parallel to the slope and to dip into it (Schytt, Maag, Mannerfelt 1960). A fourth factor, a concave and/or relatively large straight and steep slope may also influence the development of these features (Gregory 1962a, b). These criteria are probably responsible for the distribution of marginal and lateral channels in a limited area near Ampleforth and on the Wolds scarp between Thorpe Bassett Wold and Flotmanby.

a) Classification

Gregory (1962a, b) recognised four types of ice-marginal or sub-lateral channels which were arranged according to the concavity or straightness of the slope and the position and shape of the channel. In descending order downslope were glacial drainage channels, asymmetrical channels, ice-marginal benches and river-gorges - the last occur in valleys or at the foot of a hillslope (fig. 37). A fifth type of sub-marginal channel, sub-glacial chutes which ran perpendicular to the slope, were also recognised. Four of the channel-types described by Gregory have been recognised in the field area: glacial (symmetrical) drainage channels, asymmetrical channels, ice-marginal benches and sub-glacial chutes. A fifth type of channel appears to be present at the foot of the Wolds scarp which does not readily conform to any of Gregory's categories, but consists of deep asymmetrical channels - these are termed scarp-foot channels. These fit naturally into Gregory's pattern where the slope is of a slightly concave shape caused by bedding in the Chalk.

b) Description

i) Symmetrical drainage channels (glacial drainage channels of Gregory)

The author has changed the name of this group of channels to make it conform with the rest of the classification which is essentially descriptive in nature. It has also been changed because all the features described in this section are thought to be "glacial drainage channels" so a new name was thought necessary.

Only three examples of this type of channel have been found - all on the slopes above Ampleforth village at circa 228 m O. D. (fig. 38 SE5873795). They form the highest units of a larger marginal drainage

Fig. 37 Idealised succession of marginal and lateral glacial channels on the northern Wolds escarpment (modified after Gregory 1962a). For details see text.

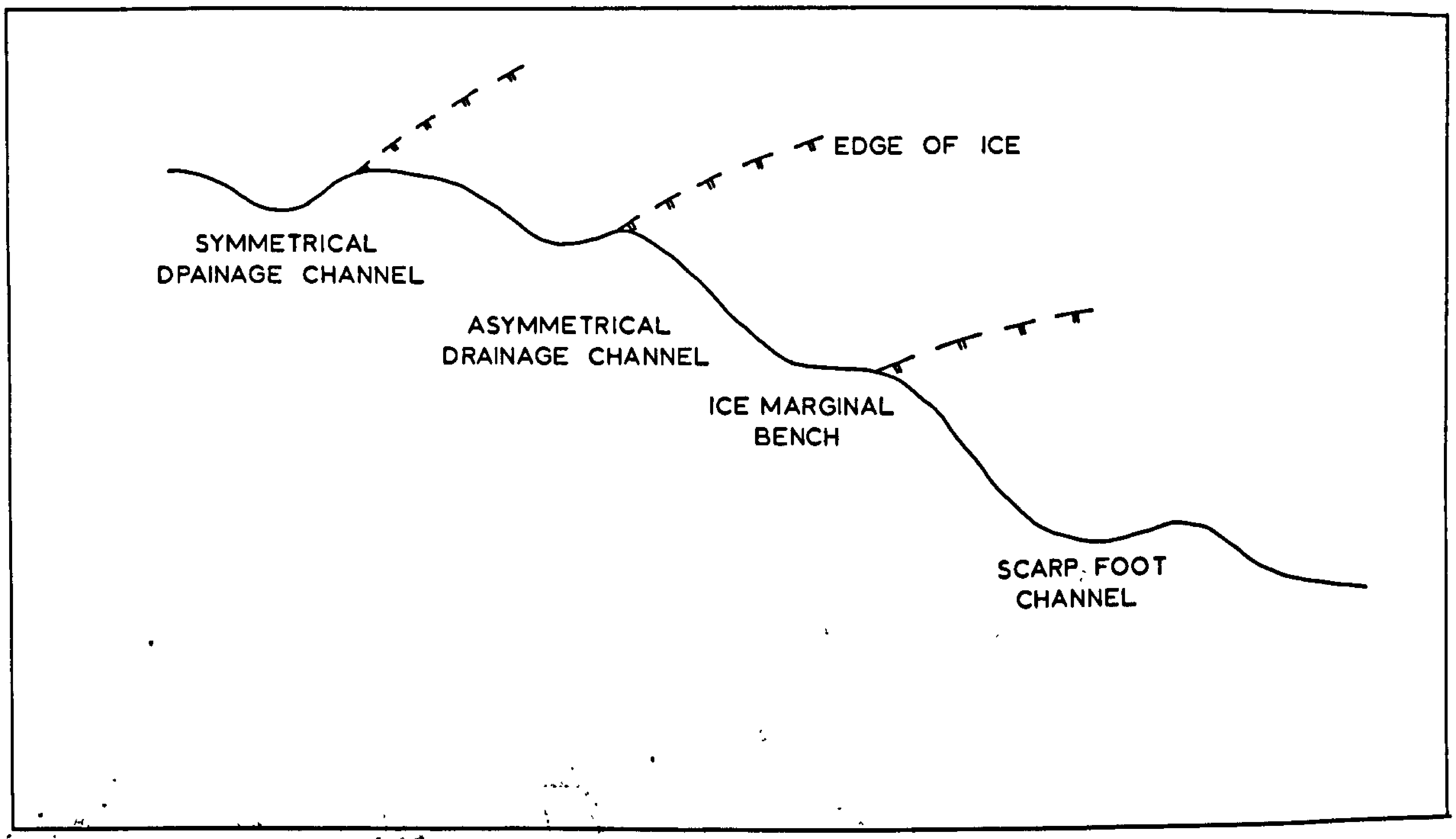
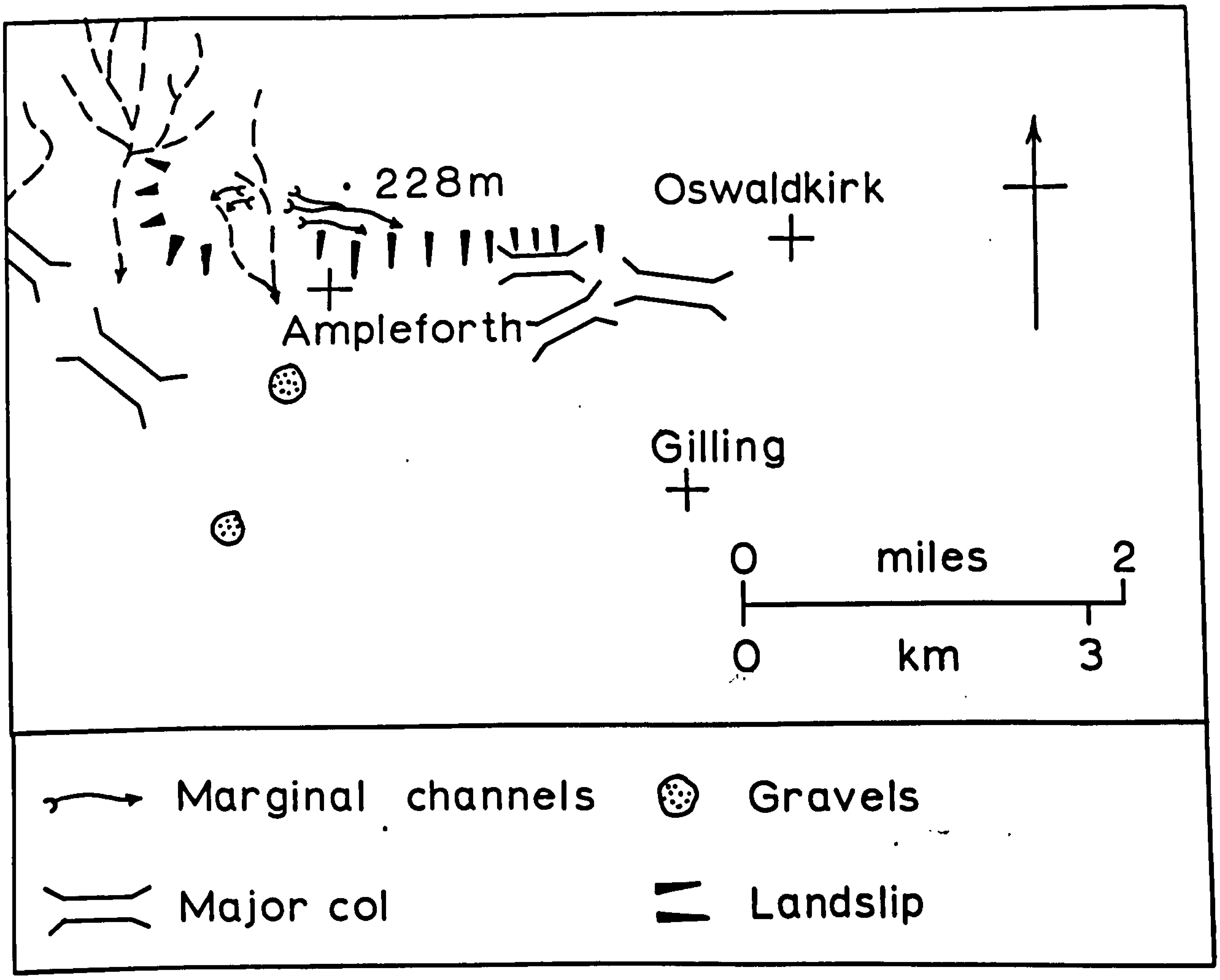

EDGE OF ICE
SYMMETRICAL
DPAINAGE CHANNEL
ASYMMETRICAL
DRAINAGE CHANNEL
ICE MARGINAL
BENCH
SCARP FOOT
CHANNEL

Fig. 38a Air photograph of the Ampleforth gap. The lateral drainage channels on the north side of the gap can be seen north of the village of Ampleforth (i.e. below it in the photograph). The Ampleforth "moraine" is a ridge marked by a line of trees to the south-west above right) of the village.

Fig. 38b Sketch map of the area shown in Fig. 38a. The location of the marginal drainage channels is shown clearly here.


228m
Oswaldkirk
Ampleforth
Gilling
0 miles 2
0 km 3
Marginal channels
Gravels
Major col
Landslip

system and are found east and west of Smith Hill Howl. Two of the channels lie to the east - these start as shallow depressions on the crest of the hill, deepen rapidly until they are 1-1.5 m (upper) and 2-2.5 m (lower) deep and grade eastwards towards Ampleforth College. The upper channel runs for circa 260 m before it turns south and enters the lower channel - however the two channels are not graded to the same level so the floor of the upper channel is left hanging above that of the lower channel. The lower channel then continues for a further 350 m before it opens out on the hillside and disappears without further trace (fig. 38). The gradients of these channels were estimated to be approx- imately 1 in 75. The third channel runs in east-west direction and lies south-east of Priest's Barn at SE576756. This is a rather short channel (250 m) with a steep gradiant which joins a shallow valley at SE577793 - the relatively steep gradient is thought to be partly due to the effects of snow meltwater erosion in the late-glacial period. In none of these channels have any fluvioglacial deposits been found, or have any tills or other evidence of the former presence of ice been discovered. The floors of these channels were augered in several places but only a relatively coarse gravelly sand was found - rock floors were not hit at the maximum depth of 0.65 m penetrated by the auger.

ii) Asymmetrical channels. Channels of this type are present both on the slopes above Ampleforth Village and on the northern Wolds escarpment. In the former area three such channels may be observed, in the latter nine (figs. 38 and 39). The channels at Ampleforth again occur as a pair and an isolated example, the pair occur on the eastern side of Smith Hill Howl (SE581794 - the third is at SE577793). The two eastern channels are relatively short (200-250 m) and have relatively steep east-west gradients: snow-meltwater modification of the channel gradients is again suspected as the major reason for the steeper than average gradients. The third channel is most notable for its depth, which is circa 6 m and by far the deepest of any of the channels in this area. It also has a humped long profile, rising slightly before plunging towards the shallow gully which runs across the western end of the channel. This hump in the profile may again be due to modification of the original channel floor by snow-meltwater but equally this may represent the original shape of the long profile: if the latter is the case it follows that the gully-like feature at the western end of the channel must represent a sub-glacial chute at least in its lower course. If this is so it would provide an alternative explanation for the steep gradient of the channel found further upslope (see i) above).

The channels on the Wolds escarpment also show variations in their shape and depth - those at Ganton (6) and East and West Heslerton Brows (8 and 9) are deeper and shorter than the channels found at Flixton (3), and Staxton (4) and West Heslerton (9) for example (fig. 39). None of the short channels are longer than 500 m and some are as short as 150-200 m (e.g. SE996766 and SE903749). Depths vary from circa 1.5 m (TA032787) to circa 2.5 to 3 m (SE996766) but excavations into the floors of the Manor Wold Farm (SE928755) and Prodham's Wold Farm (SE963753) channels revealed solifluction debris which was up to 0.7 m thick overlying large blocks of chalk which were thought to be frost-shattered chalk <u>in situ</u>. The chalk at the botton of the pits consisted of very large, angular blocks (>30 cm across) which were nearly horizontally bedded and which appeared not to have been disturbed by physical processes. Augering in the other channels on the escarpment failed to reach the blocky chalk underlying the solifluction deposits. Because the lengths of these channels were so short none of them showed any tendency towards a meandering pattern, although the entrances to the Sherburn Brow channels (SE968755 and SE963753) did appear to be at rather different angles to the main length

Fig. 39 Plan of the glacial drainage channels on the northern Wolds escarpment as mapped from aerial photographs and ground survey.

)(Col
Sub-glacial/lateral channels
?Sub glacial channel
Dry valley
0 km 1

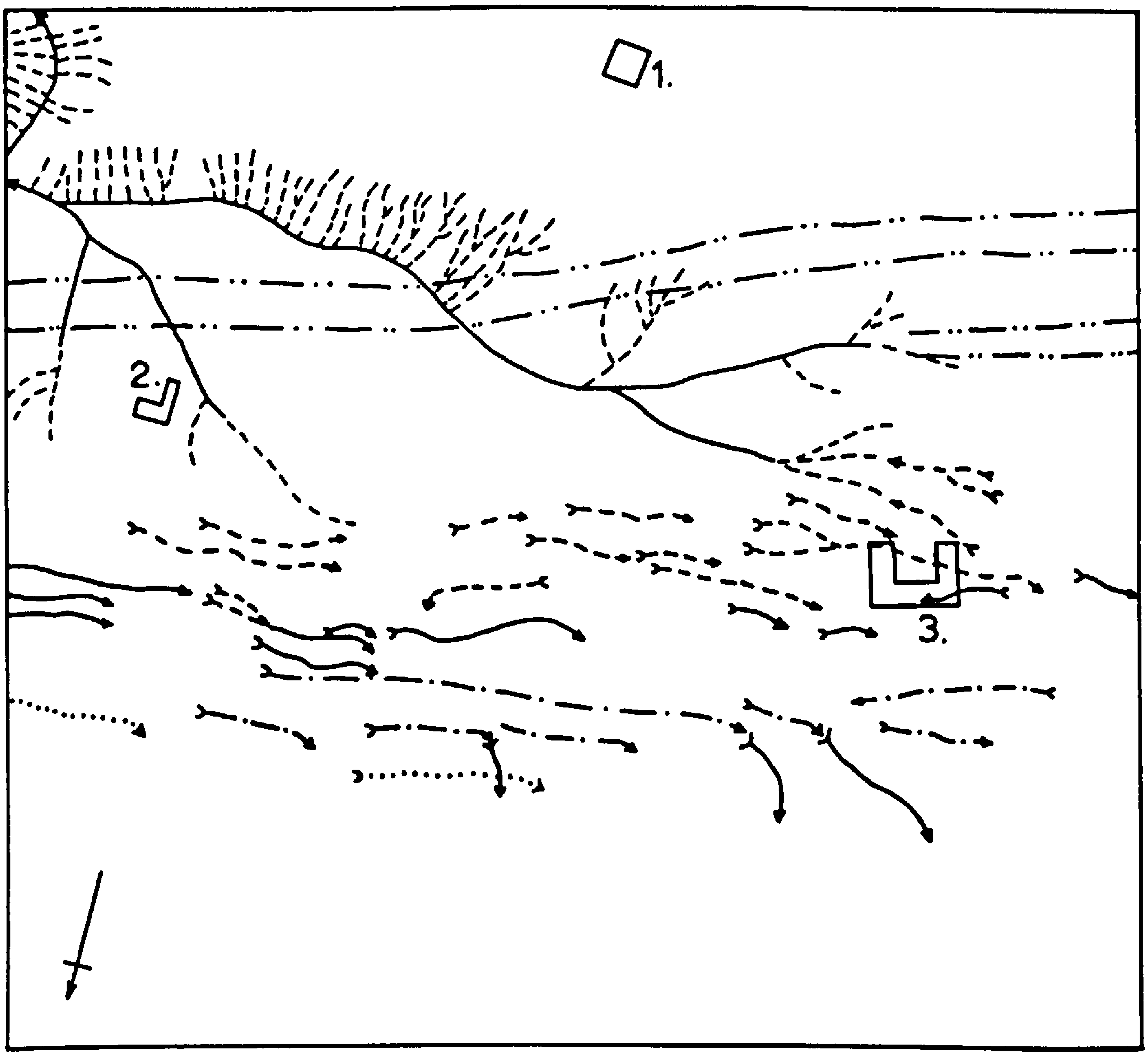
of these features. In all cases the channels opened out to the side of the Wolds scarp or passed into a gully-like feature running straight down the slope of the escarpment. The inlets of the channels were in the majority of cases rather steep as was the case with those on the Hambleton Hills. These channels were found on the upper concave areas of the scarp at heights of between 105 m and 165 m O. D. All channels except those at Ganton Brow (SE996766) and Prodham's Wold Farm (SE963753) (fig. 44) had low east to west gradients. One example of a channel of this type may be present at Luttons Lane, West Heslerton (SE910750) which is now filled with glacial deposits (fig. 43). The direction of the channel is not known but it is possible that this may have had an east-east gradient in view of the presence of the sub-glacial chute which runs parallel to the road and straight down the scarp to the north-east. The west to east gradients of the Ganton Brow and Prodham's Wold Farm channels is probably due to a local reversal of the east to west direction of the ice-gradient in these areas which was caused by the presence of the local embayment in the scarp. The variation in the height of these channels does not show any systematic fall from either east to west or vice-versa, so it would seem that the angle of the local ice-slope was probably the most important factor controlling the position and direction of these channels.

iii) Ice-Marginal benches. These are the most common of the lateral features on the scarp of the Wolds where they also form the longest continuous features. The difficulties involved in recognising some of these benches in the field have already been discussed above and will not be repeated here. Many of these benches are closely related to both the structure and lithology of the chalk on the escarpment - many of these features can be seen to follow the strike of the bedding planes in the chalk for considerable distances (e.g. East Heslerton Brow (SE934759), fig. 40). Not all of the benches are so closely related however as they

Fig. 40a Air photograph of the northern Wolds escarpment at East Heslerton Brow (Soil Survey photo).

Fig. 40b Sketch map of the area shown in Fig. 40a. The asymmetrical drainage channel south of Manor Wold Farm and a long dissected ice-marginal bench are shown, as are sub-glacial chutes.

1. East Heslerton Wold Farm (SE937740)
2. Lawsons Wold Farm (SE951749)
3. Manor Wold Farm (SE928753)



Line of tectonic disturbance

Dry valley

Dry gullies

Sub-lateral drainage channel

Asymmetrical drainage channel

Ice marginal bench

Scarp foot channel

Sub-glacial chute

cross anticlinal structures in the chalk at Binnington and Staxton Brows.

The major variations which occur in the morphology of these benches can be related to the position on the escarpment. Those at the highest parts of the scarp tend to have a steeper backwall and develop a broad meander pattern (e.g. East Heslerton Brow (SE938756) fig. 40 and Flixton Brow (TA037788) fig. 41). In addition to having steeper backwalls these benches also tend to be wider than those found lower on the scarp. The benches found lower on the scarp do have a slight backwall which is usually formed by the next resistant bed in the chalk succession; they also have much straighter courses, even though they can be as long or longer than higher scarp benches. The length of these benches sets them apart from all the other lateral drainage features on the scarp of the Wolds, many benches are up to 500 m long and some are longer than this (e.g. Flixton Brow (TA037788): 1 km, East Heslerton Brow/Sherburn Brow (SE934759): 1.1 km and SE942758 0.9 km). The longer benches cited here grade from east to west following the local strike of the bedding planes in the chalk, but some have gradients in the opposite direction e.g. East Heslerton Brow (SE929756) and one on West Heslerton Brow (SE904750). Like the symmetrical channels and asymmetrical channels many of these benches simply die out on the escarpment and leave no trace of their former courses. Some turn into sub-glacial chutes however (e.g. East Heslerton Brow (SE929759) fig. 40).

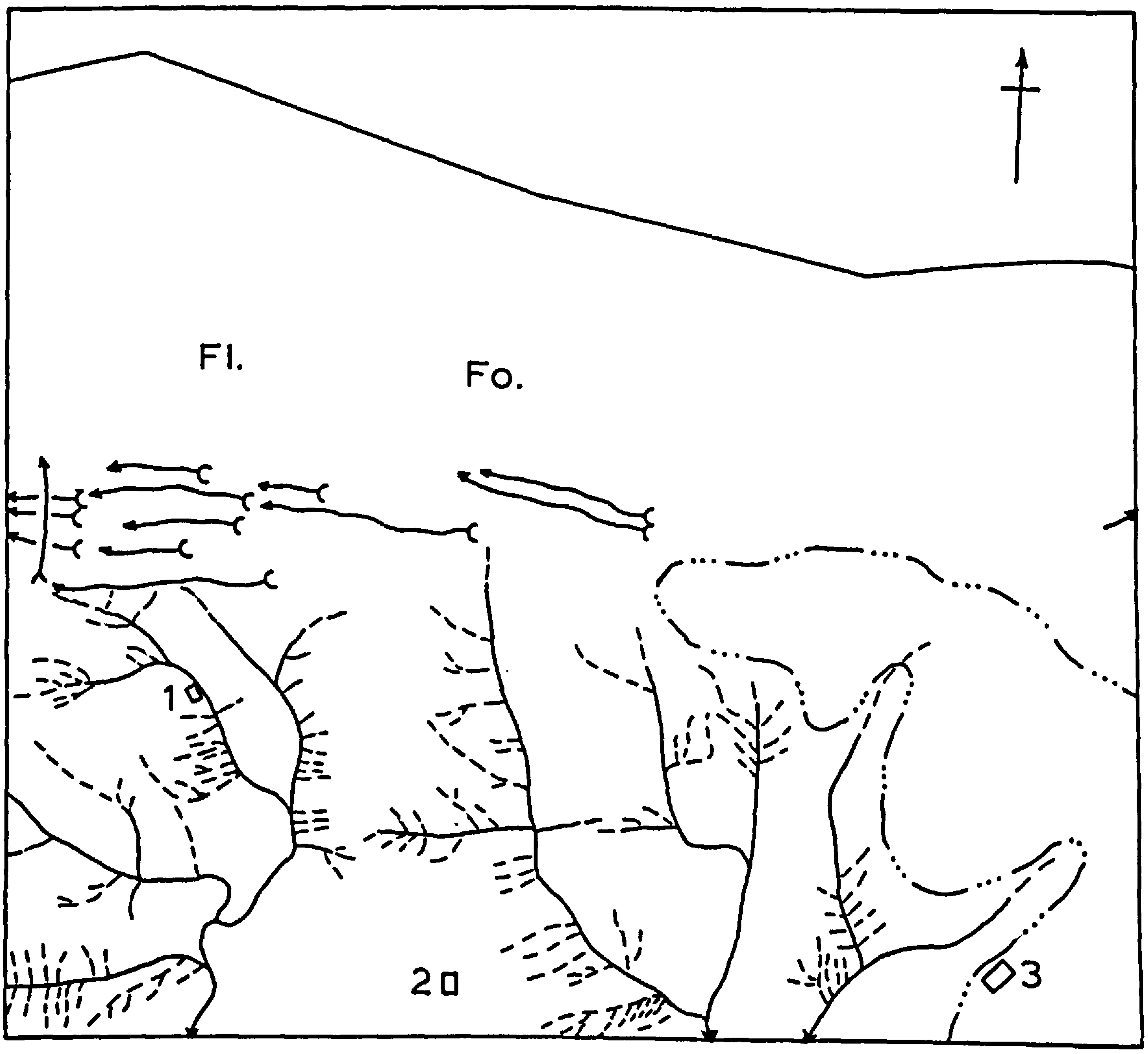
Ice-marginal benches have also been recorded at Ampleforth - two of them form the lowest marginal drainage features in the succession which extends from the top of the slope. These benches are both short and poorly developed laterally and are difficult to trace on the ground but can be clearly seen on the aerial-photographs. Benches may have formed at lower levels to those described here but were destroyed by the major landslips which scar and disrupt the lower slopes in this area.

Fig. 41a Air photograph of Flixton Wold area and the southern part of the Vale of Pickering from Flixton Carr to Flotmanby Carr. (R.A.F. photo)


0178

Fig. 41b Sketch map of area shown in Fig. 41a. The long straight line on the N. of the map is the Hertford Cut. The effects of the Flixton Wold Disturbance in the chalk, the edge of the Devensian till on the Wolds and the unusual confluence of Cotton Dale, Long Dale and North dale - which is probably structurally controlled, are all shown on this map and adjacent photo. Snevver Scar (sub-glacial chute) is visible on the left of the map (bottom of photograph) as are several marginal drainage channels (N.B. the map is rotated 90° with reference to the photograph).

Fl Flixton village
Fo Folkton village
1 Humble Bee Hall (TA040780)
2 Danebury Manor (TA054766)
3 Field Houe Farm (TA081768)



Line of tectonic disturbance

Dry valley

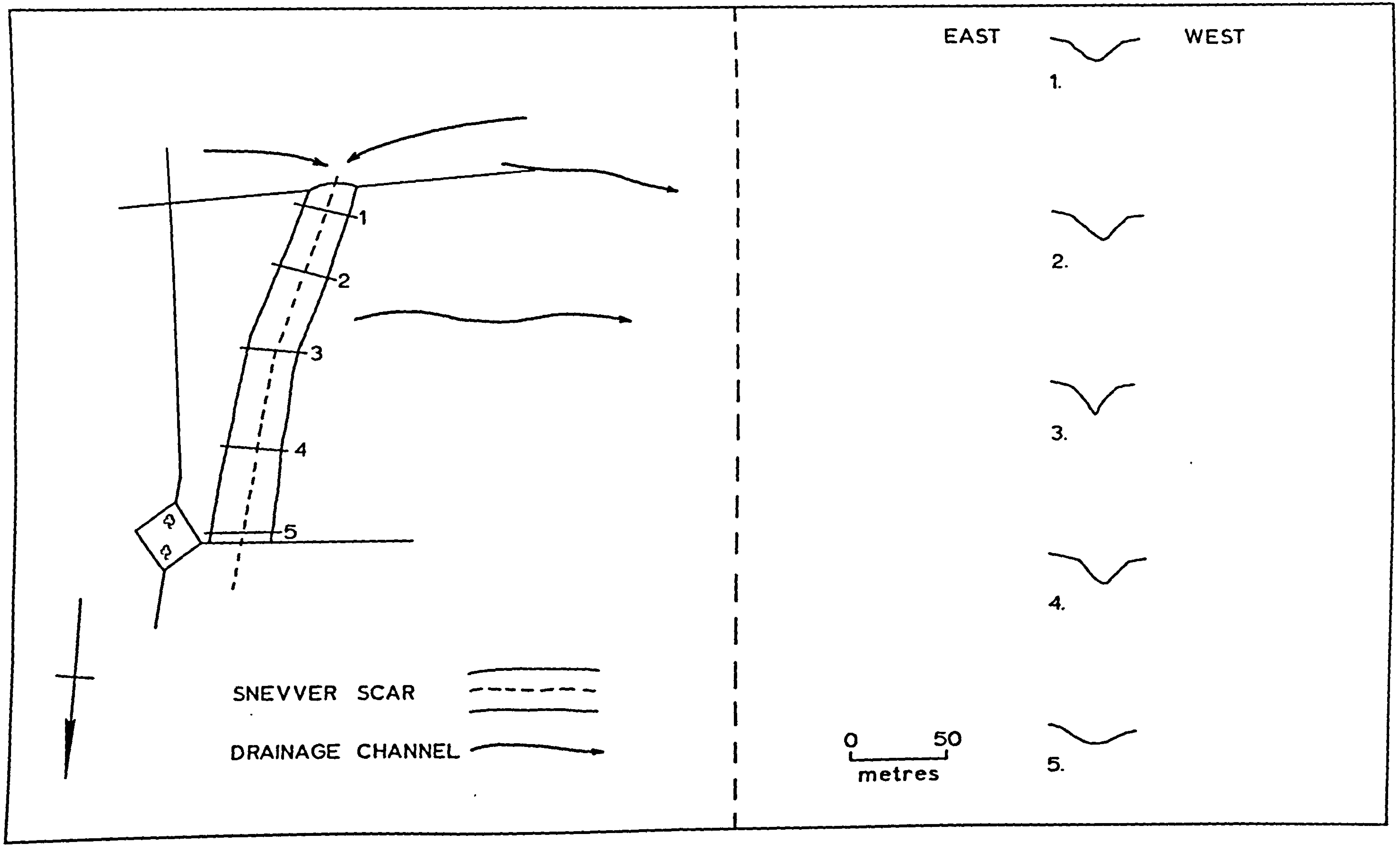
Dry gullies

Ice marginal drainage channel

Approximate limit of Devensian till

iv) Sub-glacial chutes. These and the features described in (v) below are the most difficult of the sub-glacial features on the Wolds scarp to interpret. This is because so much late-glacial gullying has occurred on this scarp that many of the gullies look like shallow chutes and some chutes look like deep snow-meltwater-cut gullies. The division between those two features is based on the supposition that those features described here as chutes were cut by meltwater (from snow and ice) passing beneath the margin of a glacier, whereas the gullies are thought to have been cut by snow-meltwater alone. Most of the above chutes are differentiated from the snow-meltwater gullies on the basis of whether a lateral drainage channel passes into the head of the chute. The major exception to this rule is Snevver Scar (TA032788, figs. 41 and 42). This narrow V shaped feature cuts across the escarpment and appears to have been fed by the channel which leads from its head westwards towards Staxton Brow (TA030787) whereas in fact the gradient of this channel is from east to west. Thus unless the channel was cut subglacially with a reversed gradient which seems highly unlikely, some other source of meltwater must be sought. There are two possibilities for this: either the channel was cut by sub-glacial meltwater flowing under high hydrostatic pressure from under the glacier at the base of the scarp into the regions of lower pressure on the crest of the scarp and possibly into the head of Merry Dale, or the water flowed in the reverse direction i.e. from Merry Dale or higher in the glacier (in an englacial tube) down the scarp into the Vale of Pickering. There is no evidence of a kame terrace or any other form of depositional feature at the foot of this channel which simply opens out at the foot of the scarp. The majority of the chutes are much less well developed than this however, and seem to be largely concentrated near the scarp-foot. Chutes which do appear to have drained from positions higher on the escarpment can be seen at Luttons Lane, West Heslerton (SE901754

Fig. 42 Plan and scale cross sections of Snevver Scar - a deep sub-glacial chute on the northern Wolds escarpment.


1
2
3
4
5
SNEVVER SCAR
DRAINAGE CHANNEL
EAST
WEST
1.
2.
3.
4.
5.
0
50
metres

figs. 43 and 52), at the eastern edge of Knapton Wood (SE902750), in Knapton Wood (SE898751), Sherburn Brow (SE965756), Ganton Brow (SE998768) and possibly (SE988765)and Staxton Brow (TA008781). Other chutes may be present at Wintringham Brow but there are some large snow-meltwater gullies in this area so great care must be taken when interpreting these features. Many chutes have very short courses confined to the lower slopes of the scarp because the benches which fed them terminated low down on the scarp e.g. East Heslerton Brow (SE929759).

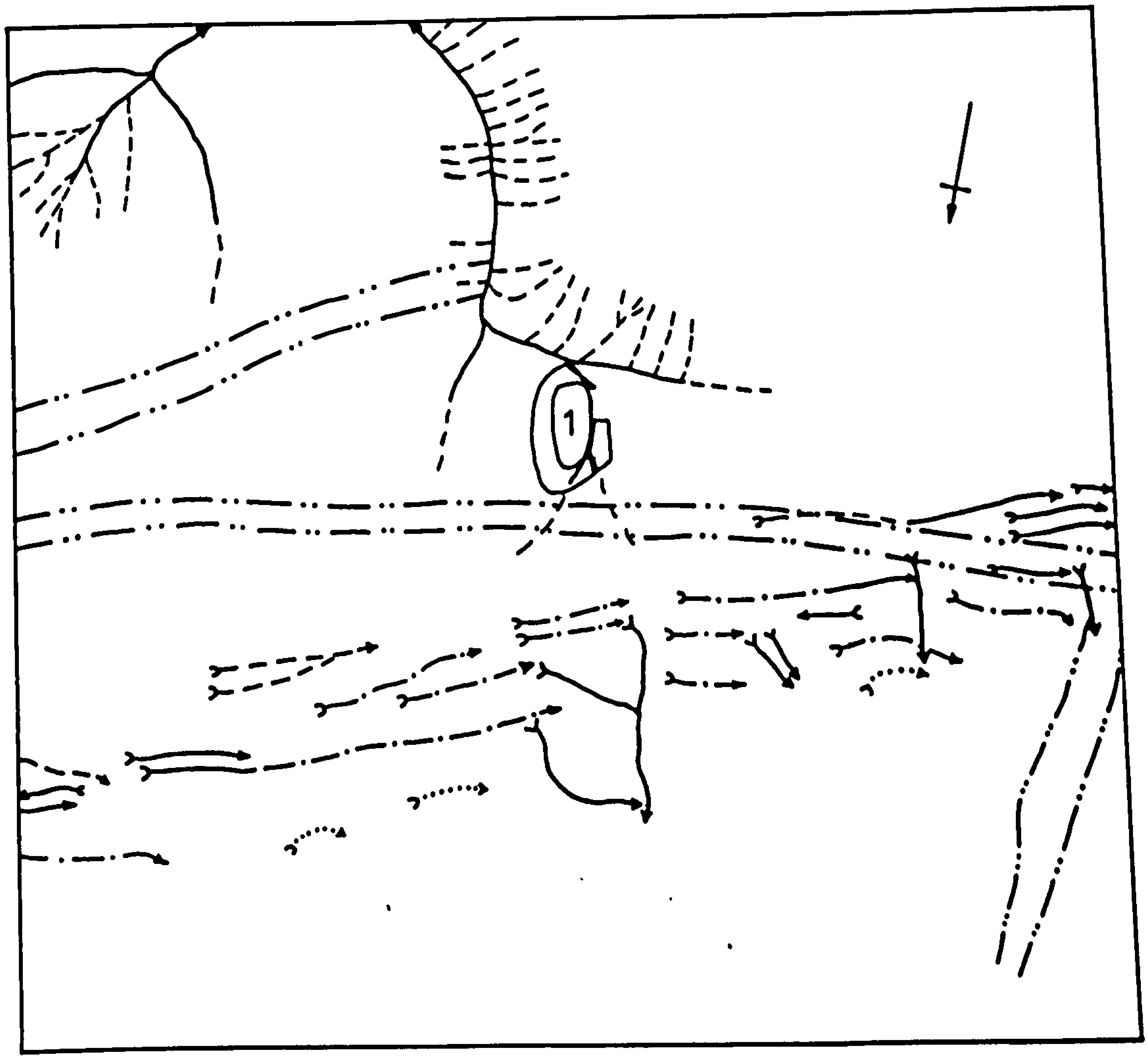
There are some bench-like features which do not conform to either the ice-marginal bench or the sub-glacial chute categories, but lie between the two classifications. These are the bench-like features which cross the scarp obliquely at too high an angle to have been controlled by the margin of a glacier and yet are not steep enough to represent chutes. They are not structurally controlled as they cut obliquely across the strike of the rocks and grade from both east to west as well as west to east. Examples of these phenomena can be seen on Ganton Brow (SE988768, fig. 8), East Heslerton Brow (SE923757, fig. 40 West Heslerton Brow (SE912754) and in Knapton Plantation (SE896749). These almost certainly represent a form of sub-glacial to sub-lateral channel system whereby meltwater was able to gain access to the lower parts of the glacier by means other than crevasses or tension cracks in the ice which tend to cause chutes to form (Mannerfelt 1949, Derbyshire 1958).

v) Scarp-foot channels. In addition to the drainage system so far described there are found, at the base of the northern Wolds scarp between Knapton and Ganton and in a short section near the junction of the base of Staxton and Flixton Brows, a series of knolls and ridges composed of dissected chalk. The channels and depressions between these areas of chalk form a highly complex pattern, the origins of which are not certain. These must represent partly at least the effects of snow meltwater erosion

Fig. 43a Air photograph of the northern Wol ds escarpment at West Heslerton Brow (Soil Survey photo).

Fig. 43b Sketch map of the area shown in Fig. 43a. Several marginal drainage channels are present including two which lead into possible chutes - at Luttons Lane in the centre and Knapton Wood extreme west (right). Part of the Knapton Disturbance is present in the west (bottom right), and the Sherburn Wold Disturbance (centre) and White Wold Disturbance (top) are also visible.

1. West Heslerton Wold Farm (SE911743)



Line of tectonic disturbance

Dry valley

Dry gullies

Sub-lateral drainage channel

Asymmetrical drainage channel

Ice marginal bench

Scarp foot channel

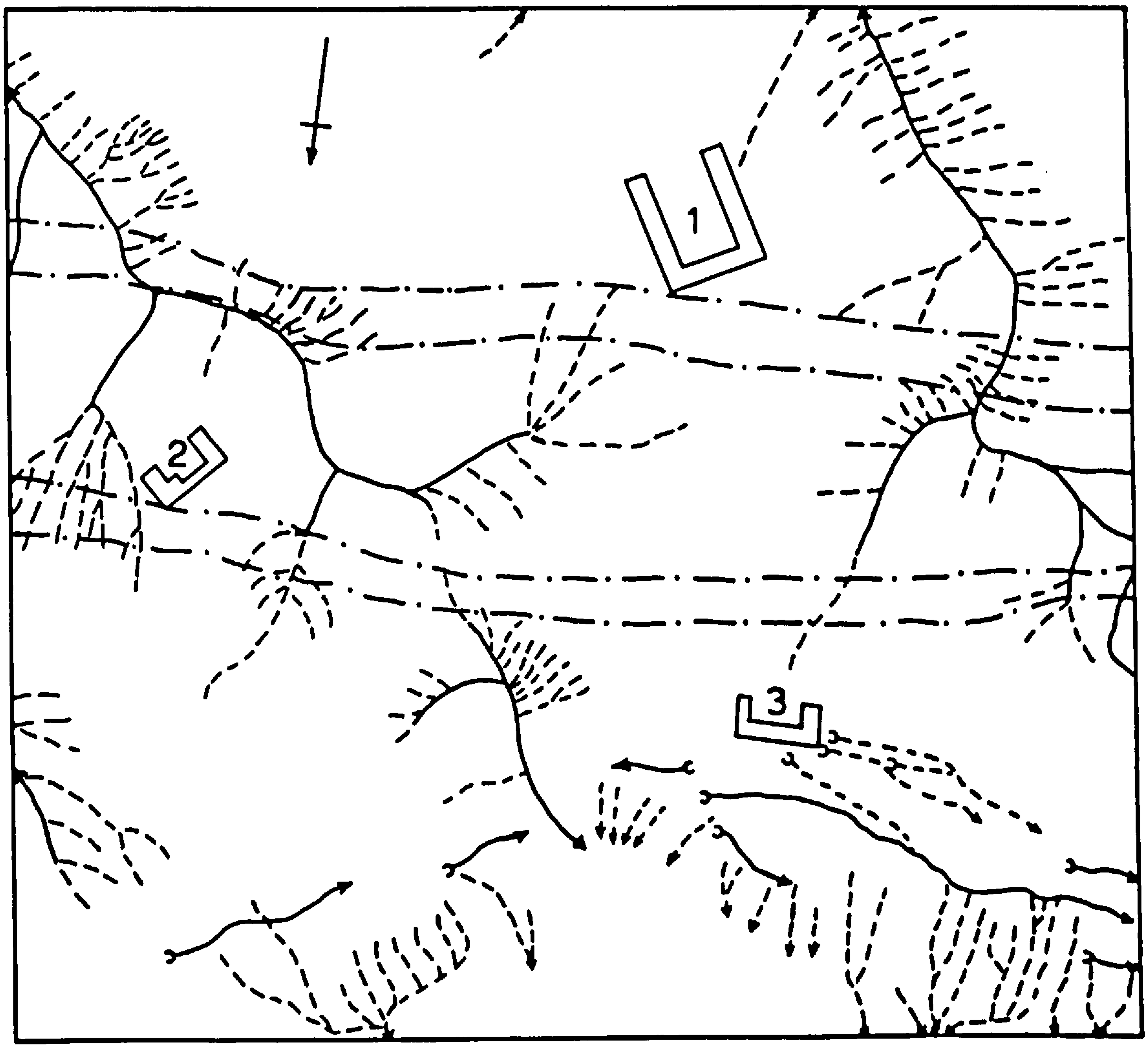
Sub-glacial chute

during the late-glacial and early post-glacial periods, but the depth and width of some of these depression is such that is seems unlikely that snow meltwater is wholly responsible. There is the added problem that if all these depressions were excavated since the last glacial period, where has all the chalk and flint gravel which would have been excavated, gone to ? Parts of the system are clearly integrated with parts of the drainage system attributed to glacial meltwaters described above, e.g. Sherburn Brow (SE970759) fig. 44. Other parts of this system on the other hand are more clearly related to what appears to be snow meltwater phenomenon e.g. East Heslerton Brow (fig. 40) Sherburn Brow (fig. 44). Many of the channels have formed parallel to the escarpment however, and while they are almost certainly related to the lithological variations in the chalk, nevertheless some process was necessary to excavate them. Spring sapping or related processes can be ruled out for several reasons, not the least of which is that there is a lack of evidence to support this hypothesis. In fact some of the evidence tends to negate this hypothesis - at the foot of Ganton Brow at SE988767 there is a small fan composed of sand and gravel (which will be more fully described in Chapter IV) which extends into the lower part of one of these lateral dry scarp-foot valleys. The fan extends almost the whole way across the valley and shows no evidence of having been eroded at its foot - although a small spring flows today approximately 130 m down-valley. Further reasons for not accepting the spring-sapping hypothesis are that many of these channels are filled with outwash sands which should have been carried away if the springs had sufficient erosive power to erode their backwalls. It is accepted that some of the sands in these hollows probably represent deposits blown there by the wind, but not all of them do because un-weathered or only partly weathered sands can be augered from the deeper parts of these channels (where the unweathered sands are found they are

Fig. 44a Air photograph of part of the Wolds escarpment at Sherburn Brow (Soil Survey photo).

Fig. 44b Sketch map of the area shown in Fig. 44a. Marginal drainage channels running from west to east and east to west are shown. The asymmetrical channel north-east of Prodham's Wold Farm is right of centre near the bottom of the map. The Sherburn Wold and White Wold Disturbances across the central parts of the map.

1. Duggleby's Wold Farm (SE962738)
2. Allison's Wold Farm (SE977744)
3. Prodham's Wold Farm (SE960751)



Line of tectonic disturbance

Dry valley

Dry gullies

Ice-marginal drainage channel

Lateral drainage channel

mixed with chalk and flint gravels). Another reason for not supporting the spring hypothesis is that at the foot of Potter Brampton Brow two channels running parallel to the foot of the scarp are seen, one being higher up the scarp than the other. If springs are suggested as a possible mechanism some means has to be found of allowing two springs to occur, one above the other. Another example of this may be seen at the foot of Sherburn Brow south-west of Westfield Farm (SE942761). Some of these channels may be very deep indeed, one at East Heslerton is circa 13-16 m deep (SE929759 fig. 40), a second at West Heslerton is 8-10 m deep (SE912755 fig. 43). These channels and cols probably partly represent a much dissected sub-marginal or sub-glacial drainage system which was excavated both parallel, obliquely across and perpendicular to the scarp foot, and partly resultsfrommodification and in places further deepening by snow-meltwater and later-stage ice-meltwater. Some of the higher channels which run parallel or sub-parallel to the scarp seem to have been especially affected by snow-meltwater by acting as gutters and drains and providing easier but more concentrated access to the scarp foot, as at Sherburn Brow (SE970759 fig. 44), Potter Bromton Brow (SE977764 fig. 8) and Knapton Wood (SE896749). It would seem therefore that the glacial drainage system, whether it was sub-glacial or marginal, was active to the foot of the Wolds escarpment, and it is conceivable that part at least may lie buried beneath a veneer of Sherburn Sand or chalk gravel. Certainly at the foot of Knapton Brow the modern surface depressions bear no relationship to the buried valley now being partially exhumed in Knapton Gravel Pit (see section E).

vi) <u>Sub-marginal drainage channels</u>. The position of marginal drainage channels can only be used to indicate the highest position at which a marginal drainage system could operate along the side of a glacier, not the maximum height attained by the glacier (Hollingworth 1952). It would seem from some of the evidence presented above (e.g. Snevver Scar) that the ice which was responsible for the formation of the marginal drainage system on the Wolds escarpment may have extended right across the top of the Wolds scarp and extended across part of the dip slope of the northern Wolds. There is good evidence in the form of till and scattered erratic debris that the Devensian glaciers did cross the watershed on the scarp and spread on to the dip-slope in the area west and north-west of Hunmanby. Snevver Scar lies beyond the western limit of the area where erratic pebbles are relatively common on both the scarp crest and dip-slope (Chapter IV) yet the freshness of this feature and the fact that it lies to the east of the known till limit in the Vale of Pickering suggest that this could well represent a Devensian ice-melt phenomenon. If this hypothesis is correct, and the marginal drainage system on the remainder of the northern escarpment does not represent the maximum height or limit of advance of the ice which filled the Vale of Pickering (the age of this glacier can, for the moment at least, be disregarded), there could be some evidence on the Wolds escarpment watershed/dip-slope area which may indicate the former presence of ice. Such evidence may take the form of a system of anastomising depressions which are found over large areas of Staxton, Flixton and Folkton Wolds and which occur sporadically along the southern fringe of the scarp watershed from Flotmanby in the east to Settrington Wold in the west. These depressions could represent a sub-marginal drainage system related to the melting margins of the Vale of Pickering glacier. These depressions are of variable but relatively shallow depth (0.5 - 1 m) and are usually quite short (50 - 150 m) when observed on the ground, although when seen on aerial-photographs they are much longer (e.g. figs. 41 and 45). In places the only way in which these channels may be traced on the ground is by testing the thickness of the sandy topsoil with an auger, in other areas (e.g. Staxton Wold, Wintringham Wold) the depressions can be easily seen. Their alignment appears to be closely related to either disturbances in the chalk (e.g. Flixton Wold, Settrington Wold) or to the course of the escarpment (Sherburn Brow, East Heslerton Brow). The depressions are filled with a slightly thicker gravelly sand and topsoil than the surrounding areas, although on Staxton Wold "yellow" sands used to be present at the bottom of the soil profile before deep ploughing and dragging by the farmer destroyed this horizon. The owner of the fields in which this sand occurred claimed that it was just like the sands which were found at the foot of the scarp at Sherburn and in the old chalk pit at Staxton Wold House (for a description of the latter see Chapter IV). Augering by the author has revealed the presence of a very thin and weathered horizon of Matthew's clay-with-flints (see Chapter IV) overlying the chalk in the depressions on the extreme southern edge of Staxton Wold, in one of the depressions overlooking the western side of Thorpe Bassett Brow and in some of the depressions on Settrington Wold. This could clearly be taken as evidence that these depressions were not excavated by glacial melt-waters, but on the other hand it could be argued that the material augered from the bottom of these depressions merely represents reworked and possibly disturbed material which has slipped into the floors of the depressions from the surrounding areas. If the latter is the correct explanation the difficulty arises of how these deposits could have survived the effects of being overriden by glacier ice, even if the latter was relatively thin and on the margins of the main glacier; an alternative explanation of the formation of these features is given in Chapter V.

vii) Other possible sub-marginal drainage features. There are two other interesting groups of features which occur near the crest of the escarpment and may be attributable to glacial meltwater. These are found at Potter Brompton (SE9775 and 9875, fig. 8) which consists of the long

Fig. 45a Air photograph of Settrington Wold and adjacent areas, including the Stack Hills and Wintringham embayment. (R.A.F. photo).


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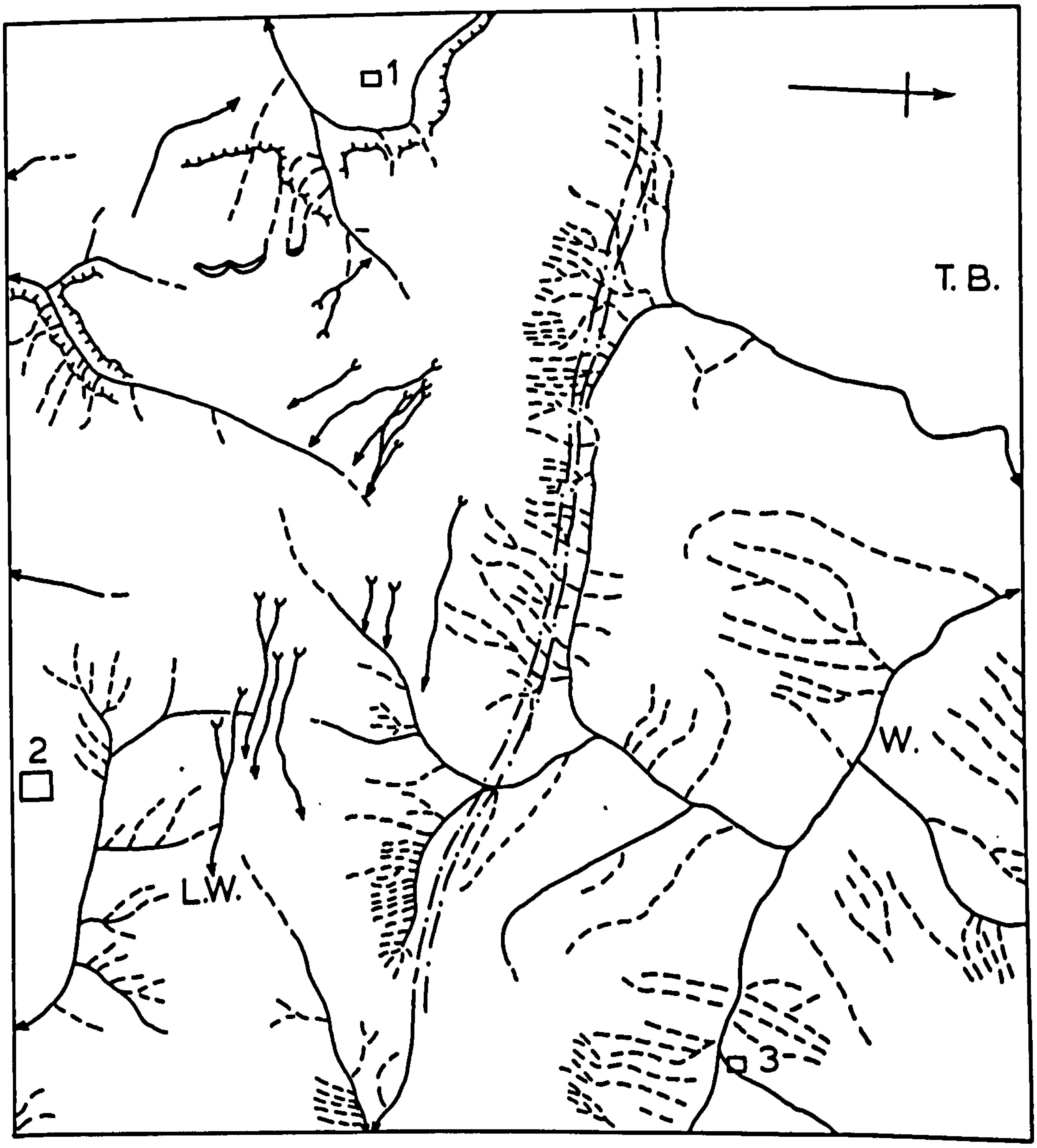
Fig. 45b Sketch map of the area shown in Fig. 45a. The line of the Stack Hills run from near the top of the photo (east side of map) to the central area. Marginal drainage channels are shown west of Linton Whins running along the escarpment and on Settrington Wold (north-west corner). The large scallop-shaped depressions on Settrington Wold are thought to be cracks and scars in the chalk caused by large-scale slipping of the underlying Kimmeridge Clay.



Line of tectonic disturbance
Dry valley/stream
Dry gulley
Glacial drainage channel
Depressions caused by landslip
Landslip scars

shallow head of Ganton Dale, and at Birdsall Wold (SE8363) where a similar long shallow valley runs parallel to the escarpment before leading into Wood Dale (fig. 14). Both of these channels gradually deepen as they enter the heads of the main parts of their respective dry valleys, but differ from all the other dry valleys in the area in that they are much longer than the average shallow depressions at the head of the other dry valleys. These depressions are found at 122 m O. D. (Potter Brompton) and 220 m O. D. (Birdsall Wold) and indicate beyond doubt that even if they were not cut by glacial meltwater, they were certainly excavated when the ground was frozen and run-off must have been very much greater than at present. The broad meander pattern which is present in the Birdsall Brow depression is strongly reminiscent of the marginal channels on the northern Wolds escarpment, but this could equally be explained in terms of the inherent nature of water in an open channel to develop a meandering course. Some evidence that ice may well have been present on this escarpment is further provided by an unusual and probably unique feature at Vessey Pasture, where a semi-circular channel can be seen extending from one of the Raisthorpe depressions (SE839623) obliquely across the slope for approximately 300 m before it joins a gully and disappears (fig. 14). The oblique channel has a constant depth (circa 1.5 m) and width (circa 2.5 m) throughout its straight course and looks very much like the lower half of a circular pipe or tube. Only a thin layer of sandy gravel has been found in the bottom of the channel and here as in other places where unusual phenomena have been found, there is no evidence of any glacial drift. It is assumed that this is a glacial phenomenon and represents a sub-glacial chute which ran obliquely across the local slope - no other explanation seems adequate. The age of this feature is not known but it is presumed to be of Devensian age because of the well-preserved nature of the channel.

C Discussion

Recognition of the marginal drainage features described above has not always been straightforward, especially in the field where they have been mistaken for fossil landslips by previous authors (e.g. Fox-Strangways 1881, Lewin 1969). Dissection of the lower level channels and especially the scarp-foot channels by late-glacial snow-meltwater gullies has helped to obscure the true nature of these features in the field, yet the asymmetrical channels and ice-marginal benches stand out quite strikingly on aerial-photographs as part of a larger complex drainage system (figs. 51 and 55). In addition levels can be measured on the isolated flats between the gullies which show that gradients of between 1 in 50 and 1 in 80 are present; these correlate well with gradients recorded from other ice-marginal channels in other parts of Britain and northern Europe (e.g. Sissons 1960, 1961, Mannerfelt 1949, 1960). In addition there is good evidence to show that the ice-marginal benches are closely related to lithological variations in the chalk and that the gradient on the benches is related to the dip of the strike of the chalk on the northern escarpment. Finally there is a very marked difference in the morphology of the escarpment of the Wolds which has been affected by landslipping (e.g. Settrington Brow and Birdsall Brow) and those parts of the scarp where ice-marginal drainage channels are present (i.e. east of Thorpe Bassett Wold and on the slopes above Ampleforth). This difference in morphology is immediately evident on both aerial-photographs and in the field (compare figs. 14 and 41). In the Ampleforth area direct comparison between slopes which have marginal drainage channels and those affected by landslipping is possible on the same hillside (fig. 38). There the upper part of the slope has had a series of marginal drainage channels cut into it while the lower slope has suffered large-scale landslipping. This confusion between landslips and ice-marginal drainage channels also affected

McLaughlin (1904) who described and illustrated landslip benches and scars in the mistaken belief that they were "overflow channels". Ultimately it seems that the best way of distinguishing between landslips and marginal drainage channels is by aerial-photographic interpretation supplemented where necessary by surveying on the ground.

One characteristic feature which is common to all the scarp drainage channels, with the exception of some of the more heavily dissected scarp-foot channels, is the freshness of the system. This may not be readily apparent at first sight in view of the amount of dissection by gullies which has occurred, but when the depth and density of the gullies on the northern Wolds scarp is compared with that on the sides of the dip-slope dry valleys it is found that the two are pretty well the same (see Chapter V for further details of the gully system). The Ampleforth channels are remarkably well preserved and undissected, probably because there were insufficient collecting grounds for snow and what meltwater there was tended to be concentrated in fewer, larger channels.

Another feature of the channels on the northern Wolds scarp is that their physical shape and character does not change when passing along the length of the scarp from Flotmanby and Muston Brows in the east to Knapton Brow and Thorpe Bassett Brow in the west.

A third notable feature is that the channels on both the Wolds and the Hambleton Hills (Ampleforth) are remarkably free of solifluction debris, blown sands, loesses, etc., or any other unconsolidated or loosely consolidated deposits except at the few localities described in Chapter IV (below). Ice and snow meltwater erosion may account for this lack of debris on the lower and middle scarp slopes, but it is inadequate to account for the lack of debris in the channels near or on the scarp crests. It would seem that although snow-meltwater was able to clear away the bulk of any glacial or fluvio-glacial deposits which may have been left in these channels and was able at the same time to achieve a considerable degree of localised erosion in gullies, it was not apparently able to transport this debris once it had reached the foot of the scarp (hence the gravel seams and lenses in the Sherburn Sands, see p. 47 above).

From the above remarks two broad conclusions may be made:

i) the drainage system on the Wolds was cut during one phase only and that the channels at Ampleforth would appear to be contemporaneous with the channels on the northern escarpment;

ii) both systems are remarkably well preserved and still easily recognisable as glacial marginal drainage systems.

This strongly suggests that these features and the associated deposits described in Chapter IV (below) are of Devensian age: the implications of this are left until Chapter VI.

J. The Settrington Dry Valley

Both Fox-Strangways and Kendall noted the anomalous dry valley which runs from Belmanaer Farm (SE843683) west and north-west wards to join the Vale of Pickering at Auburn Hill (SE800700, fig. 62c, Fox-Strangways 1892, Kendall 1902, p. 501). They were uncertain of the cause of the diversion of the North Grimston Beck northwards into the Vale via Settrington (SE8370) - Fox-Strangways suggested the stream had diverted itself by building up a large accumulation of chalk gravel in the area just south of Belmnaer Farm. This mass of gravel effectively blocked the old course of the river and diverted it northwards into the present valley. Kendall was of the opinion that the dry valley in the Jurassic limestones had been cut under peri-glacial conditions and that surface water ceased to flow when the ground thawed in post-glacial times.

The drainage history of this area is almost certainly one of great complexity having been influenced by glacial, peri-glacial and temperate processes. To what extent each of these agencies has contributed to the evolution of the drainage pattern cannot be known with certainty and any reconstruction of events is bound to be speculative. However, the diversion of the North Grimston Beck by the accumulation of a large fan of chalk gravel just south of Belmanaer Farm is almost certainly the correct explanation for the modern course of the North Grimston Beck - such diversions have been recorded at several localities in Southern England by Worssam (1974). The age of the diversion cannot be dated accurately but probably occurred either during pre-Zone I or Zone III times when run-off from the chalk and surrounding areas was much increased by melting of snow-banks and frozen ground during spring thaws. It is interesting to note that almost all of the gravel in this fan appears to be of angular to sub-angular chalk and a little angular flint, and of a size comparable to the gravels found in association with the Sherburn Sands in the Vale of Pickering and in dry valleys on the Wolds (Chapter V) i.e. between 1 and 4 cm diameter. This suggests that run-off from Duggleby Wold and Settrington Wold was very much greater than at present, and that the dry valleys at the head of Whitestone Beck may have been partly incised at this time.

Kendall's suggestion that the now dry valley which runs between Belmanaer Farm and Auburn Hill (fig. 46) is a product of river capture is also worthy of further consideration. This valley runs across theoutcrop of Jurassic limestones and it is possible that even if the North Grimston Beck flowed into this valley at Belmanaer Farm it might still have disappeared into its bed before reaching the Vale of Pickering, just as the Upper Gypsey Race disappears into its bed in the Great Wold Valley. It is not known how closely analogous the Settrington dry valley is to the dry valleys of the chalk, but it is possible that the former feature was cut under predominantly peri-glacial conditions, a factor which may account for its

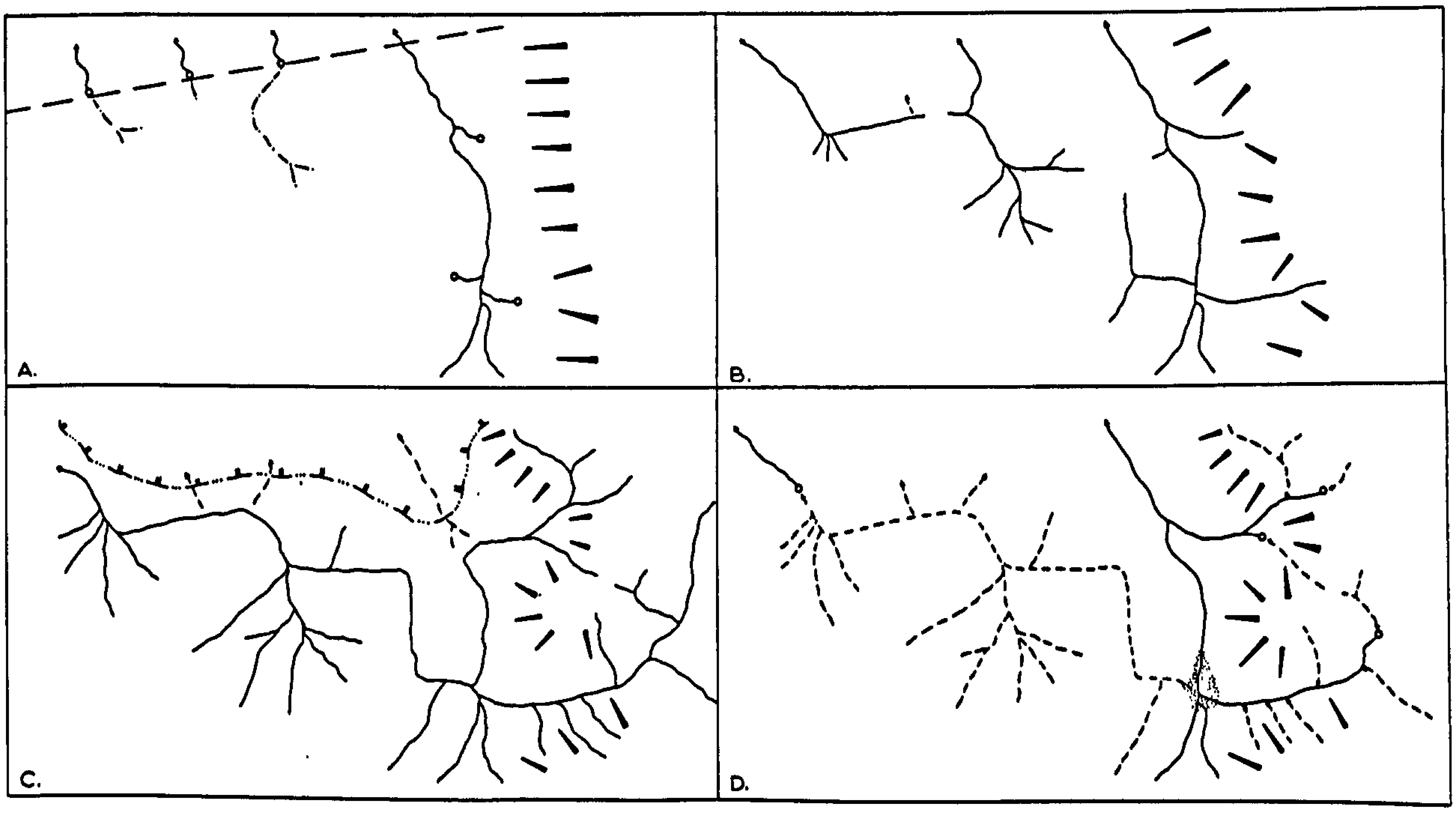
Fig. 46 Development of the drainage system and dry valleys near Belmanaer Farm, North Grimston.

A. Stage 1. Springs cut through the line of Jurassic scarp and North Grimston Beck cuts its valley.

B. Stage 2. Extension of North Grimston Beck tributaries onto the Jurassic limestone outcrop - possible headward extension of larger stream system leading to Auburn Hill gap.

C. Stage 3. Invasion and blockage of the Vale of Pickering by ice, causes diversion of drainage through last open gap into the Vale in the extreme event. All drainage diverted at this stage.

D. Stage 4. Diversion of the North Grimston Beck by Whitestone Beck building up a large fan of debris in the old gap at Belmanoer Farm. This would leave the old valley system on the Jurassic limestones dry and divert the N. Grimston Beck into the most western outlet into the Vale of Pickering.


A.
B.
C.
D.

apparently more "youthful" appearance when compared with the valley of North Grimston Beck north of Belmanaer Farm. The different geology of the two valleys may also in part account for their differences in appearance - the North Grimston Beck valley is cut in Kimmeridge Clay overlain on the eastern side by chalk. The eastern slopes of the valley are therefore largely excavated in an incompetent rock which is liable to slip under adverse conditions and so reduce the angle of slope. The limestones of the dry valley are not so unstable and consequently are able to support steeper slopes - their greater resistance to erosion may thus account for the much narrower valley which has resulted.

Other physiographical features of the area which are equally controversial are the low ridge-like hills and intervening gaps between Westfield Farm (SE818703) and Auburn Hill (SE800700). Between these there are three gaps in the Jurassic limestone ridge and three low hills - the latter are probably related to a line of faulting in the Jurassic and the ridge could represent the dissected remnants of a fault-scarp. The major problem is to explain how the scarp was dissected. In addition there is the related question of whether the river which last used the dry valley also used one, two or all three wind gaps to enter the Vale of Pickering. The latter question can only be partly answered as the air-photographic evidence clearly shows that at the last stage of use of this channel only the Auburn Hill gap (SE800700) in the west was used. Just when this valley was last used is uncertain, but as explained above it is thought to have possibly been as late as Zone III. The presence of chalk and flints in the gravels in the valley near Settrington Grange (at SE834693) suggest that it was being used just prior to the diversion by the accumulation of similar material at Belmanaer Farm. The actual origin of the wind gaps in the ridge is difficult to explain. The trench section at Sutton Grange (p. 57) may provide some evidence however. It was noted that the gastropods found in a fine clay there indicated the presence of a small spring, and the example of a spring at SE799701 was cited as an example of a modern spring in a similar situation. If under peri-glacial conditions these springs were both larger and sited nearer to the limestone ridge they could have contributed to the erosion of the wind gaps. There are two other wind gaps in this area, both of which are difficult to account for. The first is at Settrington Grange (at SE836696) which cuts across the interfluve between the lower course of the North Grimston Beck valley and the dry Settrington valley at the point where the latter turns 90° away from the former (until this point the two valleys run parallel to one another - fig 46). A second col is found at Sparrow Hall (SE828699) which forms another wind-gap leading into the Vale from the Settrington dry valley. The origin of this col is as mysterious as that at Settrington Grange.

A possible reconstruction of events during the Devension in this part of the southern edge of the Vale of Pickering is as follows. It is assumed that the North Grimston Beck flowed along its present course during the early and middle Devensian but that during the late Devensian period the modern exit into the Vale at Settrington was blocked by a lobe of ice from the North Sea Glacier which had advanced into the eastern and central parts of the Vale. This caused the beck to flow into the head of the Settrington valley (which at this time may have had a peri-glacial stream flowing in it) where it flowed into the Vale of Pickering via the Westfield Farm gap (fig. 46). However, this gap was blocked shortly afterwards by the advancing lobe of ice, so the Beck was again diverted, this time westwards towards the Newstead House gap (SE811702) which in turn was blocked by the ice. Finally the Beck made an exit into the Vale via the Auburn Hill gap until this too was blocked by ice. It is possible that the Sparrow Hall and Settrington Grange cols could have been partly excavated by meltwater draining from the margins of the North Sea Glacier into the Settrington dry valley - this meltwater finding an exit into or under the ice at one of the gaps between Westfield Farm and Auburn Hill (fig. 46b). Thus these valley systems could be taken as evidence of a possible limit of advance of the North Sea Glacier into this part of the Vale of Pickering.

K. Conclusion

In this chapter an outline of the details of the sediments and some of the landforms which are found within and around the margins of the Vale of Pickering has been given. These sediments and landforms have not been properly described before and it is accepted that there are many gaps in the above account - it is hoped that further work in the future will help to fill in some of them. Nevertheless a better reconstruction of the late-glacial history of the Vale is now possible, but this is still fraught with difficulties not the least of which is the problem of the relative ages of the various sediments and landforms. A further discussion of these will be presented in Chapter VI.

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VOLUME 2

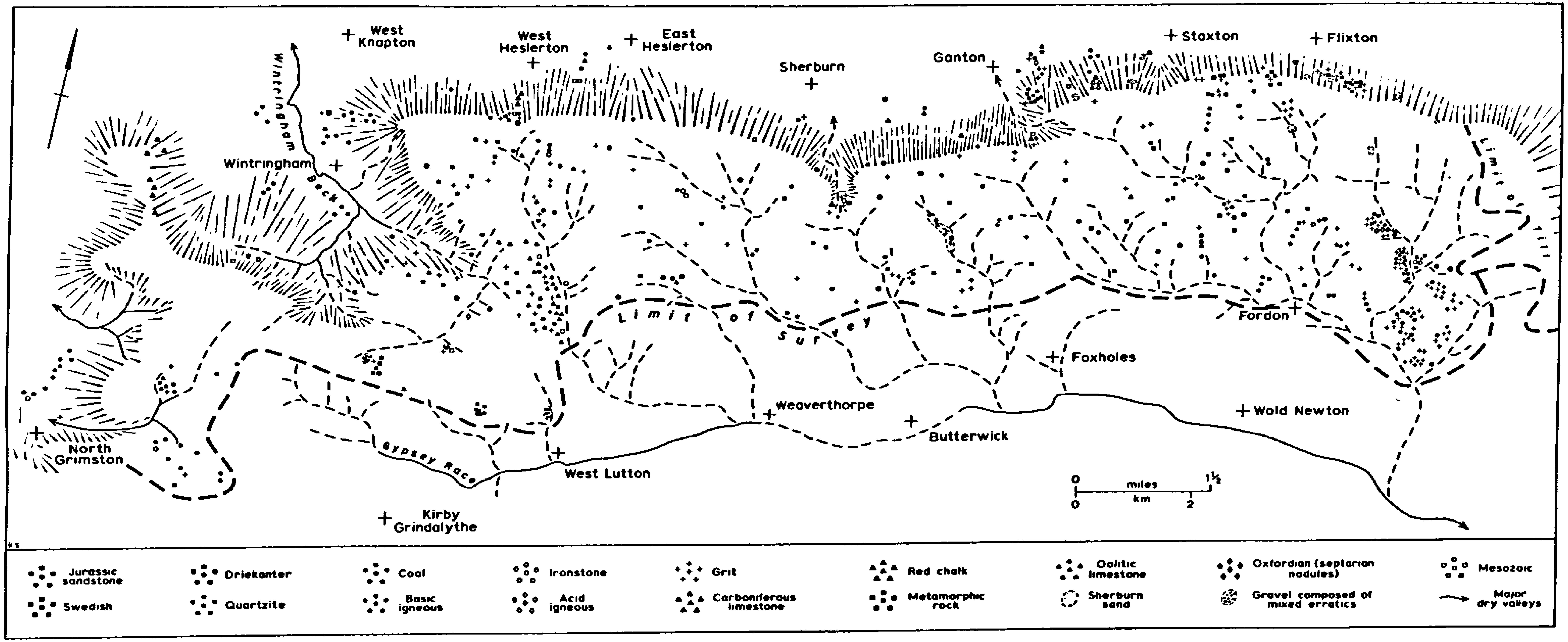
CHAPTER IV

THE DRIFT DEPOSITS OF THE NORTHERN YORKSHIRE WOLDS

Drift deposits in the form of morainic material and boulder clays are only found on the eastern fringes of the Yorkshire Wolds east of Hunmanby and over the footslopes overlooking the Holderness plain. Till deposits appear to be totally absent over the rest of the Wolds however, as even the scattered deposits mapped originally by Fox-Strangways in the High Hunsley area as boulder clays have since been shown to be only a remanié deposit or a thick mass of loess. The brickearths at Huggate originally described as "purple clays" and compared with the Purple Till (Skipsea Till) of Holderness by Rome (1868) have been shown to be partly of loessic origin (Catt et. al., 1974). However, there are extensive deposits of erratic pebbles on the Wolds which were originally described by Stather (1900, 1901, 1903, 1904), Sheppard (1904), Melmore (1935) etc., and assigned by Bisat (1940) to an "Older Drift" (i.e. pre-Devensian) origin. These authors mainly described more resistant rock types which appeared to support Bisat's theory that they represented a remanié deposit of an older drift cover. Mapping by the author has shown that many different petrological types are represented in the scattered erratic deposits of the Northern Wolds, not all of which are resistant, and which imply that because a sheet of till is absent this does not necessarily imply that glaciers did not invade the area. In addition outwash sands similar in character to those found in the southern Vale of Pickering have been found on both the northern Wolds escarpment and in at least one dry valley, implying that the northern edge of the Wolds at least must have been glaciated recently (fig. 47).

The soils of the Wolds have never been systematically mapped - the

Fig. 47 The drifts and erratics found on the Northern Yorkshire Wolds - for details see text.


West Knapton
West Heslerton
East Heslerton
Sherburn
Ganton
Staxton
Flixton
Wintringham
Wintringham Beck
North Grimston
Limit of Survey
Fordon
Foxholes
Weaverthorpe
Butterwick
Wold Newton
West Lutton
Gypsey Race
Kirby Grindalythe
0 miles 1½
0 km 2
Jurassic sandstone
Swedish
Driekanter
Quartzite
Coal
Basic igneous
Ironstone
Acid igneous
Grit
Carboniferous limestone
Red chalk
Metamorphic rock
Oolitic limestone
Sherburn sand
Oxfordian (septarian nodules)
Gravel composed of mixed erratics
Mesozoic
Major dry valleys

study by Catt et. al., (1974) consisted only of a series of isolated samples taken from selected localities. Matthews (1975) and King (in prep.) have only mapped the fringes of the Wolds escarpment and as yet no systematic survey has been carried out. This author believes that certain assumptions have been made in the past concerning the Wolds soils (i.e. that they are derived largely from loessic deposits, that the colluvial deposits in the dry valleys are derived from the surrounding interfluves, etc.) which are not wholly founded on solid field evidence, and it was decided to test these assumptions, especially in the light of evidence that the dry valleys draining the Wolds may have acted as glacial spillways.

A The Drift Deposits of the Northern Wolds Escarpment

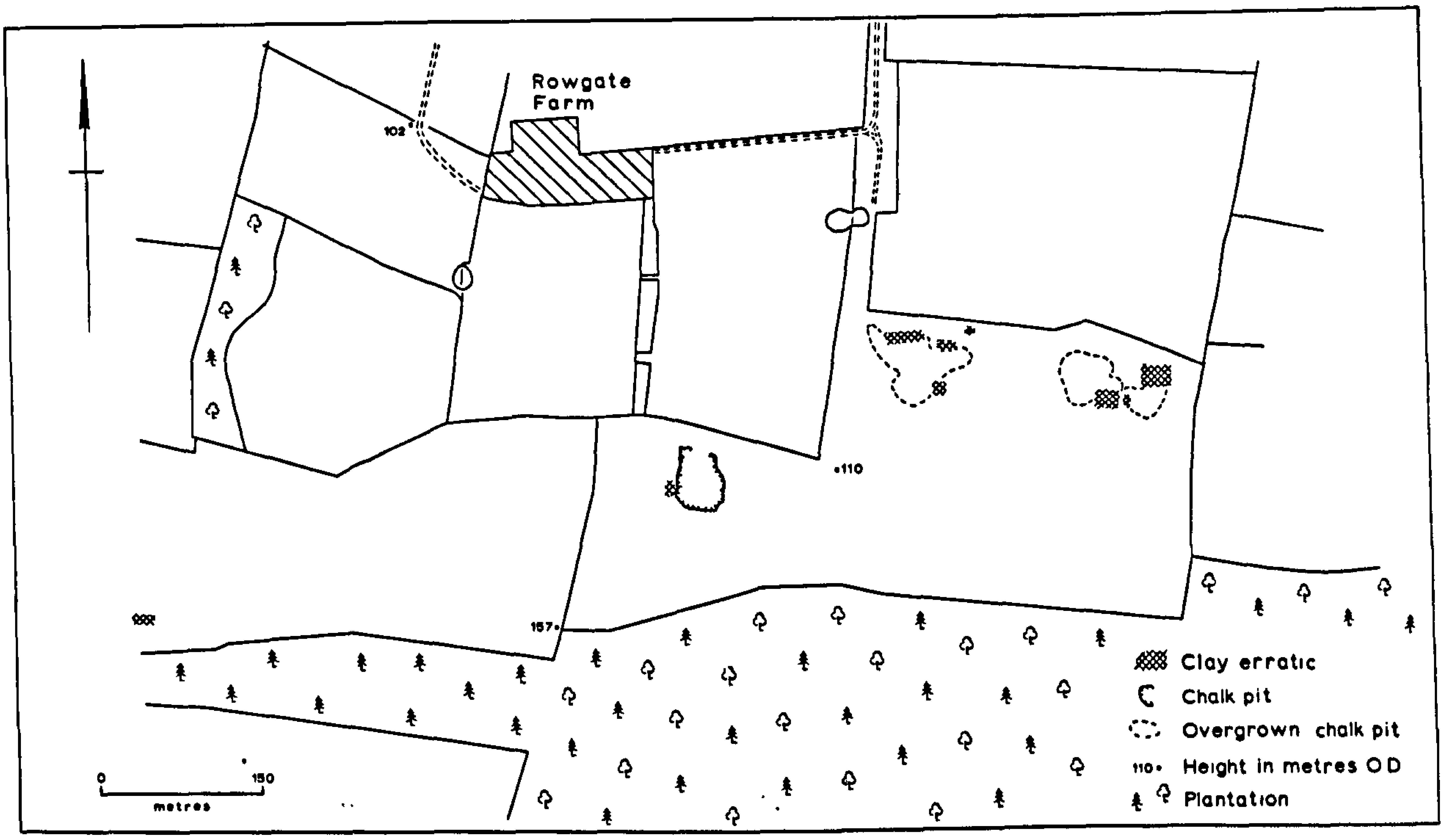
I Rowgate Farm, Thorpe Bassett Brow (SE8671)

The escarpment south of Rowgate Farm (SE8671 and 8771) is of interest for several reasons, among which is the presence of clay rafts lying directly upon the chalk. The clay rafts have been found at the foot of the scarp at a height of approximately 110-120 m O. D. The rafts may have been deposited originally at a higher level and since slipped down the scarp. In addition scattered pebbles of Jurassic and rare Carboniferous gritstone pebbles can also be found in the vicinity, as are outwash sands of substantial thickness. The latter deposits have already been described in Chapter III.

Rafts of clay were found in the following localities (fig. 48):

Chalk pit (8681 7138): Three faces were exposed by digging in this pit, the west face of which showed a raft of clay. Here up to 0.6 m of coarse (10-15 cm) angular blocky chalk rubble overlies and is interbedded with red, bluish-grey and yellowish-brown clay. None of the clay was sufficiently unweathered to show any of the original structures, but the presence of the blue-grey clay strongly suggests that this was originally a mass of Kimmeridge Clay. (The large local outcrops of this particular

Fig. 48 Clay rafts on the chalk escarpment and Stack Hills, near Rowgate Farm, Wintringham (SE867717). For explanation see text.



Rowgate Farm
102
110
157
0
150
metres
Clay erratic
Chalk pit
Overgrown chalk pit
110 • Height in metres OD
Plantation

rock must increase the chances of any clay rafts being derived from it). There were at least three different pockets of clay in the section extending over the entire length of the face, but it could not be proved that all 3 masses of clay formed a continuous raft - indeed it seemed likely that they were not joined together.

In the east face of the same chalk pit dark greyish-brown (10 YR 4/2) to dark brown (7.5 YR 4/4) silty clays were found filling fissures and gaps between the large blocks of chalk rubble at the ground surface. No continuous section between this and the erratic clay groups in the east face was observed so that the relationship between them was obscure.

Chalk pit (87037151): Two sections were recorded in the northern face of the abandoned pit, one at the western end of the face near the old entrance to the pit which was rather better exposed than the second, eastern exposure. In the western clay raft two masses of clay were exposed both of which were much slipped and overgrown. The texture of these erratics varied from tough platy poorly weathered shales to highly weathered, plastic mottled clays. The shales were black or very dark grey (2.5 YR N 3/0) in colour and contained no recognisable fossil remains. The weathered clays were banded dark greyish-brown (2.5 Y 4/2), yellow (2.5 Y 7/6) to white (5 YR 8/2) plastic clays with small pockets (< 5 cm) of yellowish-red (5 YR 4/8) ferruginous clay. The thickness of individual coloured bands varied from 5-25 cm while the junctions between these bands were marked by bands of mottling up to 3 cm wide. The estimated dimensions of the clay rafts were 10 m x 3 m (west) and 10 m x 5 m (east); the exact limits of the rafts were much obscured by vegetation and overgrowth and slipped material. They were separated by a pillar of highly disturbed and broken chalk, or possibly a large mass of frost-shattered chalk lying in situ - it was not possible to determine which.

The eastern end of this face showed an obscured and overgrown body of dark olive, dark yellow and pale cream clay with small pieces of black platy shale fragments scattered in the scree. This was overlain by 5 cm of chalky dark grey sandy rubble. The thickness of clay and shale observed was less than 15 cm, but the lateral extent could not be determined, so that thicker pockets may have been present. A small raft of clay was found on the north-east corner of the knoll into which the pit had been dug - this was at least 15 cm thick and rested upon unweathered white chalk.

Chalk pit (SE87227145): Two exposures of clay and shale were found on the south-west and northern edges of the pit. The northernmost, larger raft showed the following:

Section	Thickness
Light brown sandy silt topsoil with much root material.	15 - 17 cm
Olive green, yellow, dark yellow, mauve and very dark grey shaly clay. The clay was banded and streaked with the darker colours increasing towards the base.	27 cm
Pale creamy yellow to creamy/off-white streaked and banded weathered plastic clay. Clay slightly stiffer and more blocky when yellow.	24 cm
Pale grey (5 YR 7/2) calcareous clay.	10 cm
Highly weathered, pasty, crumbly very pale grey to off-white chalk.	10 cm
White chalk, upper horizons very weathered and crumbly.	

Throughout the section were scattered small pockets (2 - 5 cm) of orangy-yellow, iron-rich clay. Chalk and flints were entirely absent from these and all the other clays found on the escarpment. Within the pit a second section was cleared approximately 1.2 m north east of the above. The cleared exposure showed 50 cm of multi-coloured clays overlying black shales and weathered, pasty ("pugged") chalk which was 20 cm thick.

Chalk pit (SE87207145): A small, badly overgrown section was found in the southern edge of the pit which showed a clay erratic underlying approximately 1 - 2 m of large (15 - 30 m) angular, blocky chalk rubble. The following was recorded:

Section	Thickness
Large (up to 30 cm) blocks of angular broken chalk rubble with a matrix of of gritty, light grey (10 YR 7/1) silty clay.	c. 1.2 m
Yellow (10 YR 7/8) silty clay with scattered fine (< 5 cm) angular chalk and flints.	0.9 m
Very dark grey (10 YR 5/1) plastic and slightly blocky clay.	0.15 m
White, slightly weathered and pasty, broken angular blocky chalk rubble (probably chalk in situ).	

Scattered throughout the scree and rubble of this face were small (circa 2.5 cm) scattered fragments of black shale and clay in various stages of weathering. Also found, especially infilling fissures in the underlying broken chalk were pockets of silty clay of varying colour e.g. brownish-yellow (10 YR 6/8), reddish-yellow (7.5 YR 7/8) and yellowish-red (5 YR 4/8) were typical.

The presence of brown and reddish-brown clayey silts in the chalk pits at SE8720-7145 and SE8681-7138 strongly suggests that the silty clay subsoils which Matthews (1975, 1977) and this author (see p.145) have found on the interfluves of the Wolds were also present here. The pit at SE86817138 did not show a clear relationship between the clay erratics and the silty clays, but in the pit at SE 87207145 the red-brown silty clays were certainly overlain by the clay-erratic rafts. This is the exact reverse of the case at Luttons Lane, Heslerton (SE91007490) where the silty clays were observed overlying the glacial deposit (see below).

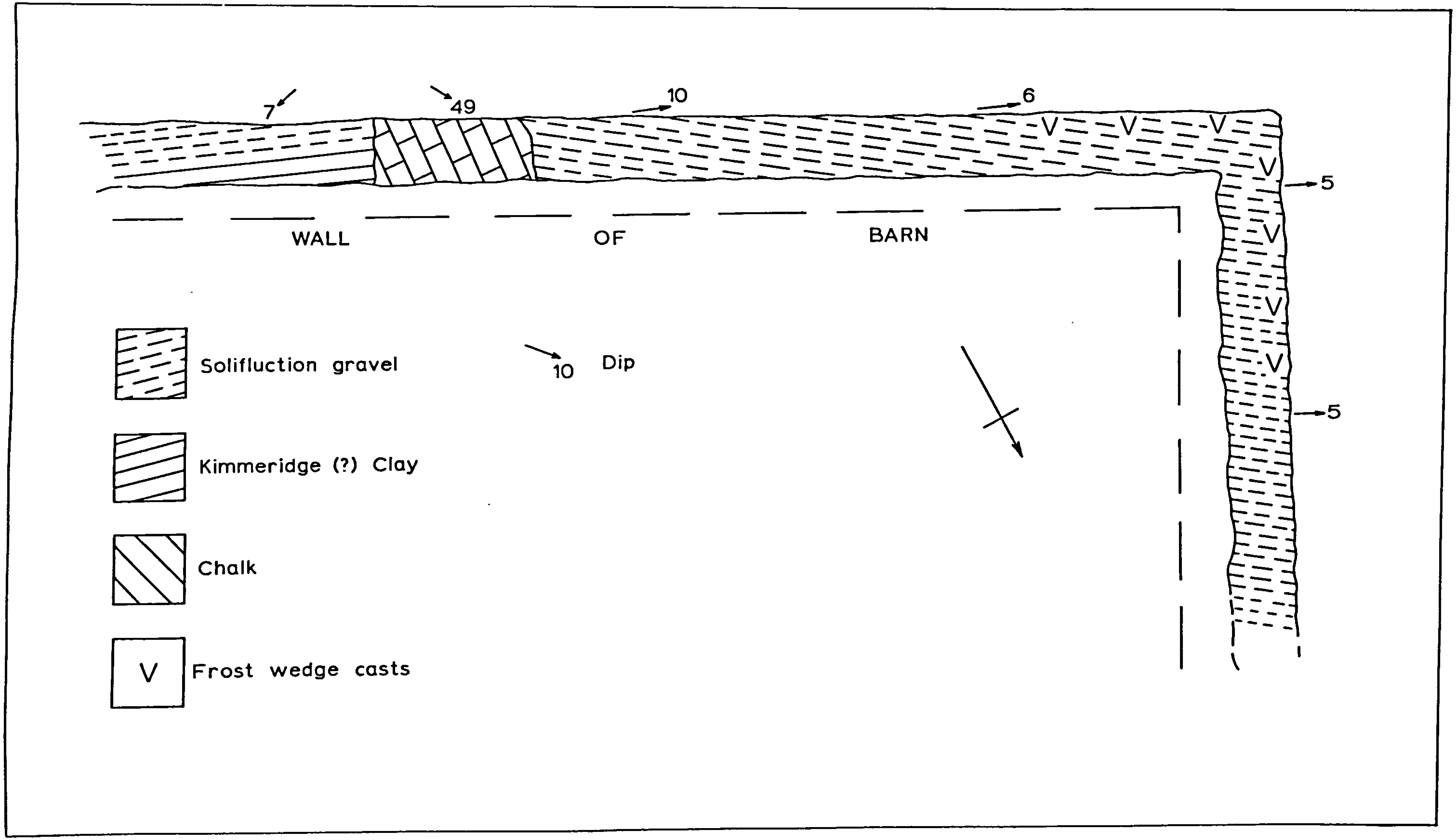
II Linton Farm (SE908709) (figs. 49, 50 and 51)

This section was exposed during the cutting of foundations and levelling during the building of a new barn. Part of the western side of the short valley in which the farm lies was cut away in the early months of 1975 - the exposure is now concealed again. Two faces - one running south-south-east to north-north-west and the other east-north-east to west-south-west were cut away to a maximum depth of 2 m. The average height of the section was just over 1.6 m and the bulk of the drift had been cut away, leaving the solid chalk between 10 and 20 cm below the cleared surface for most of the area.

a) The south-south-east to north-north-west face (figs 50 and 51)

i) Fine sandy quartz rich dark yellowish-brown fine to medium grained gravel. The coarser material was composed largely of small fragments of angular and sub-angular chalk (2 - 5 cm) with small quantities of light grey angular flints (2 - 3 cm). Occasionally larger angular fragments of chalk (and rarely flints) were found up to 10 cm across. The matrix of the gravel was a medium/fine grained (110 - 70μ) highly quartzitic sand with some fine broken chalk and angular flint fragments (110 - 150μ). No recognisable bedding structures could be found, but it was noted that certain pockets of the deposit were more sandy than others giving the impression that some mass-movement may have occurred. No foreign material was found in this gravel. The upper surface of the deposit was penetrated by frost-wedge casts up to 30 cm long x 8 cm wide at the top, filled with the dark brown sandy silts which form the bulk of the topsoil in this area (fig. 51). Small pieces of angular flints and chalk were also present in the frost-wedge fill and the topsoil. Cryoturbation phenomena were otherwise absent in this section. The gravels were between 30 cm and 1.1 m thick and thickened towards the north-west. They were found resting upon

Fig. 49 Plan of the deposits recorded at Linton Farm (SE908709), March 1975. For details see text and photos 50 and 51.


7
49
10
6
5
5
WALL
OF
BARN
10 Dip
Solifluction gravel
Kimmeridge (?) Clay
Chalk
V Frost wedge casts

a mixture of chalk (<u>in situ</u>) and highly disturbed (tectonically) black shaly clays. The gravels passed laterally into:

ii. medium to fine grained angular to sub-angular chalk/flint gravel. This had a reddish-brown (7.5 YR 6/6) very silty matrix. Thin (< 25 cm) beds of coarser angular blocky chalk gravel composed of material 10 - 15 cm diameter dipped at approximately 8° - 10° to the north. Odd fragments of chalk > 15 cm were found but these were rare. The bulk of the gravel was composed of fine platy fragments of chalk and small angular pieces of light grey flint (the latter, as in all the chalk/flint gravels found on the Wolds, was very subordinate to the chalk), set in a matrix of gritty silty clay which was slightly tenacious when wet but hard and powdery when dry. This gravel was composed almost entirely of locally derived material (except the matrix). The maximum thickness of this deposit was 1.6 m but the base was not seen along the entire length of the section, although it was thought to rest directly upon chalk which was present just beneath the base of the exposure. The gravel thinned in both a south-westerly and north-easterly direction as it overlaid the mass of disturbed chalk (see section, fig. 50) and was itself overlain by a second gravel mass. Crude stratification within the deposit consisted of poorly defined lenses and beds of coarser and finer gravel. In some of the coarse/fine couplets some indications of graded bedding (the coarse unit grading into an overlying finer one) were present, but this was not universally so. The dip of the stratification was 8° - 10° north.

iii. A third mass of gravel was found overlying the above from which it could be distinguished by a lack of the coarse blocky chalk rubble. It was also finer and sandier and better and more clearly stratified. The gravel clasts were dominantly sub-angular platy chalk fragments but some small (< 2 cm) rounded pebbles were also present. Small fragments of light grey angular flint were also present. Within this gravel were found

Fig. 50 Photo of part of the south face of the section at Linton Farm showing steeply dipping (i.e. disturbed) chalk (right and centre) overlain by coarse rubbly solifluction gravels (top and left). Rule gives scale (30 cm). Photo by Mr. B. Fisher.

Fig. 51 Photo of part of the east face of the section at Linton Farm, showing ice-wedge casts penetrating fine-grained solifluction gravels (chalk and flint). Rule gives scale (30 cm). Photo by Mr. B. Fisher.

small quantities of red chalk, black, well rounded flints and chert pebbles, well rounded pieces of ferruginous sandstone (estuarine ?), rare fragments of weathered oolite, rounded quartzitic sandstone pebbles (yellow and pale buff: of Jurassic origin), gritstones (also Jurassic) and black fine-grained igneous rock of unknown provenance. All of the foreign material was small, well rounded and generally scattered throughout the gravel. It was estimated that they comprised between 2 and 4% of the total coarse fractions. The bulk of the gravel consisted of alternating beds of medium (7 - 10 cm) matrix poor and fine (< 5 cm) matrix rich, sandy gravel, composed of chalk and flint. The finer beds contained the bulk of the foreign material. Bed thicknesses varied from 5 to 20 cm but showed great lateral variations - in some cases coarse seams were observed to pass laterally into fine material and vice versa. The dip of the strata was approximately 10° north-north-west and the maximum thickness < 2.5 m. The base of this deposit was not exposed, but at the southern end was found to be resting on solid (?) chalk 15 cm below the ground surface - at the northern end the gravel was augered to 25 cm without chalk being reached.

iv. More crudely stratified beds of chalk/flint gravel composed of sub-angular material with coarse (15 cm) chalky angular blocks forming beds and lenses within a generally finer groundmass comprised this deposit. A matrix of silty reddish-yellow (7.5 YR 6/6) clay was again present. No foreign material was found in this gravel which was between 1.5 and 1.7 m thick and which rested with strong discordance upon the underlying material (iii above).

v. This consisted of more of the finer, better rounded and stratified, platy sandy chalk/flint gravel which comprised section iii. The lower layers of this horizon were poorly stratified especially near the junction at the base of the deposit, but this stratification disappeared in the main body of the material which assumed a uniform character of unsorted chalk and flint fragments in a matrix of fine pale yellow sand. Rare very sandy fine gravel lenses and pockets were scattered in this groundmass of sand and gravel, but these were thin (< 7 cm) and showed poor lateral development with mixing and general disturbance under cold, frozen ground conditions such as festoons and involutions. The steeply dipping, in some cases near vertical long axes of many of the platy clasts also indicated frozen ground activity. At the extreme north-eastern end of the deposit 5 frost-wedge casts were found; the shallowest was 30 cm deep x 8 cm wide at the top, the deepest was 1.1 m deep x 20 cm wide. The infill of the casts consisted of dark reddish-brown (5 YR 3/3) silty sand which contained scattered angular to sub-angular chalk and angular flint fragments (< 5 cm long). This soil horizon was 10 - 30 cm thick and observed to overlie all the gravel deposits just described and was also found overlying the bulk of the material exposed in the second face (below). This deposit was involuted and cryoturbated into the underlying gravels to a depth of 20 cm along the whole of the contact between the topsoil and underlying gravels except where frost-wedge casts were present.

b) The north-north-west to south-south-east face

Deposit vii was observed to continue along this face for another 4.5 m along the length of exposure - this deposit was still affected by frost-wedge-casts, these becoming shallower and narrower towards the south-eastern end.

viii. This deposit overlaid vii from which it could be distinguished by its reddish-yellow (7.5 YR 6/6) colour, silty-clay rich matrix and angular to sub-angular nature of the fine chalk-flint gravel. This deposit was also affected by shallow (30 cm) frost-wedge casts and had an extremely uneven cryoturbated upper surface. The dark reddish-brown silty clay which overlaid this deposit was involuted into the gravel to a maximum depth of 45 cm. Like deposit vii no stratification or bedding was found in the gravels, and coarse material was notably absent. The maximum thickness observed was 1.8 m.

ix. Lying below deposit viii was a large pocket of sandy, sub-rounded, platy chalk gravel which also lacked any stratification or bedding. The matrix was composed of a fine silty sand which in places was slightly gritty due to the presence of angular pieces of flint. This deposit was very poorly exposed and the dimensions of it are not known.

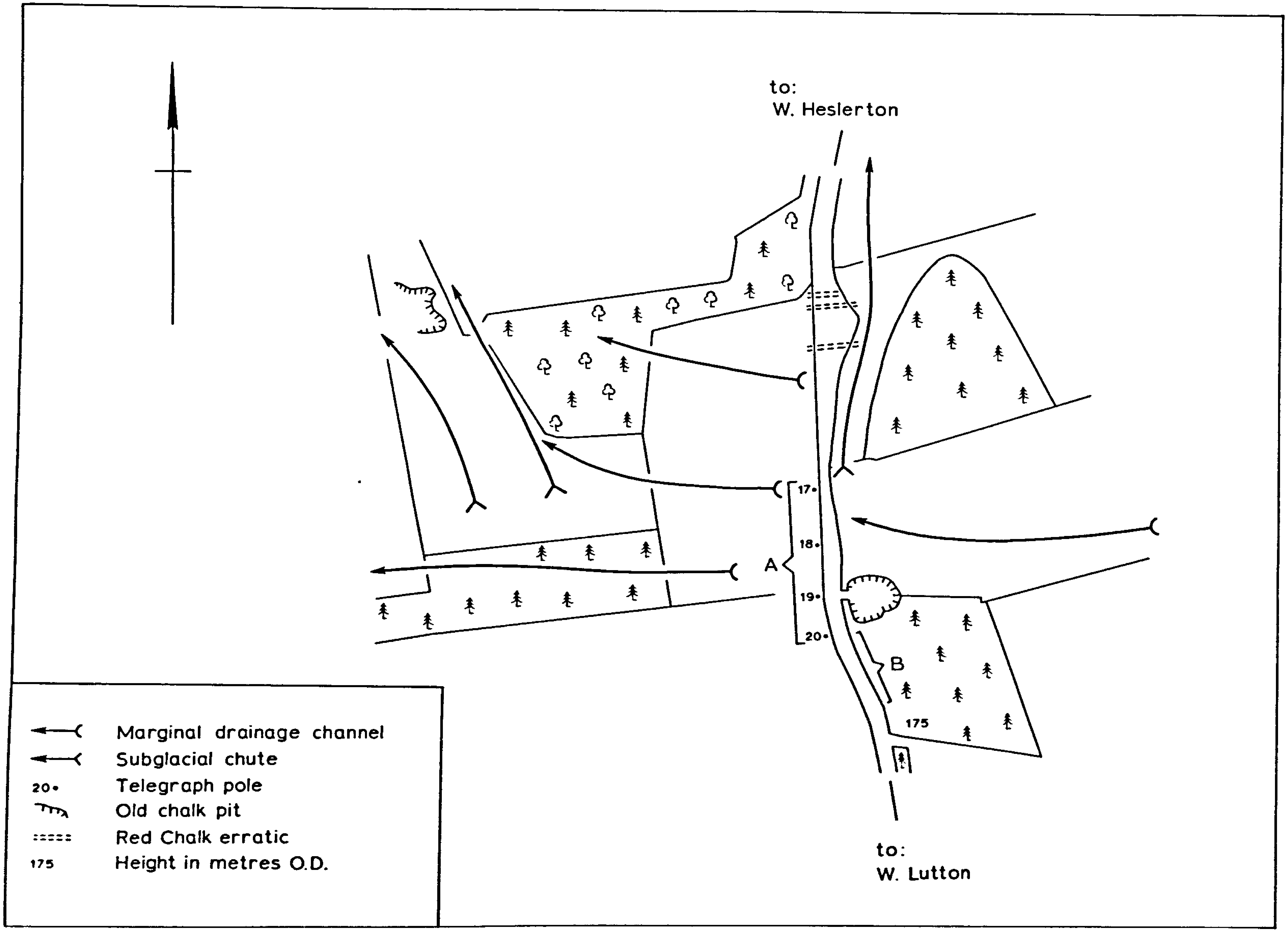
x. Enclosed within deposit ix was a second pocket, this time composed of fine, brownish-yellow (10 YR 6/8) almost stoneless silty sand which was devoid of any bedding. Scattered pebbles of sub-angular chalk were found throughout the mass which was 2.7 m long x 1 m thick. This pocket of sand was sampled and after sieve analysis the results plotted (fig. 58). From this particle size curve it could be seen that this was a very well sorted deposit (unlike the gravels described above with which it contrasted markedly), probably of loessic origin. The full significance of this particular deposit is discussed below.

III. Heslerton Hill (SE91007490)

Of all the glacial deposits of the northern escarpment of the Yorkshire Wolds, the secton at Luttons Lane, West Heslerton is probably the most complete, the most instructive and certainly has the easiest access of any of the section described here. Within the confines of a single section are found all the features which may be observed either singly or in various combinations elsewhere on the northern escarpment which point to ice having invaded the Vale of Pickering during the Devensian Glaciation. Although both glacial and peri-glacial deposits are described together here, the individual deposits will be dealt with separately in the discussion (below).

The major section forms part of the road cut on the western side of

Fig. 52 Map of glacial and peri-glacial features at Luttons Lane, West Heslerton (SE91007490). For details see text and photo Fig. 43.


to:
W. Heslerton
to:
W. Lutton
A
B
17
18
19
20
175
Marginal drainage channel
Subglacial chute
Telegraph pole
Old chalk pit
Red Chalk erratic
Height in metres O.D.

Section No.	Description	Distance south of telegraph Pole 17
4	1.3 m overgrown medium (> 10 cm) angular chalk rubble with grey (5 Y 5/1) sand matrix. 15 cm white (N 8/) to light grey (N 7/) laminated calcareous shale. 5 cm black (N 2.5/) shale passing into grey (N 5/) slightly weathered shaly clay. 4 cm reddish-brown (5 YR 5/3) clay passing into dark grey (5 Y 4/1) to (5 Y 4/1) to black (N 2.5/) shale. 6 cm finely laminated (1 - 2 cm) black (N 2.5/) to greyish-brown (10 YR 5/2) shale. Note that up to 5 laminations per cm at top; 20 laminations per cm at base. 15 cm black (N 2.5/) shaly clay with strong brown (7.5 YR 5/6) ferruginous sand pockets. 8 cm greyish-brown (10 YR 5/2) to light grey (10 YR 6/1) banded shale passing into laminated shales. 7 cm black (N 2.5/) shale with olive (5 Y 5/6) streaks. 17 cm olive (57 5/6) to light grey (5 Y 6/1) shaly clay. Olive material hard and blocky. 1 cm black (N 2.5/) shale. 8 cm olive (5 Y 5/6) to light grey (5 Y 6/1) to olive yellow (5 Y 6/8) shale with ferruginous pockets scattered throughout. 15 cm banded olive (5 Y 5/4 - 5/6) and very dark grey (5 Y 3/1) shale. 20 cm olive (5 Y 5/6) shale with small strong brown (7.5 YR 5/6) ferruginous pockets scattered throughout. Upper parts very blocky. 5 cm white pasty chalk. White chalk.	23.5 M
5	70 cm yellowish-brown (10 YR 5/8) to yellowish-red (5 YR 4/8) tenacious silty clay with many angular chalk fragments and small angular light grey flints. Small pieces of very pale brown (10 YR 8/4) to white (10 YR 8/1) chalk scattered throughout. Small fragments of pasty red chalk fragments, black chert and small rounded gritstones also found.	

Section No.	Description	Distance south of telegraph Pole 17
	30 cm white (10 YR 8/2) and very pale brown (10 YR 8/3) to brownish-yellow (10 YR 6/8) fine silty clay. Closely packed chalk fragments (0.5 cm - 10 cm) and scattered angular flints (0.5 cm - 2.5 cm) throughout.	29 - 30 M

The upper horizon of this section probably represented either a slipped or glacially disturbed and transported subsoil of the type described else where as "reddish-brown" silty clay subsoil, and found on the interfluve areas of the Wolds. The above section passed laterally southwards into brownish-yellow (10 YR 6/8) sandy silts with much angular chalk and flint debris. Some of the chalk and flint blocks up to 0.5 m diameter. Both tabular and nodular flints were present, plus calcite veined and slickensided chalk. Striated chalk also found between 24 - 29 m.

5	60 cm medium (> 10 cm) sub-angular chalk rubble with a highly weathered shaly clay matrix and weathered light grey (10 YR 7/2) sandy chalk gravel. 30 cm of mixed Sherburn sand and angular chalk and flint gravel (circa 2 - 2 cm). Coaly fragments present in thin lenses. No sedimentary structures were observed. 50 cm of large (up to 0.3 m) of sub-angular chalk rubble witha sandy silt matrix. 60 cm + of brown (7.5 YR 5/4) to strong brown (7.5 YR 5/6) clayey silt with fragments of Red and White chalk and angular grey flints. Base not seen. The northern and southern limits of the Sherburn sands in this section were very narrow and only extended 25 cm on each side of the exposed section (which was 30 cm wide). In both directions the sands pass laterally into very sandy fine chalk gravel.	34.5 M
6	10 cm grey (5 Y 5/1) gravelly sand, with angular chalk and flint fragments. 15 cm light grey (N 7/) silty, sandy chalk rubble, with some shaly fragments.	

Section No.	Description	Distance south of telegraph Pole 17
	Much of the chalk was split by frost action. 10 cm very dark grey (N 3/-) to black (N 2.5/) shaly clay with scattered red (2.5 YR 4/6 - 4/8) ferruginous pockets. Dip varied from 30° north to vertical. 25 cm olive (5 Y 5/4 - 5/6) clay with thin (2 - 4 mm) black (N 2.5/) streaks. Dip was 80° north. 20 cm band black (N 2.5/) and olive (5 Y 5/3 - 5/4) shales. Bands from 2 - 7 cm thick. Dip 80° north. 20 cm light grey (5 Y 6/1) shales. 5 cm weathered white pasty chalk overlying hard white chalk.	35 - 37 M

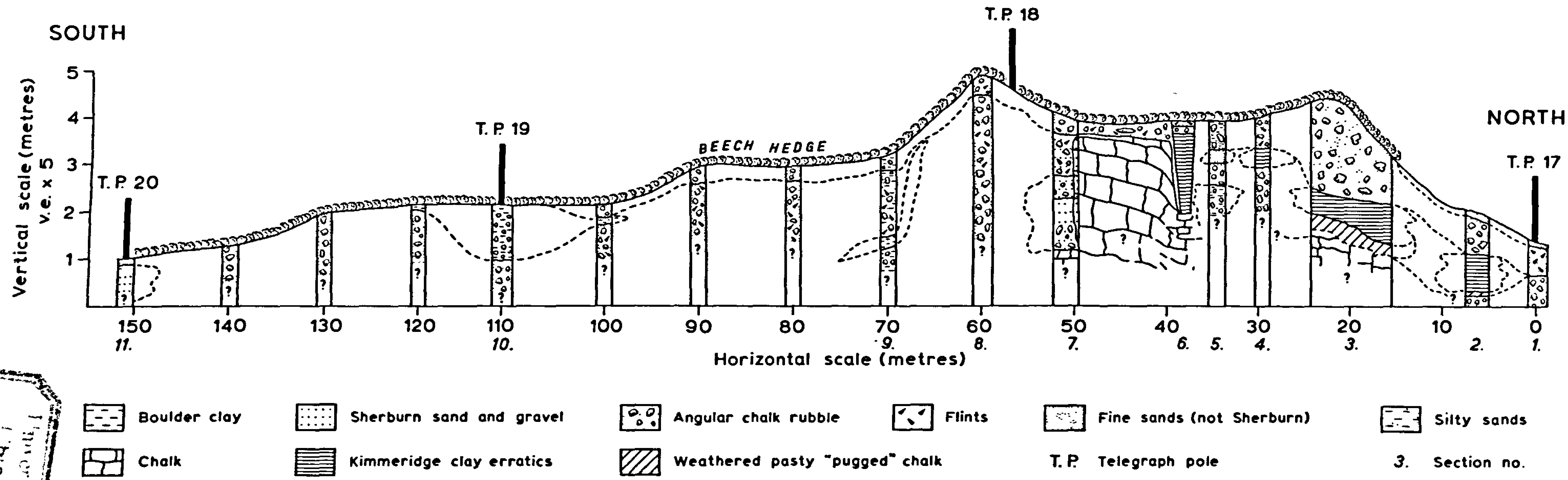
This section was 40 cm wide at the base and 1.2 m wide at the top. The shaly clay mass filled a hollow between shattered chalky rubble to the north and disturbed, frost shattered, possibly moved chalk to the south. The clay/shale erratic extended southwards over this chalk mass, gradually thinning until it disappeared at 40 m south of telegraph pole 17.

Section No.	Description	Distance south of telegraph Pole 17
7	0.3 m white (5 Y 8/2) silty chalk rubble containing a small lens (2 cm long x 5 cm thick) of fine silty sand (probably loess).	45.0 M
	90 cm of grey (5 Y 5/1) silty sand mixed with weathered brown (7.5 YR 5/4) silty clays. Much of this deposit consisted of an angular coarse (>> 10 cm) chalk rubble. 30 cm (observed - this deposit is probably much thicker), weathered brown (7.5 YR 5/4) to yellowish-red (5 YR 4/6) clayey silts with much angular chalk and flint fragments (av. 3 cm dia.). A thin (5 cm thick) lens of yellowish-brown (10 YR 5/4 - 5/6) Sherburn Sand and gravel was enclosed in this deposit. The matrix became increasingly sandy downwards through the profile; this gravelly sand mass abutted against the southern edge of the shattered chalk described above.	50.0 M

Section No.	Description	Distance south of telegraph Pole 17
	90 cm grey silty sand mixed with weathered brown silty clays (as above). 20 cm very weathered sub-angular chalk and flints, set in a matrix of sandy silt. Red chalk, quartzites and gritstone pebbles were recovered from this material. The sandy matrix was composed of slightly weathered yellowish-brown (10 YR 5/6) Sherburn Sand and brown (7.5 YR 5/4) silts. 1.0 m of yellow (10 YR 7/8) to brownish-yellow (10 YR 6/8) Sherburn Sands with thin (1 - 2 cm) lenses of finely comminuted coal. In places laminar and trough-cross bedding was observed. The sands were of medium/fine grain, highly quartzitic, becoming gravelly towards the base of the section (chalky gravel from 10 - 15 cm diameter).	51.5 M
8	20 - 30 cm dark grey (10 YR 4/1) sandy chalk/flint gravel. 2 m very coarse (> 25 cm) angular, blocky chalk rubble with much sandy silt in the matrix. Pockets of sand and/or clay may have been present but slipped scree and vegetation made this difficult to prove.	60.0 M
9	30 cm brown (7.5 YR 5/4) to reddish-brown (5 YR 4/4) and yellowish-red (5 YR 4/6) silty clay with much fine (2 - 5 cm) angular chalk. 1.5 chalk/flint rubble, very coarse (> 20 cm with some chalk blocks up to 0.5 m long) with sandy silt and silty clay which formed matrix between blocks. 10 - 15 dark reddish-brown (5 YR 3/4) tenacious plastic clay silts, in which were embedded pockets of erratic pebbles. These pockets were rare, but the erratics included Red Chalk, gritstones (Carboniferous and M. Jurassic), quartzite pebbles, oolite, dark fine grained igneous material of several types, light-coloured "acid" igneous rocks of several kinds, assorted metamorphic pebbles (mainly gneissic), coal, chert, driekanter (of gritstones) and slickenslided chalk fragments. Striated chalk also present. 0.5 m mixed angular chalk/flint gravel with a sand and sandy silt matrix.	

Section No.	Description	Distance south of telegraph Pole 17
	Striated chalk fragments were recovered from this horizon. Base not seen.	70 M
	25 cm dark reddish-brown (5 YR 3/4) stoneless silty sand. 5 cm white (10 YR 8/2) weathered chalk and sandy silt. 1.5 m angular, blocky chalk/flint rubble (> 20 cm) with scattered erratics and striated chalk fragments set in a matrix of very silty light reddish-brown (5 YR 6/4) to reddish-yellow (5 YR 6/8) sand.	80 - 110 M
10	1.1 m dark reddish-brown (5 YR 3/4) silty clay (0.5 - 15 cm), Red Chalk, Estuarine (ferruginous) sandstone, gritstones (Carboniferous and Jurassic), quartzites, cherts, oolitic material, coal, various "acid" and "basic" (i.e. light and dark) igneous pebbles, and gneiss and dreikanter. The bulk of the erratics were found in small pebbly pockets, the Red Chalk was disseminated throughout the clay. 0.5 m coarse (10 + cm) angular blocky chalk/flint rubble with fine sand matrix - very quartzitic. Much broken fine (< 1 cm) angular grey and white flint. Thin (10 cm) seam of reddish-brown (5 YR 4/4) clay with small (< 2 cm) angular flints. Very sandy blocky angular chalk rubble. Some striated fragments.	120.135 M
	10 - 15 cm grey (5 Y 5/1) to dark grey (10 YR 4/1) silty sand with sub-angular chalk and angular flint fragments. Coarse (> 15 cm) angular blocky chalk/flint rubble with very sandy matrix. This matrix passes southwards into increasingly finer matrix (sandy silt), and lenses and pockets (up to 5 cm long) of reddish-brown (5 YR 4/3) to dark brown (5 YR 3/4) silt started to appear. Thin lenses (5 cm thick x up to 25 cm long) of Sherburn Sands also started to occur; some of these seams showed laminar bedding, and some had streaks of finely comminuted coal.	135 - 150 M
11	18 cm very dark grey (5 YR 3/1) to black (N 2.5/) organic, weathered quartzitic fine sand.	

Fig. 53 Section in road cutting on the west side of Luttons Lane, West Heslerton. For details see text.



SECTION IN WESTERN SIDE OF ROAD CUT : HESLERTON HILL, NORTH YORKSHIRE (S.E. 910750) 10.7.77

Section No.	Description	Distance south of telegraph Pole 17
	35 cm of highly disturbed and mixed reddish-yellow (7.5 YR 6/6) sand, gravel and subsoil. Gravel composed of flints (< 1.5 cm).	
	12 - 13 cm reddish-yellow (7.5 YR 6/6) to strong brown (7.5 YR 5/8) Sherburn Sands with scattered angular flints.	
	35 cm Sherburn Sands with very fine (< 1.5 cm) angular flints and scattered chalk fragments.	
	14 cm Sherburn Sands with scattered angular flints (< 2 cm).	
	45-48 cm mixed pockets of Sherburn Sand and gravel, and yellowish-red (5 YR 4/6 - 1/8) silty clay. Sherburn sand and gravel became generally coarser as pass down profile, until near the base much coarse (> 15 cm), angular blocky chalk and flint present. No bed-structures observed in sands. Base not seen but may be either chalky moraine or solid chalk.	152 M

In addition to the sections in the road-cut (above) there were observed further north, three strips of Red Chalk running approximately east-west across the road. None of the strips were more than 0.5 m wide, but they could be traced from the field banks on the western side of the road, across the old bed of the road and into the field adjoining on the eastern side. They could also be found in the roadside verge which runs between the old road-bed and the modern surface. The small dry gully which ran along the eastern side of Luttons Lane perpendicular to the escarpment seemed to form the eastern limit of these Red Chalk erratics. A fourth much smaller patch of Red Chalk was later found approximately 50 - 60 m south of telegraph pole 17, again in the bed of the old road, but this was very limited lateral extent. The thickness of these erratics varied from place to place - in the western road verges up to 1 m was present, but in the bed of the old road this was reduced to less than 30 cm on average, (probably because the upper parts had been cut away when the area was levelled whilst in use as a trackway), although in places less than 10 cm was found. In all cases the Red Chalk was resting directly upon White Chalk. Where the Red Chalk could be most clearly observed, in the western bank where the northern-most strip crossed the road, the material was seen to be very broken, weathered and highly disturbed. The outcrop of the Red Chalk (i.e. solid) is approximately 500 m north of the northernmost of the three strips of Luttons Lane. Shaly clay was also found (20 cm thick) just north of the southernmost small patch of Red Chalk described above.

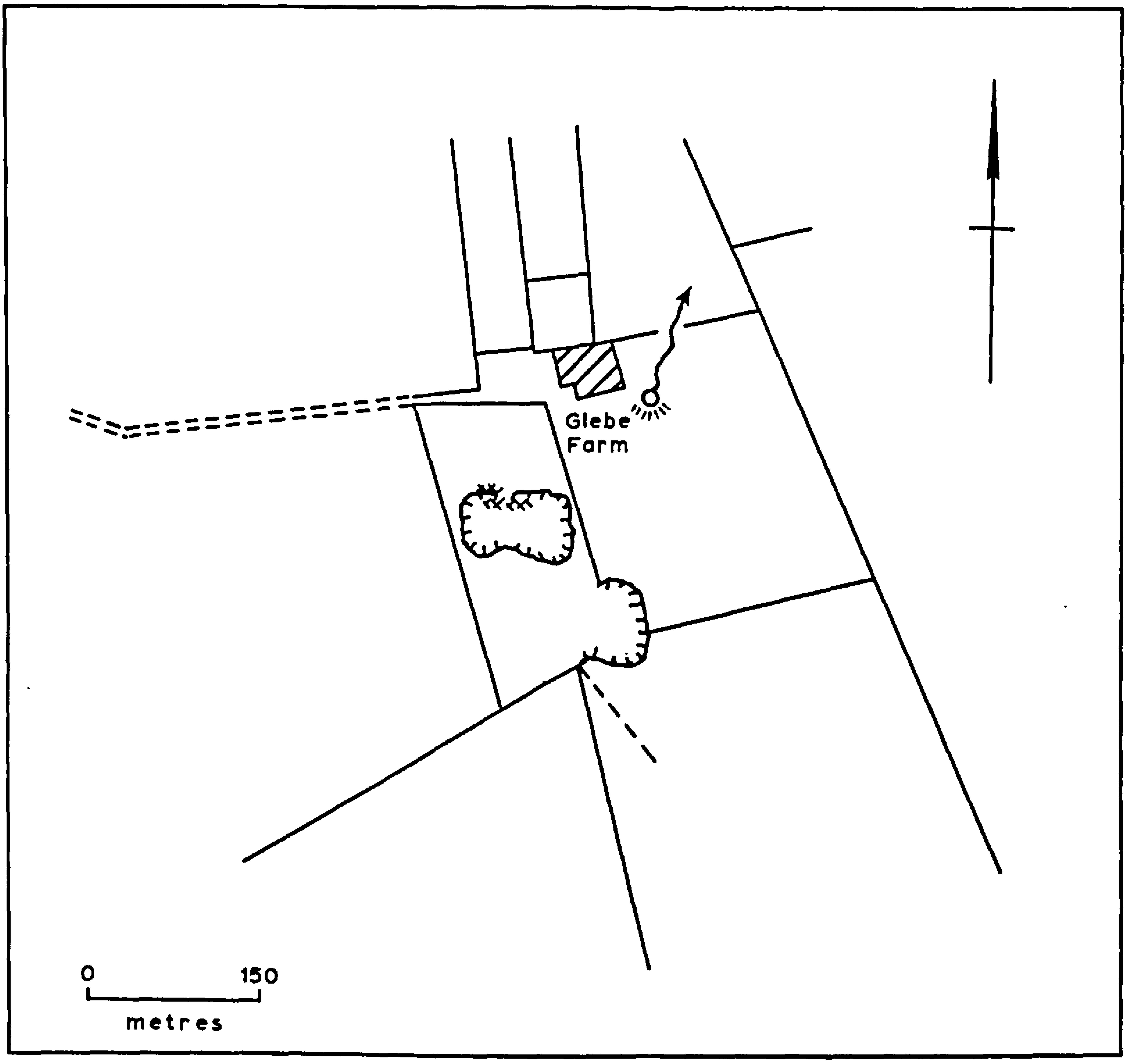
On the eastern side of the road a pocket of olive (5 Y 5/4 - 5/6 and 5 Y 5/8) and olive grey (5 Y 4/2) shaly clay was found, approximately 120 m north of the old chalk pit entrance, (see fig. 52). This was overlain by 10 - 15 cm of very weathered pasty white chalk and hard white chalk. The maximum thickness of the clay mass was 25 cm and the exposed width 25 - 30 cm.

On the eastern side of Luttons Lane south of the entrance to the old chalk pit, section B (fig. 52) was observed. For the most part this section consisted of coarse to very coarse (20 - 50 cm) angular blocky chalk and flint rubble with a sand and sandy silt matrix, similar to that described in sections 8 - 10 on the western side of the road (above). No striated chalk pebbles have been found from the eastern side of the road, and erratics also appear to be absent. There were however, a series of six sand-filled, slightly connected depressions in the upper part of this coarse rubble, which in turn were overlaid by a closely packed, fine (< 2 cm) sub-angular chalk gravel. The depressions varied from 0.8 - 1.2 m wide x 30 - 45 cm deep, and were filled with yellowish-red (5 YR 4/6) to dark reddish-brown (5 YR 3/4) silty sand. Northwards the depressions could be further traced, this time filled with the finer chalk gravel, each depression becoming progressively narrower and deeper until at the extreme north end (approximately 15 m south of the chalk pit entrance) a depression 1 m deep x 25 cm wide was recorded. Altogether eight gravel-filled hollows were counted. The fine chalk gravel was observed to cap the whole length of section and was approximately 30 - 50 cm thick (excluding the areas over the hollows described above).

IV. Glebe Farm, West Heslerton (SE91807583)

In two old chalk pits south-south-west of Glebe Farm were found several much obscured sections which showed small patches of clay overlying highly shattered white chalk (fig. 54). Not all of the sections were large enough to warrant detailed recording, but one, on the eastern side of the old entrance to the pits, showed the following in March 1975:

Section	Thickness
Very dark grey (5 YR 3/1) humic sandy silt topsoil with small (0.5 cm) fragments of black shale. At 2 cm and 6.5 cm from surface were two thin (1 cm) pebble beds of angular to sub-angular chalk.	15 cm
Yellowish-red (5 YR 5/6 - 1/8) small (<4 cm) angular to sub-angular chalk gravel with a medium sand matrix.	12 cm
Medium (4 - 8 cm) angular, slightly blocky chalk gravel, with yellowish-red (5 YR 5/6) silty sand matrix.	5 cm
Strong brown (7.5 YR 5/8) homogeneous, stoneless plastic silty clay.	8 cm
Mottled brownish-yellow (10 YR 6/8), yellow (10 YR 7/6) and reddish-yellow (7.5 YR 6/8) silty clay passing into more uniform yellowish-brown (10 YR 5/8) at base.	14 cm
Black shale.	1.5 cm
Yellow (10 YR 7/6) clay overlying brownish-yellow (10 YR 6/8) plastic silty clay. Banked against these brown and yellow clays was a pocket of light greenish grey (5 G 7/1) plastic clay with red (2.5 YR 5/8) mottling.	13 cm
Mottled light greenish-grey (5 G 7/1), yellow (10 YR 8/6) and reddish-yellow (5 YR 6/8) plastic silty clay. Pockets of ferruginous material (0.5 cm dia.) scattered throughout.	2.5 cm



Glebe
Farm
0
150
metres

Section	Thickness
Weathered pasty (wet), powdery (dry) white chalk. In places thin chalk has been stained to yellow (10 YR 8/6 - 8/8) and reddish yellow (7.5 YR 7/8) hues, especially at the junction with the overlying clays.	

B "Outwash" Deposits of the Northern Wolds Escarpment

In addition to the large clay erratics described above, there have been found small pockets and patches of outwash sands and gravel (Sherburn Sands). One of these patches, at Luttons Lane on Heslerton Brow, has already been described. Fox-Strangways mapped two small patches of sand and gravel on the crest of the Wolds at Binnington Brow (TA005773) and on Staxton Brow at TA006777 (fig. 47). No descriptions of these deposits were given however. In addition to these patches of sands and gravels, other small fragments of outwash deposits have been found on the eastern parts of the escarpment and these will be described in turn. From west to east the deposits were found at:

i. Ganton (SE987767) fig. 55. A large mass of Sherburn Sands was found at the foot of the escarpment approximately 500 m west of Ganton Hall and 150 m south-east of Winter Beck Hole Spring. The slope of the deposit was rather like a fan and could be seen on air-photographs of the area (fig. 8). Augering in the area failed to find the maximum thickness of the deposit, but did help to determine the limits of the deposit. It was found that more than 1 m of this sand (albeit in a weathered condition) was found in the northern edge of the floor of the small dry valley into which it extends, but no trace of any other sands could be found either in the minor valley or on the scarp to the south of it. (The feather edge of the main outcrop of Sherburn Sands ran along the southern edge of the small valley which runs parallel to the escarpment there). A soil pit was dug into the central part of the fan to the depth of 2.4 m and the deposit was augered for another 1 m. The following succession was recorded:

Section	Thickness	Depth To
* Dark grey sands with small pieces (< 5 cm) of angular chalk gravel. The whole of this horizon was very mixed and disturbed by animal burrows.	0.4 M	0.4 M
Trough-cross-bedded (troughs 6 - 8 cm long x 2 cm thick) medium grained pale yellow sands with scattered lenses of finely comminuted coal fragments. Some coal fragments were also scattered throughout this horizon.	0.25 M	0.65 M
Sub-angular to to angular, very sandy, yellow chalk/flint gravel (0.5 - 10 cm). Chalk comprised 85 - 90% of total coarse material, up to 5% Red Chalk.	0.15 M	0.8 M
Trough-cross-bedded (average troughs 12 cm long x 4 cm thick) yellow medium grained sands, with small (< 2 cm) sub-angular chalk fragments and thin lenses of finely comminuted coal fragments scattered throughout. Some thin (2 cm) laminar bedding present between trough-bedded sands.	0.15 M	0.95 M
Angular chalk/flint gravel (0.5 - 8 cm), very sandy with rare Red Chalk fragments. One small piece (0.5 cm) of ferruginous sandstone (Jurassic ?) found. Gravels might have been imbricated.	0.2 M	1.15 M
Yellow sands with traces of trough-cross-bedding. Thin pebble beds of scattered sub-angular chalk (1 - 4 cm) with their long axes horizontal or nearly vertical and thin (0.5 cm) lenses of finely comminuted coal were present.	0.08 M	1.23 M
Small (0.5 - 2 cm) angular to sub-angular, very sandy chalk/flint gravel. Rare chalk clasts 6 - 7 cm included in gravel.	0.17 M	1.40 M
Trough-cross-bedded (?) yellow sands with thin (< 0.5 cm) seams of finely comminuted coal		

* N.B. Munsell colours not recorded

Section	Thickness	Depth To
fragments.	0.2 M	1.65 M
Sub-angular and angular chalk/flint gravel (0.5 - 5 cm) with small amounts (5 - 10%) of Red Chalk pebbles. Sandy matrix to gravel.	0.15 M	1.65 M
Densely packed fine/medium-grained dark yellow sand with traces of laminar bedding in the upper 0.2 M of this horizon. No chalk or flint pebbles. Base not seen.	1.6 M	3.4 M

The colour of these sands varied very little throughout the profile, although overall they became slightly darker towards the base. Unfortunately the current-structures in the sands were not suitable to determine accurately the direction of flow of the fluvial system which deposited them other than a broad south or south-south-east to north or north-north-west trend. Within individual trough-units there were fining-upward sequences however, and local unconformities and non-sequences were common, the truncated troughs and dissected laminar structures indicated that local erosion as well as deposition was taking place when these deposits were laid down. The presence of Red Chalk in the gravels and pebble beds is also notable.

ii. Binnington Brow (TA00357755): Although Fox-Strangways mapped two patches of sand and gravel on this part of the Wolds escarpment, only one has been found by this author and that was much smaller than indicated on the one-inch geological map.

Two soil pits were dug into this deposit in the base of the hedgerow which runs along the western side of the track from the A163 (Wold Lane). The first pit was dug approximately 120 m south of the old chalk pit and showed:

Section	Thickness	Depth To
Fine angular to sub-angular chalk/flint gravel with dark brown, weathered sandy matrix. Gravel size = 0.5 - 6 cm.	0.4 M	0.4 M
Medium to coarse grained yellow to dark yellowish-brown quartzitic sand. This horizon contained thin lenses of finely comminuted coal fragments, especially near the top. Scattered fine (< 2 cm) chalk fragments were also found. Small (1 - 2 cm) light grey flints also scattered throughout. No bed structures visible.	0.6 M	1 M
Large blocky or solid chalk in situ.		

It was not possible to determine whether the chalk blocks exposed in the bottom of the pit represented solid chalk or a rubbly disturbed chalk horizon overlying solid undisturbed chalk. The second pit was also dug into the base of the hedgerow, approximately 95 M south of the old chalk pit. The following was observed:

Section	Thickness	Depth To
Grey to dark grey weathered fine sandy silt topsoil.	0.1 M	0.1 M
Fine (0.5 - 3 cm) angular chalk gravel with few flints (< 5%). Very sandy.	0.3 M	0.4 M
Stoneless medium-grained yellow sand with comminuted fine coal fragments concentrated into thin lenses.	0.1 M	0.5 M
Medium (4 - 8 cm) sub-angular		

Section	Thickness	Depth to
chalk gravel with yellow sand matrix.	0.5 M	0.55 M
Stoneless medium to fine-grained yellow sand with streaks and scattered pieces of finely comminuted coal.	0.1 M	0.65 M
Fine chalk < 5 cm) pebble bed with much sand matrix.	0.05 M	0.7 M
Stoneless medium grained yellow sand.	0.05 M	0.75 M
Chalky gravel (1 - 3 cm) with yellow sand matrix. Gravel slightly graded with finer clasts towards top.	0.12 M	0.83 M
Stoneless medium grained yellow sand.	0.03 M	0.86 M
Angular light-grey flint gravel (< 6 cm)-with yellow sand matrix.	0.09 M	0.95 M
Stoneless medium/fine grained yellow sand.	0.4 M	1.35 M
Large (> 20 cm) angular blocky chalk rubble with fissures and cracks between blocks filled with fine (< 2 cm) angular chalk gravel and sand. Thin lenses of sand found beneath some of the chalk blocks.	0.3 M	1.65 M

N.B. The blocky chalk rubble found at the base of soil pit 2 was slightly finer and more open than that found in pit 1 and almost certainly represented highly disturbed and broken chalk either in situ or slightly moved downslope. The dip of the upper bedding planes of the blocks was between 5° and 8° S. E., which would apparently suggest chalk in situ or nearly in situ. Although no bed structures were observed when the pits were dry, trough-cross bedding had been previously recorded in horizon 2 of pit 1, showing that parts of this sand are completely undisturbed. The aerial extent of this deposit was very difficult to prove because access

* N.B. Munsell colours not recorded

to the surrounding fields was limited, but the deposit was thought to extend in a north to south direction for approximately 20m on each side of the pit. No lateral (i.e. east to west) estimates could be made. All the sands were of the Sherburn facies.

iii. Flixton Brow: Several isolated patches of Sherburn sand were found scattered over Flixton Brow between 140 m and 170 m O. D. The first of these was found in the old chalk pit on the west side of the Flixton-Fordon Road (TA039792) where 30 - 35 cm yellowish-brown (10 YR 5/4 - 5/6) stoneless, highly quartzitic medium sand was found directly overlying frost-shattered angular chalk rubble. In the field opposite the chalk pit on the eastern side of the Flixton-Fordon Road, at TA04137896, 40 cm of reddish-yellow (7.5 YR 6/8) highly quartzitic Sherburn-type sands were augered. These sands overlaid directly shattered angular chalk rubble. Similar but thinner patches of sand were found in the fields to the west and south of the above, none of the sandy patches being more than 10 m and often the only indication of their presence was given by the colour and sandy nature of the subsoils turned up by the plough.

iv. Folkton Brow. This area lies immediately to the east of Flixton Brow and has features on it which continue onto Flixton Brow (see ice-marginal drainage channels). There were also found several patches of Sherburn-type yellow outwash sands and gravels, again of limited thickness and area, many of which were disturbed by slippage down the escarpment face. Two outcrops of sand were found in an undisturbed condition however. The first of these was near the foot of the escarpment in the abandoned chalk pit at TA058793 which lies to the south of the Folkton-Hunmanby Road. The maximum thickness of the sands observed in the pit was 30 cm although the area was obscured by scree and vegetation. Again medium grained, dark yellow sands containing angular to sub-angular fragments of chalk (5 cm) were found, but no sedimentary structures were visible. Around the fringes of the deposit the sands were again observed to lie directly upon large, angular, frost-shattered chalk-rubble. The second pocket of sand was found at approximately 117 M O. D. (TA05787906) in the base of the hedgerow. Its presence was indicated by animal burrows, in the sides of which possible traces of sedimentary structures were observed. The sands were mixed with angular to sub-angular fragments of fine/medium gravel (4 - 8 cm) composed dominantly of chalk - a few flints were present. Although only 0.6 m of sand and gravel could be proved, the base of the deposit was not reached (permission to dig to find the total depth was not granted). Laterally the gravels did not extend very far, possibly 10 - 15 m upslope and downslope of the exposure, no indication was present of how far the sands extended along (i.e. parallel to) the scarp. Small patches of yellow sandy subsoil were found in the fields around the second exposure, but augering showed that these were isolated pockets not linked either to each other or the exposure. A small pocket of dark-brown fine sand, 40 cm thick, was found at TA06157885 directly overlying chalk which might have been of outwash origin but equally may have been a coversand deposit.

C. The Scattered Erratic Pebbles of the Yorkshire Wolds

Scattered erratic pebbles have been known to exist on the Wolds for a long time, but it was not until the turn of the century that Stather (1900) first published records of this material. Since then few papers have been written concerning the composition or distribution of this material, nor has any attempt been made to systematically map the deposits. The different rock types found on the Wolds are dealt with separately here, (see fig. 47).

Quartzite pebbles and chert. These are the most ubiquitous of the erratic types found on the Wolds and appear to be present at all levels and in all areas beyond the limits of the Devensian boulder clays of

Holderness and the Vale of York. One of the first records of quartzoze drift was that of Stather (1903) (hence the name for this drift type: "Stather's potatoes"), who collected his specimens from the area around High Hunsley and North Nab on the Southern Wolds. He recorded that they occurred in large numbers, were on average 2" - 3" (5 - 7 cm) in diameter, well rounded and varied in colour from "dull yellow to a yellowish-red". The similarity to pebbles and quartzites found in the Bunter (Triassic) pebble beds was remarked upon. In association with the quartzite pebbles, Stather also found pebbles of "hard reddish sandstone somewhat larger than the quartzites, but fewer in number but not so waterworn" (i.e. less rounded). He also found that although the pebbles were present in large numbers they were scattered somewhat unevenly; in some areas none were found, yet in others densities of up to 6 per sq. ft. (approximately 60 per m^2) were recorded. No pebbles were found on valley sides and they appeared to be most numerous where the angle of slope was lowest, and were found on interfluves between 130 - 164 m O. D. Stather also noted that quartzite pebbles were the only foreign material found in the chalk gravels underlying Devensian tills at Hessle.

Cole (1904) reported that quartzite pebbles had been found in clayey deposits ("but not boulder clays") from some pits near Wetwang, whilst at an earlier date Mortimer (1884) reported that he had seen quartzite pebbles in "clays" at Fimber Village. Sheppard (1904) also recorded quartzite pebbles in a sand pipe which was exposed in a chalk pit on Painsthorpe Wold (SE8258). Sheppard also reported quartzoze drift from the chalk gravels which underlaid the Devensian tills at Hessle, and added that whilst in the upper parts of the gravel the quartzite pebbles were less numerous, in the lower parts "dozens of pebbles were noticed amongst the large angular chalk fragments". Sheppard also reported that similar pebbles had been recovered from chalk breccias at St. Austin's Stone (near Drewton) and the Fairey Stones (near Burdale) by Mortimer, although the latter made no mention of them. Furthermore a large block of quartzite measuring rather less than 2 feet (0.6 m) long was found by Sheppard in the chalk gravels at the base of the Sewerby Cliff section. Lamplugh (1887) also recorded quartzitic drift during the course of his excavations there. Melmore (1931, 1934) reported that drift composed almost entirely of small rounded quartzite pebbles had been found on the western scarp of the Wolds in an area extending from Elloughton via North Cave, Newbald, and Haughton Moor to an area south of Pocklington. Similar drift was also found at Brayton Barf and Holme-on-Spalding Moor in the Vale of York. All the gravels were very thin and patchy and some of the gravels contained far travelled material other than quartzites, e.g. Cheviot pebbles, oolitic drift and Lake District material (Melmore 1932, Bisat 1940), and formed part of a terrace system associated with higher sea levels than those of the present (Melmore 1931).

Quartzitic drift in the form of vari-coloured, well rounded quartzite pebbles has been found over all the interfluve areas of the northern Yorkshire Wolds (i.e. north of the Great Wold Valley) (fig. 47). Colours of individual pebbles varies from dark blood red via lighter hues of browns, pinks and yellows to milky white and colourless. Size also varied from < 2 cm to 10 cm +, but the average size was similar to that recorded by Stather (i.e. 5 - 7 cm). The pebbles were found scattered about in the topsoil and always occurred as single specimens - no grouping of the kind recorded by Stather and Melmore was found. Other erratic types were occasionally found nearby, and the quartzite pebbles were always found where small pockets of gravel were recorded (e.g. at Luttons Lane, West Heslerton; Linton Farm, etc.). Numerous pebbles of this type were also found in the area just west of the feather edge of the tills at Hunmanby where their densities per unit area were highest. Within the margins of the Devensian tills these pebbles were very common. Quartzitic drift has also been recovered from the interfluve north of Thixendale and on Elmswell Wold (sq. TA0061).

Cherts were found by Stather though not apparently recognised by him - (Bisat 1940), some of which were derived from Carboniferous strata - from the High Hunsley and North Nab areas. This author has also found chert pebbles on the Northern Wolds and like Stather found that it was much less common than the quartzoze material. The colour of these pebbles was generally a very dark red, sometimes black. The pebbles were small (< 5 cm) smooth and well rounded (unlike the quartzites which had pitted and cracked surfaces).

Gritstones-Sandstone and gritstone pebbles were also found by Stather on the southern Wolds. Jurassic grits and sandstones had also been found by Mortimer (1884) and the author from the chalk breccias which form the Fairey Stones and St. Austin's Stone. These were thought to have been derived from the Upper Calcareous Grit. Sandstone pebbles of probable Jurassic origin were also found by Lamplugh at Sewerby. Similar drift has been found on the Northern Wolds both as isolated pebbles and in gravels associated with other erratic material (e.g. Luttons Lane, Linton Farm, Croom Dale). The pebbles are generally rather small (< 5 cm) although rare larger fragments have been found, well rounded, medium grained, highly quartzitic and slightly weathered with pitted and cracked surfaces. The degree of weathering of these Jurassic pebbles was the same wherever they were found, i.e. within limits of and on the Devensian tills in the east, on the interfluve areas or within gravelly drift on the escarpment. Small pieces of highly ferruginous dark yellowish-brown sandstones, probably derived from the Estuarine beds (M. Jurassic) of the North York Moors were also found on the N. Wolds but these were very rare.

Carboniferous gritstones, many of them wind-faceted, were commonly found in the area surveyed. They were also common in the Thixendale area. They were larger than the Jurassic material (i.e. up to 15 cm long) and formed some of the largest pebbles (other than chalk or flints) found on the Wolds. The degree of roundness was variable, but generally sub-rounded to rounded material only was found. The pebbles were composed of medium to fine-grained quartzitic sandstones the surfaces of which were much less pitted than the Jurassic material. Like the Jurassic sandstones they were also very common in the drift-covered area around Hunmanby and were also recovered from the gravels metioned above (see quartzites). Matthews (1977) reported dreikanter on the interfluves of Staxton Wold.

A third group of sandstone pebbles were composed of red to reddish-brown, medium grained, well cemented quartzites. These were rare (only 6 have been found) but were found over the whole of the surveyed area. Their size ranged from 4 - 15 cm long and were sub-rounded in character. They are thought to have been derived from Permo-Triassic deposits either from the floor of the North Sea or the Durham region. Greenish-grey, fine grained weathered sandstones (grey wackes ?) were also found within the limits of the Devensian tills and at 2 localities on the northern escarpment.

Coal.Coal was first reported by Rome (1868) in a letter to Wood when he described the sands at Thixendale Grange (see below for details). This is the only published record of coal having been found on the Wolds, despite the fact that this was one of the most common of the erratic types in the area. It has not been found elsewhere on the Wolds however, except at Wharram Percy Village (see discussion). The fragments found were again isolated, generally < 2 cm across in various stages of weathering and disintegration. Finely comminuted coal fragments have also been found in outwash sands and colluvial deposits on the northern escarpment and in some of the dry valleys (see above - outwash sands).

Oolite. Stather (1900) first recorded oolite drift from the area "near the head of the main valley (i.e. the Great Wold Valley) near Lutton". He went on to describe "a patch of drift (marked on the Geological Survey maps) in which are foreign stones, (are) derived chiefly if not wholly from the oolitic rocks". Dakyns and Fox-Strangways (1886) say of the deposit marked on their map that "to the north and west of Thirkleby there is a considerable spread of a red sandy clay with angular fragments of chalk, which we at first thought to be boulder clay, but which is very likely merely the insoluble residue resulting from the decay of the chalk". This author found much oolitic material in the area referred to by Stather, and slightly to the west and north as well (fig. 47). This material was very common along the south western side of Old Dale and scattered fragments were also found around Black Plantation (SE895715); to the south of Wold Barn, Settrington (SE863681); on Staxton Brow (TA022784) and on the west side of Camp Dale (TA061767), where a large (35 cm x 17 cm x 13 cm) block of sandy grey oolitic limestone which was in a badly weathered condition but had recognisable casts of the gastropod Aptyxiella sp. and assorted but undentifiable lamellibranchs was found. Small fragments of oolite were also found in the gravels at Luttons Lane, Heslerton. In the main area where they were recorded by Stather no examples were found by the author, but this was probably due to the dense crop cover at time of surveying rather than an absence of material. The clays recorded by Dakyns were found however, and will be discussed below (see soils).

Carboniferous Limestone. Occasionally small sub-rounded fragments of Carboniferous limestone have been recorded from the Northern Wolds. The bulk of this drift was found scattered on Staxton Brow (TA022784) on the south side of Staxton Brow Plantation. Much of this limestone was badly weathered and in places small pits were visible - the average size of these pebbles was from 5 - 15 cm. In the same area but at the foot of the escarpment a piece of similar limestone with specimens of Lithostrotion sp. was found. It was not certain whether this was derived from the erratic group found on the upper part of the escarpment or whether it came from a different source. A notable piece of Carboniferous limestone, complete with a large quartzite vein and some galena (which was found on breaking open the pebble) was found on the west side of Camp Dale approximately 200 m east of Dane bury Manor (TA062767).

Igneous and Metamorphic Types. According to Bisat (1940) some of the erratic pebbles collected by Stather were of igneous types, although no details were given. Stather (1901) found that all the erratic types found in Holderness were found on the Wolds (probably within the Newer Drift limits and on its fringes) but also found that Cheviot porphyries were very common and formed the outermost fringe of erratic pebbles on the eastern Wolds. These observations have not been supported by the author's work in the Hunmanby-Folkton area, although Cheviot porphyries are common both on and off the tills in that area. Fine-grained, black igneous pebbles have been found over all of the Northern Wolds, as have odd pebbles of Cheviot porphyry. Igneous and metamorphic material has been recovered from the gravels at Heslerton Hill including a small fragment of Shap Granite, one or two other "acid" type igneous pebbles and pebbles of unknown type and provenance. Gneissic-type metamorphic pebbles (two) have also been found at Heslerton. Rocks of all igneous types and coarse-grained metamorphic rocks are very common in the till-free areas just west and north-west of Hunmanby, (see note, fig. 47).

Ironstone. Small nodules, generally < 5 cm in diameter, of kidney-ore (haematite) have been found on all parts of the northern Wolds but these were rare erratic types; care had to be used not to confuse other possible ironstone nodules with marcasite nodules which can be found in the chalk. Ferruginous sandstones of possible Jurassic origin have also been recovered (see gritstones and sandstones above).

Red Chalk. Small fragments of Red Chalk have been found in the gravels at Linton Farm and Luttons Lane, Heslerton; similar fragments have also been found in numerous other places especially near the escarpment, (fig. 47).

Oxfordian/Kimmeridgian Septarian nodules. Fossil-bearing septarian nodules have been recovered from a small area which lies just to the South East of Danebury Manor on the west side of Camp Dale. Over 12 of the nodules or fragments of nodule have been recovered so far, consisting of a fine-grained (phosphatic ?) groundmass ramified by a series of calcitic veins. Individual nodules measured 15 cm x 8 cm were found but the bulk of specimens found were broken pieces and were consequently smaller. In one piece of this material a fragment of the Jurassic ammonite Amoeboceras (? kitcheni) was identified by Drs. J. Neale and L. Penny of the Department of Geology. This genus spans the Oxfordian-Kimmeridgian boundary but if the species identification is correct a Lower Kimmeridgian age would be indicated.

Chalk and Flints. These are the most difficult of erratics to prove because the homogeneity of the chalk (to the untrained eye) precludes identification of chalk fragments derived from specific horizons in the chalk. However, fossil bearing Middle Chalk fragments have been found scattered in the fields on Thorpe Bassett Wold and the area just to the south (this area was mapped by Fox-Strangways as Lower Chalk), and fragments of striated chalk have been recovered from the section on Heslerton Brow. These latter specimens are highly unusual because normally the superficial markings found on such an easily weathered limestone should be expected to have been destroyed rapidly, yet their survival indicates that fragments of chalk were moved above by the glacier which invaded the Vale of Pickering. It would seem reasonable that if this glacier overtopped the north escarpment of the Wolds (as will be argued below) more chalk fragments would have been eroded and transported by the ice, and the presence of chalk fragments in the outwash sands on the escarpment and in the Vale of Pickering would seem to support this idea. However, the fact remains that unless clearly diagnostic fossils are found in chalk blocks, or unless the fragments are striated, proof is not forthcoming to establish how much chalk was moved around by the glacier ice.

Flints, like the chalk, are very difficult to prove to be of erratic origin, except again perhaps where they are found in association with other erratic types in outwash or till deposits. Well rounded, black flint pebbles have been recorded from several localities however, and these are almost certainly erratic. They were probably derived from other glacial or pre-glacial deposits in the North Sea; as black flints are very rare in the Yorkshire Chalk, it is not unreasonable to assume that they were therefore glacially transported.

In addition to the isolated pebbles described above, in a few localities small groups of erratic pebbles were found scattered in the topsoil. These were most numerous in a belt several hundred metres wide which lies to the west of the feather edge of the Devensian till sheet in the area west and north-west of Hunmanby. The numbers per unit area of pebbles in the topsoil fell off markedly towards the west, and it was notable that much higher densities were found on interfluves than on valley sides and bottoms. Less resistant material (e.g. limestones, schists, etc.), rapidly disappeared towards the west, leaving only the more resistant material (igneous pebbles, gneisses, sands and gritstones, etc.), to form the outer fringe which ran approximately from the

Flixton-Fordon road on the northern scarp to the head of Lang Dale where the line swung to the east, then continued as far as North Wold Farm (TA062783). Here it turned south again and followed the line south of the small tributary to Camp Dale and then it turned east to run along the north side of Camp Dale, and off the surveyed area (see fig. 47).

Other small patches of drift have been found on the north-western edge of the surveyed area, at four sites, Luttons Lane (above), where the gravels were found in association with large clay erratics, Linton Farm (above), Rookdale Farm (SE913717) and Croom Dale, West Lutton (SE928699).

The deposits at Rookdale were found on the spur approximately 200 m west of the farm where the soils were also noticed to be particularly fine-grained and very silty. Pebbles of Jurassic and Carboniferous grit-stones, quartzites and igneous material were all found, but the Jurassic material was by far the most common. The drift pebbles were more numerous than in the surrounding areas (up to 20 per m^2) but the area over which they were scattered was no more than 20 - 30 m^2. A similar assemblage of erratic pebbles was found at Croom Dale, just north-west of West Lutton Village, although small fragments of ferruginous sandstone were found in addition to the material described above. The patch of drift was found extending across the track which ran past the old chalk pit, 250 m north of the latter. The area over which this material was found was again limited, approximately 20 m x 10 m. Surprisingly no oolitic material was found there.

D. The Soils and Sediments of the Northern Wolds

The major soil groups mapped by Matthews on the western escarpment of the chalk near Acklam were the Wolds Series and Icknield Series (Matthews 1975). These represent brown earths and rendzinas respectively. He also mapped small amounts of Coombe Series (a calcareous brown earth) in the bottom of the dry valleys and on the scarp. Mr. S. King (pers. comm.), has mapped a similar soil assemblage on the northern scarp of the Wolds between East Heslerton and Staxton and on the dip slope to the south. Both authors recorded a high proportion of silt present in the soils and this is taken to indicate the presence of a much more continuous and widespread cover of silt (Catt et. al., 1974, Catt 1977a, 1977b, 1982). Loess deposits had been recorded from several scattered and isolated sites on the Wolds including some beneath Devensian tills, in hollows and fissures in the chalk and on the open Wolds (Catt et. al., 1974, Bray et. al., 1981, Perrin et. al., 1974). Matthews reported clays-with-flints from three widely separated localities on the northern Wolds (Matthews 1977).

Blown sand and coversand - like material were reported at Fimber (Bray et. al., 1981), and on the northern Lincolnshire Wolds by Straw (1963) and by various authors in the Vale of York (Matthews 1970, Gaunt et. al., 1971) and Holderness (Catt and Penny 1966, Boylan 1967, 1977). Edwards (1978) recorded blown sands at Knapton gravel pit in the Vale of Pickering.

The result of these studies is that a rather patchy picture has been built up of isolated pockets of clays-with-flints overlain by extensive spreads of thin silts of loessic origin. In the dry valleys much of the colluvium was supposed to have been derived by erosion from the adjacent slopes and interfluves, aided by the nature of the loess and its peculiar properties when saturated (Catt 1982). The preservation of the silts on the Wolds was attributed to a lack of any prolonged cold phase in post-glacial times which prevented high run-off conditions from being established, and the incorporation of a Ca-rich element at an early stage which cemented the silt grains together and prevented their rapid removal (Catt et. al 1974, Catt 1977b). However, this rather simple picture does not seem to readily apply throughout the region, as the removal of much loess does seem to have occurred in late-glacial times, via a dense network of temporary drainage channels (see chapter 5 and section d below).

In fact the soils of the Wolds can be conveniently grouped into 4 major units - the clays-with-flints, an extensive but discontinuous cover of reddish-brown sandy and silty clay subsoils, loess and a mixed group of blown sands and loess, the latter dominated by blown sands.

a) The clays-with-flints

These have long been recorded on the chalk hills of central and southern England and have been frequently described and their origins discussed (e.g. Avery et. al., 1959, Barrow 1919, Dines and Edmunds 1933, Hodgson et. al., 1967, 1974, Jukes-Browne 1906, Loveday 1962, Pepper 1974, Reid 1898, 1903, Thorez et. al., 1971, Wooldridge and Linton 1955). Similar deposits have been recorded from beneath archaeological sites on the Yorkshire Wolds (Mortimer 1905, Manby 1963, 1976, Crompton and Bullock in Matthews 1977): however, they have only recently been fully described (Matthews 1977). In spite of an intensive search of the field area by the author, no new sites of clays-with-flints were found, so no new information can be added here.

b) Coversands and Loess

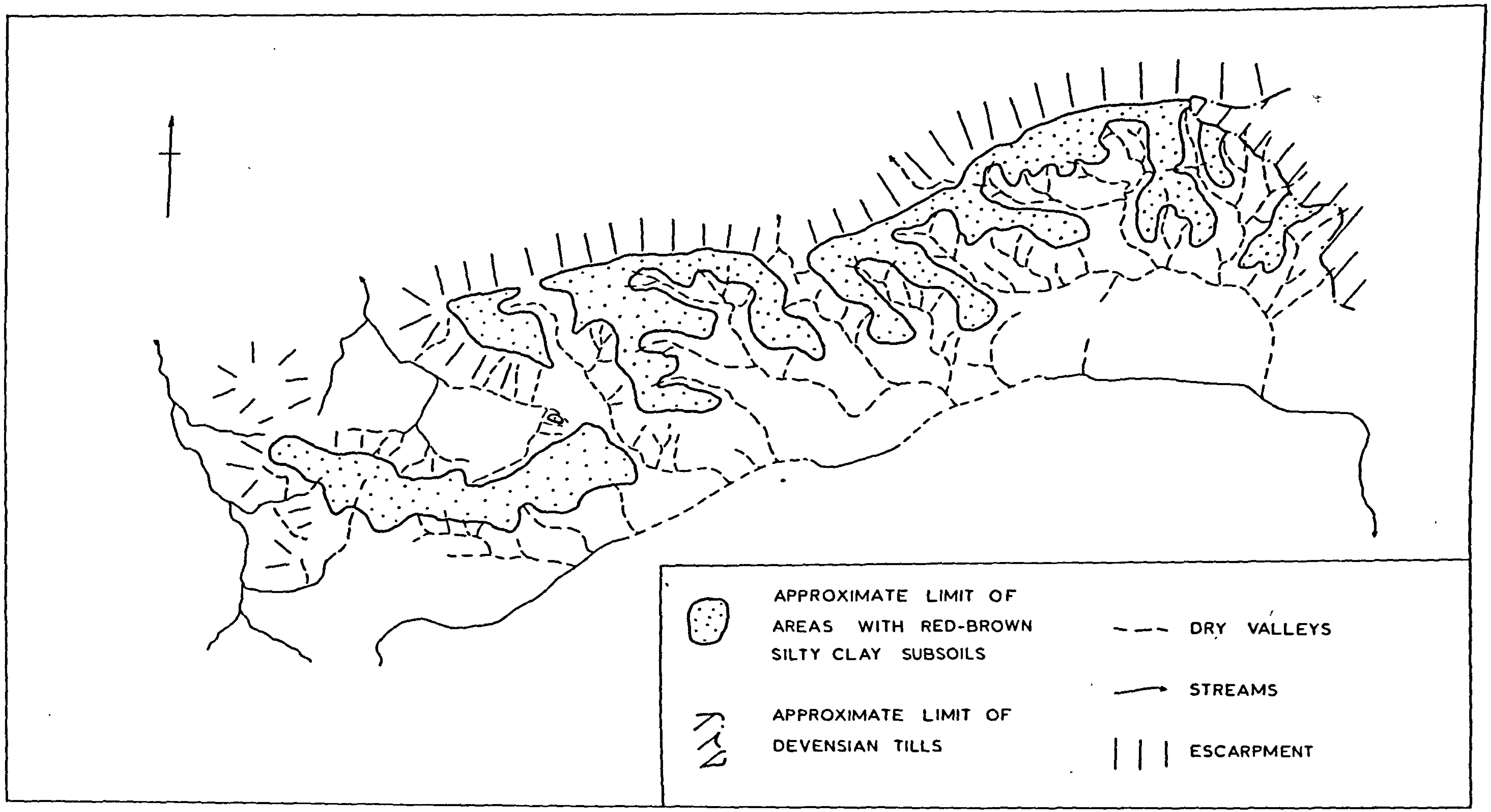
To test the hypothesis that loess formed the dominant part of the Wolds soils the following experimental design was instigated:-

i. samples of topsoils were collected from a widely dispersed set of localities.

ii. these samples were individually analysed and their sedimentary characteristics determined.

iii. a statistical analysis to test the similarity between published loess data and those data derived from the soils, the origin of which was uncertain, was carried out.

Fig. 56 Map showing the distribution of scattered sandy - and silty-clay subsoils on the northern Wolds dip slope.


APPROXIMATE LIMIT OF AREAS WITH RED-BROWN SILTY CLAY SUBSOILS
APPROXIMATE LIMIT OF DEVENSIAN TILLS
DRY VALLEYS
STREAMS
ESCARPMENT

In addition material was collected from the fine-grained matrices of solifluction gravels and buried lenses of sandy silts found at various localities on the scarp and in dry valleys. These samples were then prepared by dry sieving at 1 Ø intervals to 4 Ø and then taking subsamples from the < 4 Ø fraction: the subsamples were dried and then put into distilled water before adding nonidet dispersant and then dispersed in a sonic disperser. A very small sample was removed (while the disperser was in motion) and added to circa 500 ml. of particle-free saline solution and analysed with a coulter counter. The raw data were then converted into percentage values for each grade size.

The results were then compared with published data on coversands and loess deposits from a wide variety of sources (Avery et. al., 1969, 1972, Bray et. al., 1981, Catt et. al., 1971, 1974, Coombe et. al., 1956, Hodgson, et. al., 1967, Lee 1979, Matthews 1977, Piggott 1962, Pitcher et. al., 1954, Robson and George 1971, Vincent and Lee 1981). N.B. the definition of loess as used by the above authors varies somewhat. Loess was originally defined by Russell (1944) as < 60 μm, later Rutten (1954) redefined this as 54 μm. In the definition used here 64 μm has been taken as the upper limit and the term "loessic silts" rather than "loess" used to describe this author's results. (Other authors' data will be referred to as "loess").

The first important result from the data was the small number of sites which had a significant loessic silt component. Apart from the confirmed and isolated deposits at Fimber, Huggate, Linton Whins and Linton Farm, all of which were covered by more recent deposits and thus protected, the only other samples to contain > 20% silt (< 4Ø) were a matrix of a solifluction gravel at Waterdale, soil in a small hollow in a chalk pit at Fridaythorpe, a similar deposit at High Mowthorpe and soil from an interfluve site on West Heslerton Wold (SE926747). Of the remaining 42 sites, only 11 had more than 10% silt content (i.e. < 4Ø).

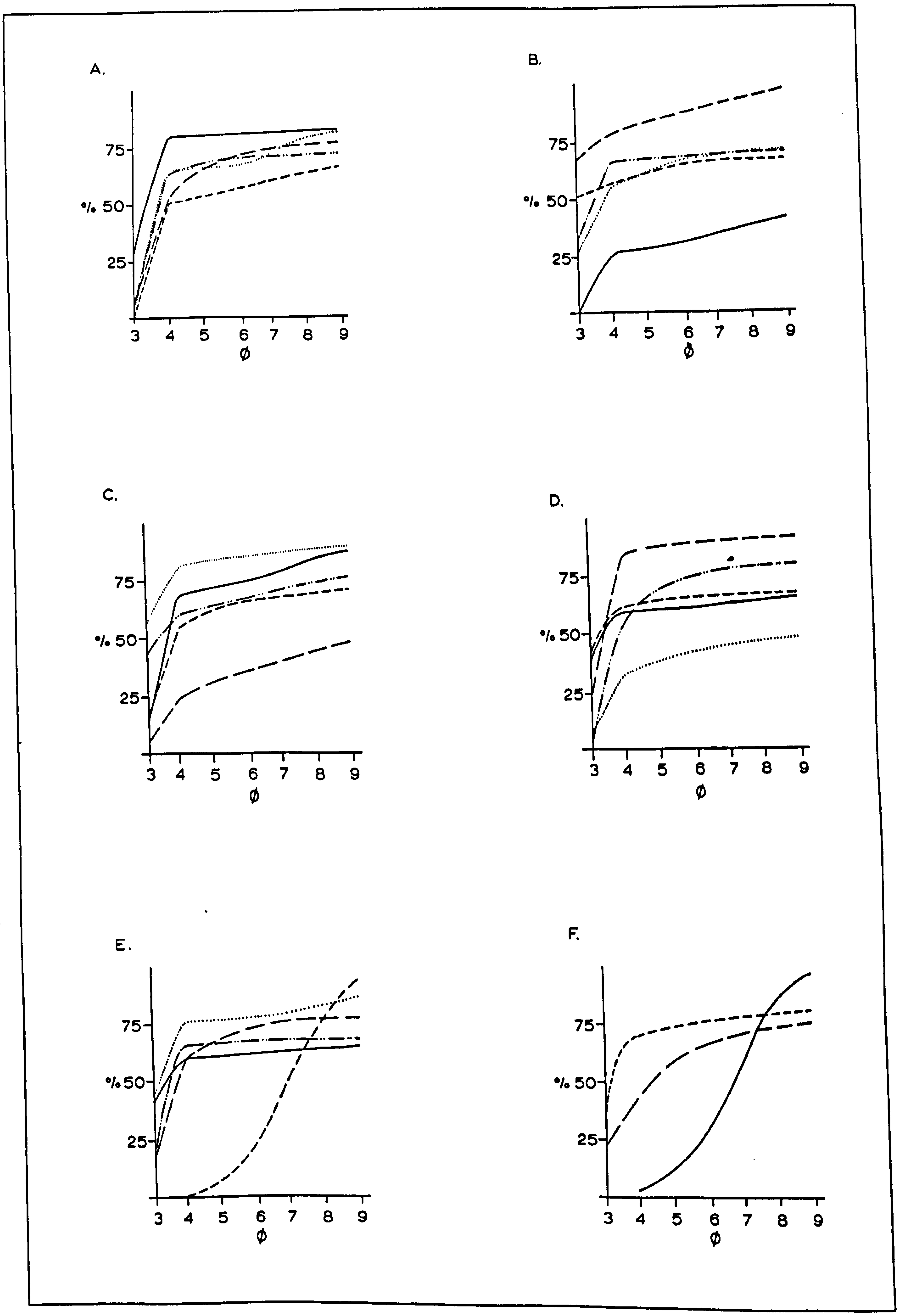
The second significant result was the relative importance of the fine

Fig. 57 Particle-size distribution curves for the fine fraction of the sandy- and silty-clay subsoils of the northern Yorkshirer Wolds. Lines on graphs numbered as follows:-

———————— 1
— — — — 2
- - - - - - - 3
— ·· — ·· 4
.... 5

A1 SE 8529135
A2 TA 026766
A3 TA 03937927
A4 TA 04778
A5 TA 048778
B1 TA 0397793
B2 TA 07187671
B3 SE 929728
B4 TA 01537511
B5 TA 0728471
C1 TA 014734
C2 TA 014734
C3 SW 97257290
C4 TA 00127660

C5 TA 06317798
D1 TA 06137824
D2 SE 981727
D3 TA 00127689
D4 SE 875548
D5 SE 99753
E1 TA 0156750
E2 TA 05907596
E3 SE 895750
E4 SE 828701
E5 SE 852714
F1 SE 927705
F2 SE 9287592
F3 SE 911749



A.
B.
C.
D.
E.
F.
%
75
50
25
3 4 5 6 7 8 9
ϕ

sand fraction (64 µm - 120 µm: 4Ø - 3Ø) - 6 samples had > 50%, 10 between 40 - 50% and 15 between 20% - 40% (i.e. 31 samples had > 20% fine sand compared with 8 with > 20% loessic silt (> 4Ø)).

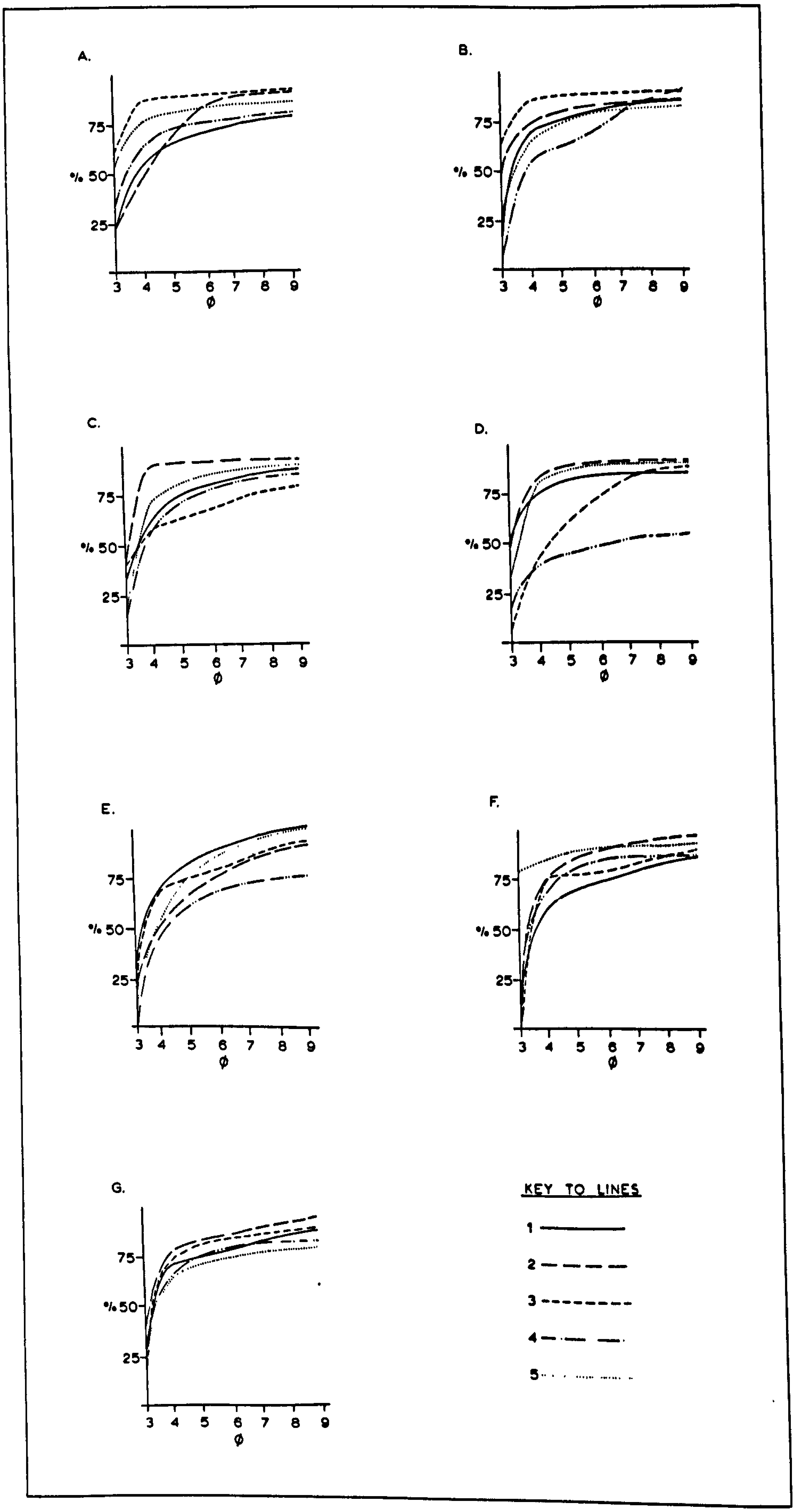
If the coarse sand fraction (2Ø - 3Ø, 120 µm - 250 µm) is considered, this is even more important, because over half the samples had > 20% coarse sand present, (5 > 50%, 5 between 40% - 50%, 13 between 20 - 40%). If the total sand fraction is considered (i.e. coarse and fine combined: 2Ø - 4Ø), 5 samples analysed had > 80% sand, 12 between 70% - 80% sand, and only 6 had < 60% sand (lowest value 41%).

In order to test this apparent difference the means of 24 samples of loess from the Wolds were compared with the data gained in this study. (The loess data was taken from the published data of Catt et. al., (1974) and Bray et. al., (1981). Students t test was used and a null hypothesis set up which stated that there was no significant difference between the published data and the results of this study. The result of the test was that t = 2.8 with 35 degrees of freedom: the null hypothesis was therefore rejected at the 1% level, and that the deposit analysed by the author above could not have been derived from the same sedimentary group.

From the above data it is very clear that loess is a far less significant constituent of the soils analysed from the Wolds by the author than is blown sand. When compared with published data for loess, the samples analysed do not have a close affinity to loess - a conclusion which is at variance from the results of Catt et. al., (1974) who took a more limited number of samples from sites to the east and south of this region, and by Perrin et. al., (1974). Instead the results show that these sediments have a much closer affinity to blown sands (or "coversands") and, from particle-size data, appear to be a relatively coarse wind-blown deposit.

Fig. 58 Particle-size distribution curves for topsoils, subsoils and sandy fissure deposits from scattered sites on the northern wolds. For key to letters and numbers see table 11.

A1 SE 840683	D1 TA 07787550	G1 SE 874680
A2 SE 826613	D2 TA 00097487	G2 SE 742918
A3 TA 01867713	D3 SE 908708	G3 SE 868694
A4 TA 01537511	D4 SE 840567	G4 SE 924718
A5 TA 0140768	D5 SE 94507525	G5 SE 94457438
B1 SE 886699	E1 SE 914603	
B2 SE 99877584	E2 SE 915603	
B3 TA 04107800	E3 SE 868653	
B4 SE 879701	E4 SE 9266717	
B5 SE 94847307	E5 SE 891699	
C1 SE 992753	F1 SE 8665681	
C2 SE 92007525	F2 SE 952674	
C3 SE 948709	F3 SE 964657	
C4 SE 917698	F4 SE 908613	
C5 SE 95507365	F5 SE 910750	


A.
B.
C.
D.
E.
F.
G.
75
% 50
25
3 4 5 6 7 8 9
Ø
KEY TO LINES
1
2
3
4
5

c) The reddish-brown sandy clay subsoils

As part of an attempt to further clarify the above picture (i.e. that sands rather than silts were dominant in the Wolds soils), samples of the reddish-brown sandy-clay subsoils were collected from a wide variety of localities on the chalk dip slope, including, in many cases, actual fissures in the chalk. These samples were also collected to assess whether the clays-with-flints described by Matthews (1977) from isolated sites on the Wolds were present at any other localities.

Samples were collected by scraping away the Ap layer and collecting undisturbed material from beneath it, or by excavating small exposures in road-side sections and old chalk pit faces - in the latter the material filled fissures in the chalk. In the course of the collection of this material it was noted that that colours varied according to the state of weathering and amount of time that a sample was exposed to air. Where samples were found in solution hollows and in some fissures in chalk pits (e.g. at Flixton Hill chalk pit (TA048778), a fissure over 4 m deep was recorded), the colours were observed to darken towards the surface in fresh unweathered sections: The typical range of colours was :-

Strong brown (7.5 YR 5/8)

Red (2.5 YR 4/8)

Yellowish red (5 YR 4/6 - 5/8)

Light olive (5 Y 6/2) or light grey (5 YR 7/1)

The non-red colours at the base were only found at two sites - in a soil pit at Warren Slack (page 156, fig 60) and in a fissure on Binnington Ness (at TA01537511); they were reported by Matthews and Evans and Dimbleby (in Manby 1976) at the bases of their respective soil profiles.

Samples were prepared for analysis as described for the soils above, except that after removal of organic material and $CaCO_3$ the samples were dried and then put into distilled water before adding nonidet dispersant and then being dispersed in a sonic disperser. A very small sub soil sample was then removed (while the sample was still being agitated), and added to circa 500 ml of particle free saline solution and analysed with a coulter counter. The raw data were then converted into percentage values for each size grade.

The first important conclusion to be drawn from the results was that no clays-with-flints like material was found to be present in any of the samples - all had too small a proportion of clay i.e. ≮ 65% (Loveday 1962 defined 80% clay as the lower limit for clays-with-flints <u>sensu stricto</u>).

The second result was that a dearth of silt-sized material was found in these soils (only 2 samples, both in deep fissures, had > 20% of particles in the 2μm - 64μm range and both of these had very large quantities of fine silt (2μm - 16μm) i.e. ≮ 65%). Once again sand grade material was dominant - fine sand constituted > 50% of the total of 4 samples, 40% - 50% in 3 samples, 20% - 40% in 11 samples and only 3 samples had < 10%. If the total sand fraction was considered, a high proportion of the 28 samples analysed had over 50% of material coarser than silt grade (18 with ≯ 50%, 13 > 60% and 2 < 80%). If the topsoil and subsoil samples were compared, the variation in clay content was a better guide than the means of the 2 groups (mean of topsoil = 3.58ø, mean of subsoils = 3.6ø) - the subsoil had, as would generally be expected, a much higher clay content.

d) <u>The Dry Valley Deposits</u>

In an attempt to see if the products of the late Neolithic/Bronze-age erosion phase had accumulated over and buried pre-existing soil profiles in the dry valleys, a series of soil pits were excavated in four of the trunk valleys of the northern Wolds dip-slope. The following was recorded:

i) Camp Dale Pit 1 (TA05817744) fig. 59a.

Section	Thickness	Depth To
* Dark grey fine sand with scattered very badly weathered sub-angular pieces of chalk. Very few flints.	0.2 M	0.2 M
Dark yellowish-brown fine sand with scattered chalk and flints (angular). Some pebbles had their long axes vertical or near vertical.	0.6 M	0.6 M
Fine grained dark yellowish-brown silty sand with sub-angular chalk and flints. Marked increase in finer grained sediments (silt) here.	0.2 M	0.8 M
Fine silty sandy gravel. Colour brown to very dark brown. Gravel content decreased with increase in depth. Gravel fraction fine (2 - 4 mm) with more flint than chalk (unlike overlying horizons).	1.4 M	2.2 M
Fine angular chalk/flint gravel with fine silty sand and much angular flint matrix overlying coarse blocky chalk/flint gravel with fragments 25 x 13 cm common. Tabular flints present.		2.25 M Base not seen

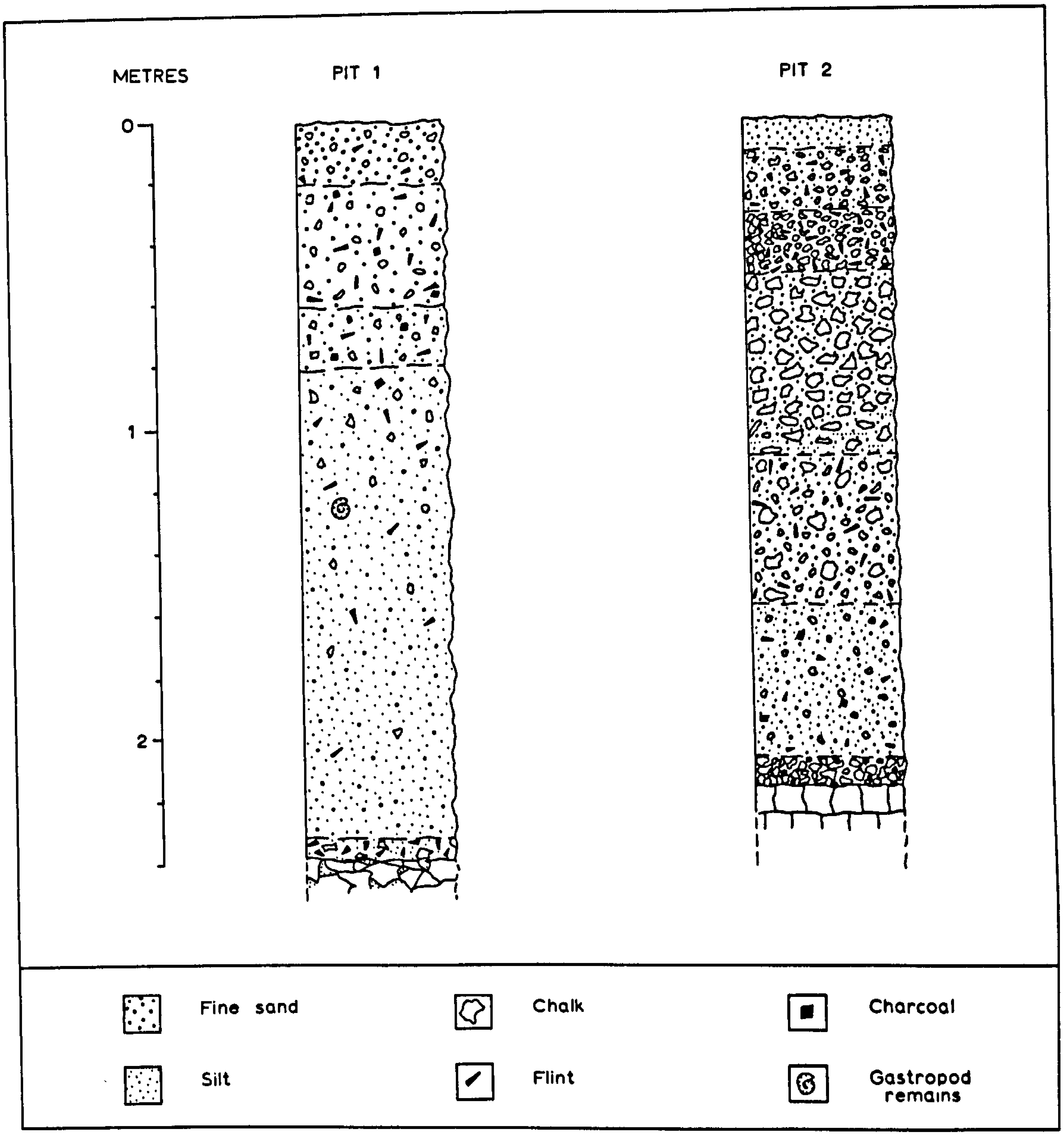
At 1.2 m a single very weathered gastropod shell was found but this disintegrated on extraction. Charcoal was occasionally found to a depth of 1.9 m below the ground surface.

ii) Camp Dale Pit 2 (TA05787754). This was dug 100 m north of the confluence of the two tributary valleys and the main trunk valley (Camp Dale): fig. 59.

Section	Thickness	Depth To
Dark grey stone-free sand.	0.1 M	0.1 M
Dark grey sand with much angular chalk and flint gravel		

* N.B. Munsell colours not recorded

Fig. 59 Diagrammatic sections of excavated pits in Camp Dale.

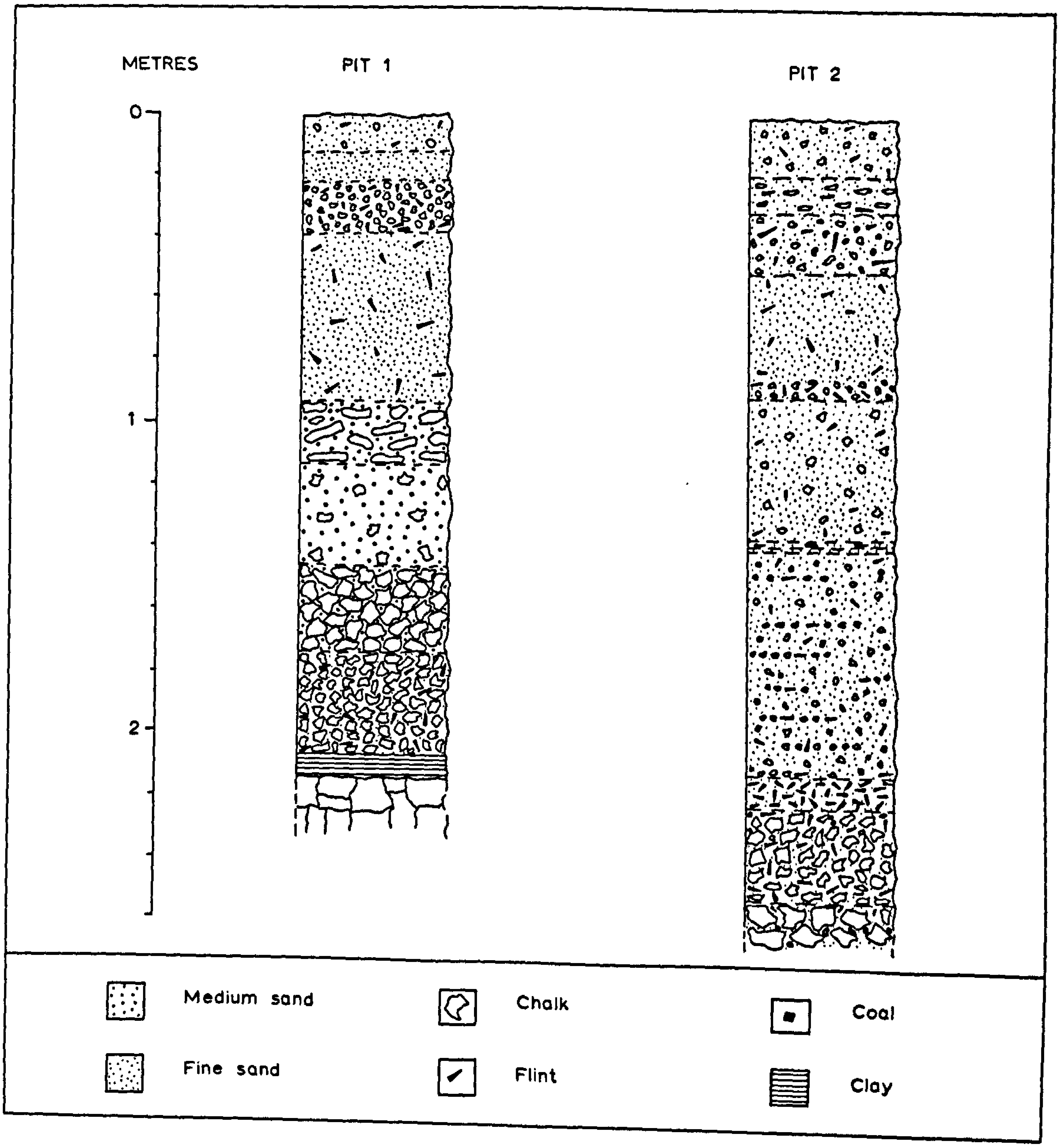

METRES
PIT 1
PIT 2
0
1
2
Fine sand
Silt
Chalk
Flint
Charcoal
Gastropod remains

Section	Thickness	Depth To
intermixed, (chalk - 2 - 4 cm, flint - 1 - 4 cm).	0.2 M	0.3 M
Compact sub-angular chalk gravel with matrix of very pale brown fine sand (size gravel 2 - 4 cm).	0.2 M	0.5 M
Less densely packed angular chalk gravel with slightly more sand matrix. Sand matrix increased with depth until near base thin discontinuous silty sand appeared, (up to 2 cm thick).	0.5 M	1.0 M
Dark brown silty sand with scattered angular chalk-flint gravel (chalk 1 - 5 cm, flint 1 - 8 cm dia.). Stones scattered throughout sand matrix. The chalk lumps became puggy (pasty) towards the base of this horizon.	1.45 M	1.45 M
Dark brown fine silty sand (coversand ?) Black streaks of charcoal were common in this horizon, but actual fragments were rare. Small angular flints (< 2 cm) and sub-angular chalk stones (< 0.5 cm) were scattered throughout.	0.4 M	1.85 M
Angular/sub-angular clasts of chalk up to 4 cm. Much of this chalk was "pugged" (i.e. very weathered and pasty). This horizon formed a compact almost matrix-free horizon overlying "pugged" chalk <u>in situ</u>.	0.1 M	1.95 M
Weathered chalk <u>in situ</u>?		1.95 M

Charcoal was recorded at a maximum depth of 1.3 M from the surface. Much of the gravel in the base of this section had pyrolusite (manganese dioxide) growths on the surface of the clasts which is indicative of an open-air environment i.e. this gravel was at one time exposed to weathering under free-air conditions. Alternatively the manganese may have been deposited as a result of pH changes due to the well drained nature of the site.

iii) Warren Slack Pit 1 (SE986751) fig. 60.

Fig. 60 Diagrammatic sections of excavated pits in Warren Slack.



METRES
PIT 1
PIT 2
0
1
2
Medium sand
Fine sand
Chalk
Flint
Coal
Clay

Section	Thickness	Depth To
* Dark grey to very dark greyish-brown fine sand, with scattered angular fragments of flint and chalk.	0.12 M	0.12 M
Dark brown fine stoneless sand.	0.10 M	0.22 M
Dark brown fine angular chalk/ flint gravel (< 4 cm).	0.18 M	0.40 M
Dark brown fine sand with pebbles of angular flint scattered throughout. No chalk present. Gravel < 4 cm.	0.55 M	0.95 M
Very dark orangy-yellow medium grained sand with large densely packed angular lumps of chalk (10 - 15 cm x 5 - 8 cm). Most of the chalk blocks horizontally bedded.	0.30 M	1.25 M
Dark orangy yellow medium grained sand with scattered lumps of angular chalk scattered in the sand matrix.	0.30 M	1.55 M
Dark yellow sandy matrix filling cracks between very coarse (> 15 cm) angular chalk gravel which was fairly densely packed.	0.20 M	1.75 M
Fine angular blocky chalk gravel with little sand matrix. Chalk in upper 5 cm has average size of 2 - 3 cm dia., but in lower section size increase to 4 cm average. Much broken chalk and flint formed matrix between blocks.	0.22 M	2.07 M
Mottled light-grey and dark orange clay. Very plastic and tenacious.	0.03-0.05 M	2.10-2.12 M
White chalk probably *in situ*.		

No charcoal was found in this pit. The dark orangy-yellow sands and yellow sands contained disseminated finely comminuted coal (?) fragments below 1.3 M.

iv) Warren Stack Pit 2 (SE98857460) fig. 60b.

* N.B. Munsell colours not recorded

Section	Thickness	Depth To
Dark greyish-brown (10 YR 4/2) fine sand with small sub-angular chalk fragments and angular flints.	0.2 M	0.2 M
Yellow-brown (10 YR 5/6 - 5/8) fine sand with much flat-lying chalk and flint gravel.	0.10 M	0.3 M
Yellowish-brown (10 YR 5/6) to dark yellowish-brown (10 YR 4/4) fine silty sand with much angular chalk and flint (2 - 3 cm). Some flint nodules up to 10 cm.	0.20 M	0.5 M
Yellowish-brown (10 YR 5/8) sandy silt with scattered angular flints up to 4 - 8 cm.		
A stone bed (10 cm thick) was found between 0.8 and 0.9 M. Stones consisted of sub-angular chalk and angular flints (2 - 4 cm dia.). Matrix of silty sand.	0.40 M	0.9 M
Reddish-brown (5 YR 4/4) silty sand with scattered angular flints (< 1 cm) and angular chalk (< 2 cm). Surface of chalk pebbles was weathered and friable when dry, "pugged" (pasty) when wet.	0.5 M	1.4 M
Reddish-brown (5 YR 4/4) fine to medium grained sand. Scattered in the sand were small (< 2 cm) angular flints.	0.5 M	1.45 M
Yellowish-red (5 YR 4/8) medium sand. This was slightly ferruginous.	1.01 M	1.46 M
Yellowish-brown (10 YR 5/8) medium grained sand with thin streaks of finely comminuted carbonaceous material (probably coal). Scattered throughout were angular flints (2 - 4 cm) and sub-angular chalk stones (< 5 cm). Bulk of stones tended to be mainly concentrated in thin beds however. No bed structures were visible in this sand, which was markedly quartzitic. Small fragments of haematite were		

Section	Thickness	Depth To
present in one pebble bed.	0.64 M	2.10 M
Loosely packed flint gravel with yellowish-brown (10 YR 5/8) sand matrix. Flints up to 110 x 3 cm formed a horizontally bedded horizon.	0.10 M	2.2 M
Light yellowish-brown (10 YR 6/4) medium grained sandy gravel with much angular chalk and flint (< 2 cm). Sand matrix highly quartzoze with thin streaks of finely comminuted ? coal. This material formed the matrix of a very coarse blocky chalk gravel (blocks 10 x 10 x 5 cm).	0.3 M	2.5 M
Very pale brown (10 YR 7/3) fine sandy gravel filling interstices between densely packed angular chalk gravel.	0.1 M	2.6 M Base not seen

N.B. Excavations ceased at 2.6 M because the lower sands kept collapsing and undermining the upper soil pit walls, leaving the latter in a dangerous condition. It was thought that the solid chalk surface was not very far below the bottom of the base of the pit. Charcoal was found to a depth of 0.7 M. The junction between the reddish-brown (5 YR 4/4) sands and the yellowish-red (5 YR 4/8) sands was very uneven. A possible frost-wedge cast 35 cm deep x 4 cm wide at the top was recorded, but involutions were not observed. The variation in the depth of the base of the upper horizon varied from 1.4 to 2.4 M over a lateral distance of 60 cm. However, this uneven surface may be the result of a "weathering front" and due to translocation of iron from the upper part of the profile into the lower (N.B. the slightly iron-rich horizon at 1.45 - 1.46 M). However, where the base of the upper horizon dips into the underlying yellow sands, the upper horizon was noted to contain scattered flints up to 10 cm long and weathered(pugged) chalk fragments up to 5 cm long. Long axes of these pebbles were horizontal or nearly so. Small pockets (10 x 20 cm) of chalky flint gravel were found scattered in the yellow sands (between 1.4 and 2.1 M).

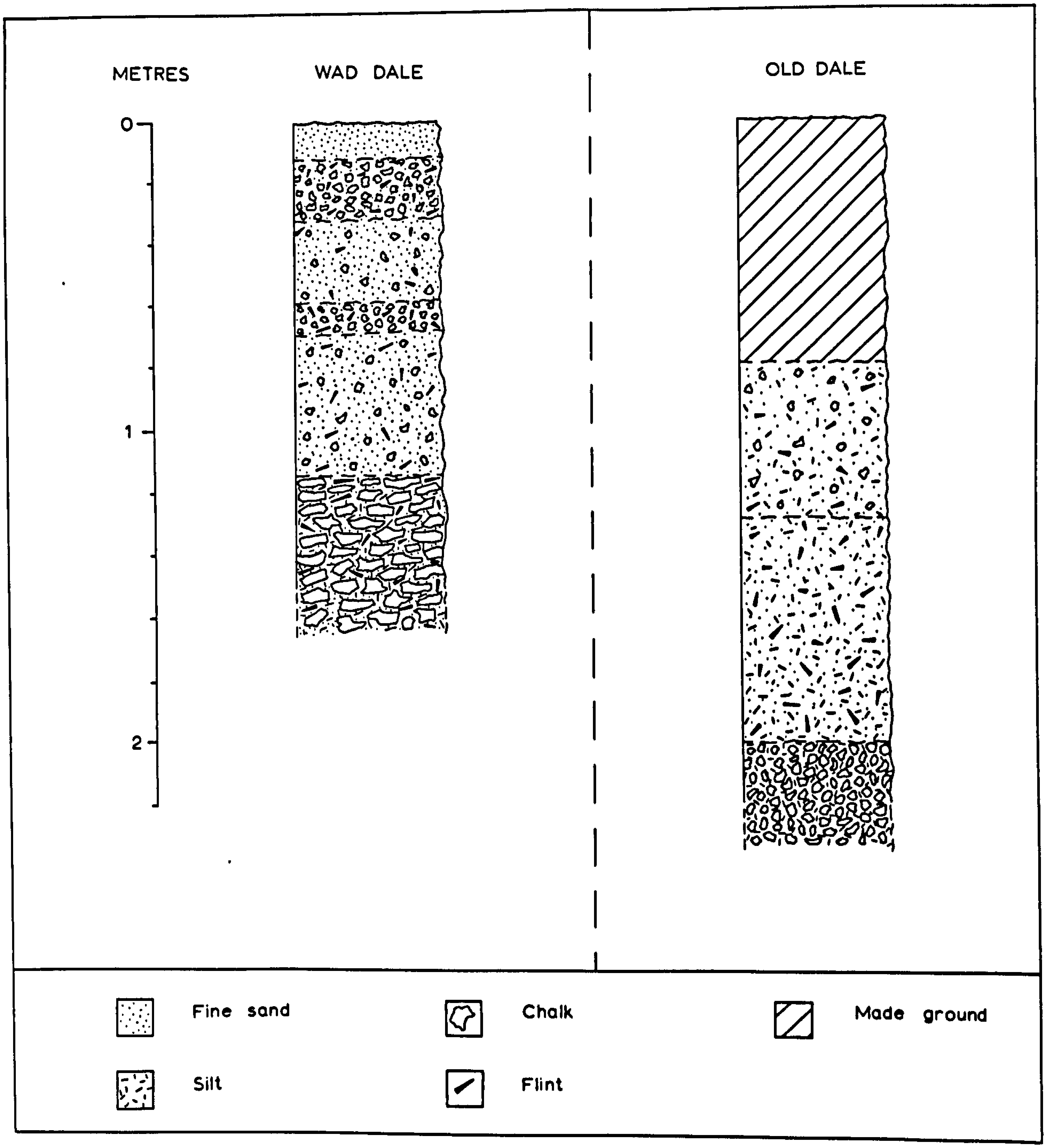
v) Wad Dale, near Moor Farm (SE94657255): fig. 61.

Section	Thickness	Depth To
Fine sandy dark grey stoneless topsoil.	0.12 M	0.12 M
Angular chalk-flint gravel (1 - 2 cm) with some nodular flints. Matrix of gravel was fine grained dark yellow sand. Small sand pockets contained fragments of charcoal 1 - 3 cm dia.	0.21 M	0.33 M
Very dark yellow fine sand with scattered angular flints and sub-angular chalk fragments (4 cm). Old roots found up to 0.5 cm diameter.	0.27 M	0.6 M
Sandy angular chalk/flint gravel, up to 8 cm dia. Sand dark brown in colour.	0.1 M	0.7 M
Dark yellow to dark yellowish-brown fine sand with scattered angular chalk and flints stones (< 5 cm).	0.75 M	1.15 M
Horizontally bedded, densely packed angular chalk/flint rubble (coarse gravel > 10 cm) with dark yellow silty clay matrix. Within the matrix were small pieces of angular flint and chalk (1 - 2 mm). This may have been either a solifluction deposit or frost shattered chalk *in situ*.	0.35 M	1.5 M Base not seen

vi) Old Dale (SE92707195): fig. 61

Section	Thickness	Depth To
Made ground.	0.8 M	0.8 M
Mottled yellowish-brown (10 YR 5/6) and pinkish-grey (7.5 YR 7/2) fine silty sand small pebbles of angular flint and sub-rounded pasty white chalk scattered throughout.	0.5 M	1.3 M
Mottled dark reddish-brown (5 YR		

Fig. 61 Diagrammatic sections of excavated pits in Wad Dale and Old Dale.



METRES
WAD DALE
OLD DALE
0
1
2
Fine sand
Chalk
Made ground
Silt
Flint

Section	Thickness	Depth To
3/3) and light grey (7.5 YR N7) very silty sand with numerous small (1 - 2 mm) angular flints scattered throughout. Larger flints (up to 1 cm) rarer.	0.7 M	2.0 M
Rounded small (0.2 - 1.0 cm) chalk gravel with white powdery chalk and silt matrix.	0.2 M	2.2 M Base not seen

The first conclusion was that no evidence for buried soil profiles could be found in any of the sections. The second is the presence of charcoal in the upper 0.7 m - 1.2 m of colluvial fill, which strongly implies soil erosion following clearance of the natural or semi-natural vegetation. In the case of charcoal found at a depth of 0.33 at Wad Dale, this could be related to a known scrub - clearance event which occurred at some time between 1890 and 1900 A. D. This apparently minor event precipitated the erosion of soil and subsoil which accumulated in the dry valley below the field slopes. This seems to support the hypothesis that soil creep and soil wash over many centuries is, in part at least, responsible for the accumulation of the colluvial deposits in the dry valleys, especially during times of flash flooding as occasionally happens on the Wolds (Anon 1904, Catt 1982, Cole 1887, 1910, Foster 1978).

A third point is the discrepancy between the average thickness of the soils in the dry valleys (between 1.5 m and 2.2 m was recorded by the author), and the amount of soil which had apparently been lost from the Wolds interfluve areas (the thickness of the buried soil profile found beneath a long barrow on Willerby Wold was 90 cm - Manby 1976). If all of the soil in the dry valleys were put back onto the interfluves, it would only represent a layer circa 0.25 m thick, leaving a large amount of soil which had been totally removed from the Wolds area altogether. This assumes that the original cover was loessic in character, but if the means of the colluvial deposits (2.5 Ø - 3.9 Ø range; 2.99 Ø mean), are compared with the means of the topsoil and subsoil data from the Wolds dip slope (3.58 Ø - 3.6 Ø) which are probably blown sands, it is closer to the latter than the means for samples of loessic silt found on the Wolds by the author, and of loess recorded by Bray et. al., (1981), Catt et. al., (1974) and in Lancashire (Vincent and Lee 1981) and Merseyside (Lee 1979) where all the samples had means > 4Ø, (< 63 μ).

If the colluvial deposits were derived from silty soils on the interfluves by either wind or water, much more silt would be expected to be present - Chepil (1957) found that during erosion of soils by wind, sorting and separation of coarse and fine material was minimal. If water was the agency responsible for the build-up of the colluvium, not so much silt would be expected to be present because although the water would rapidly drain into the valley floors and leave the suspended sediment load (which the silt would form), behind, some would be carried away totally in suspension. It is therefore suggested that water is or has been a major agent in removing soil from the interfluves and dumping the coarser fraction in the dry valleys.

e <u>Discussions of particle-size distributions and possible origins of the soils</u>

i <u>Reddish-brown sandy and silty-clay subsoils</u>

In this category are included all the subsoils analysed by the author, but excluded are the clays-with-flints of Matthews. These two deposits are distinguishable by clay content (clay-with-flints has > 80% clay, sandy and silty-clay subsoils < 65% clay), pH values (clays-with-flints < 4.5, subsoils usually > 5.5), slightly different colours (clays-with-flints have higher chromas in the 5 YR range) and the high flint content of the subsoils.

The origin of the clays in the subsoils almost certainly seems to have been by illuviation of clay from higher horizons of a soil profile (or profiles) which have now been totally removed. The proportion of fine clay (< 0.02 µm) found in similar material by Matthews (1975) in his survey of the N. W. Wolds supports the hypothesis that illuviation may well be the origin for much of this clay - possibly from Older Drift tills.

The reddish hues are of interest as they help indicate a pre-Devensian age - these colours are associated with a warmer, wetter climate than that which prevails at present - the Ipswichian Interglacial is the most probable period (Mitchell et al 1973). Matthews (1977) suggested a similar origin for the red hues in the clays-with-flints recorded by him. The textures of these soils (sandy and loamy clays), when combined with the red colouration, strongly indicate that these horizons probably represent a palaeo-argillic horizon (Avery 1980), possibly developed on Older Drift tills.

If these subsoils were derived from an earlier group of soils which were almost totally eroded before or during the Devensian, they would probably have been exposed or only just buried, and may therefore have contributed to the high run-off conditions which existed at the end of the Devensian (see Chapter V: Section D). The much attenuated remnants that we now find on the interfluves may well be in part due to severe erosion of soils at this time.

The origin of the olive and grey hues is a little less certain.

Matthews (1977) suggested that they represent the insoluble residues derived from the solution of the chalk, but in view of the purity of the Middle and Upper Chalk of the Wolds (between 95% and 98% $CaCO_3$), the thickness of the clays recorded by the author and Matthews would require the solution of up to 5 m of limestone without incorporating flints - a highly unlikely event in view of the flinty nature of the rock. Further, in southern England Chartres and Whalley (1975) found that insoluble residues derived from the chalk beneath clays-with-flints were blackish in colour and generally thinner than the horizons discussed here. It would seem therefore that waterlogging of the subsoil and reduction of the iron would be the most likely origin of these non-red colours.

The coarse fraction found in these subsoils is consistent with blown sands which were found to be dominant in the topsoils. Mixing of the two groups of materials could have occurred as a result of cryo - or bio-turbation if the clays represent a relic of an earlier, now eroded, soil horizon. Alternatively, if the clays were derived by illuviation from a Devensian or post-Devensian soil, the sand fraction would have been present from the start.

ii. Blown sands and loessic silts

The results of the particle-size analyses of the soil samples on the Wolds dip slope are at variance with previously published data for material from this area (Catt et. al., 1974, Cornwall (in Manby 1963), Evans and Dimbleby (in Manby 1976), Matthews 1975, Perrin et. al., 1974), but they are similar to the "coversand-like" material reported by Bray et. al., (1981) at the top of the section at Fimberfield House Farm (N. B. a thick lens of loess was also reported here). The differences between the results recorded by the author from a large number of varied sites, and their internal consistency (including the fact that "loessic silts" have also been found), compared with the fewer examples from other authors is too large to be accounted for by slight variations within a slightly inhomogenous population. Clearly there are two groups of sediments which have different particle size distributions, and this variation has to be accounted for. The first question which needs to be answered is why authors have found silts to be the most important constituent of the soils. Other authors have, in the main, taken samples from sites which were buried and therefore to a certain extent, protected from subsequent erosion. Of the "loessic silt" deposits recorded by the author, the majority were from buried sites. This leaves a few examples which were not buried, but which could be explained as the remnants of a loessic cover, the bulk of which had been stripped by erosion in late-glacial times: (Chapter V). If this latter hypothesis is true, then some of the silty material which forms the matrix of the gravels in the floors of the dry valleys may have been deposited by percolation of surface water when the rivers dried up at the end of the melting phase and while the ground surface was still seasonally thawed in late glacial times. Further evidence that the loessic silt cover may well have been subjected to severe erosion during or even prior to late-glacial times is supported by evidence from frost-wedge cast infill and other cryoturbation phenomena on the Wolds. The frost-wedge casts at Linton Farm (SE908708) and the hollows on the scarp at Luttons Lane, West Heslerton (SE910749, page 125) were filled with blown-sand material. If loess was present in the area it should have been more strongly represented than it was - its absence suggests that in these areas at least it had been removed by meltwater or other erosive agencies (? wind) and largely replaced by coarser, blown sand deposits.

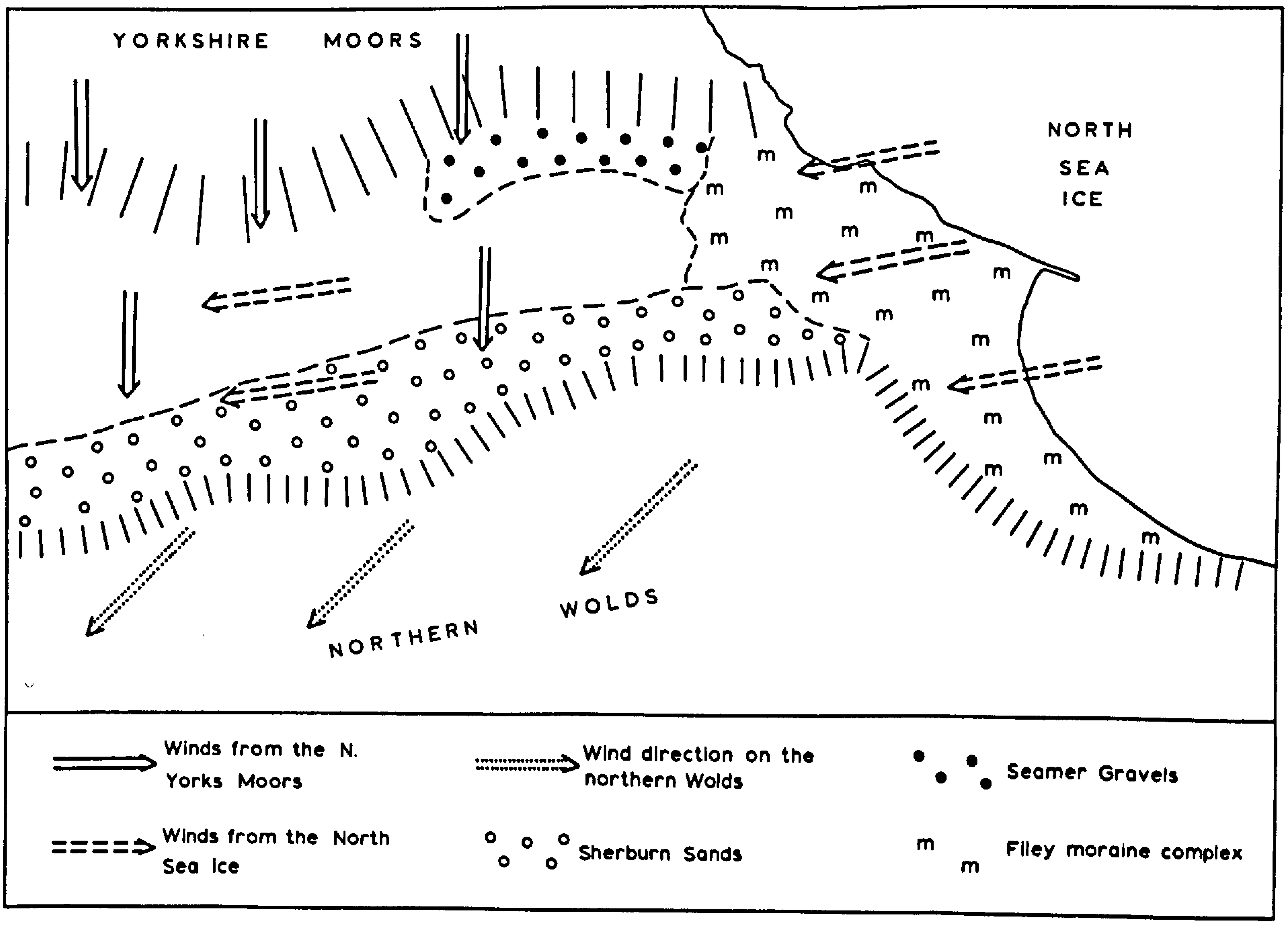
In addition to this early phase of erosion must be added the later phase which followed man-induced vegetation changes in the area (Manby, pers. comm.). Thus there may have been a continuous and thick (< 1 m) loess cover as suggested by Catt (1977a, 1977b, 1982) but that this started to be eroded in late-glacial times and in places was replaced by blown sands by this time.

The age and origin of these sands remains to be resolved. A possible origin is that they represent coversands contemporaneous with coversand phase II in the Netherlands (Van der Hammen 1952, Rutten 1954: i.e. they post-date the main loessic phase of the Devensian period). If this is the case it is perhaps surprising that they survived the severe erosion which stripped away the loess at the end of the Devensian. A more probable origin is that they are of Zone I and/or Zone III age and are derived from outwash and sandur plains in the adjacent lowland areas i.e. the Vale of York, Vale of Pickering, Holderness and possibly North Sea. Further, local glacially derived sands, of which remnants have been found scattered on the scarp and dip slopes, may also have been laid to contribution. There is evidence from the Vale of York of a blown sand phase which occurred at or just after the end of Zone III times (Matthews 1970, Gaunt et. al., 1971.) There appears to be some limited evidence to suggest a northerly or north-easterly direction. When the % sand/% silt versus distance from the escarpment was tested using Spearman's rank correlation coefficient (r_s), negative correlations were found between % sand and distance from escarpment if transects were taken at an angle of 90° from the escarpment ($r_s = 0.74$ with 17 degrees of freedom which is significant at the 0.01% level) and at an angle of 45° to the scarp i.e. N. E. - S. W. ($r_s = 0.68$ with 17 degrees of freedom which is also significant at the 0.01% level). No positive correlations were found when a transect was taken parallel to the escarpment. These results showed that the sand content of the soils decreases from the N. E. and N. and could support either a source on the Wolds dip slope (derived from outwash sands as suggested above), or from the eastern Vale of Pickering or North Sea. This would also help to account for the shortage of blown sands in the soil samples analysed by Catt et. al., and Matthews whose sample sites lay well to the south and west of this area (Catt et. al., 1974, Matthews 1977).

The relationship between the sands in the soils analysed above and the Upper Sandy Beds (Bray et. al., 1981) is not clear, but contemporaneity cannot be ruled out. If this is the case, relatively high percentages of blown sands should be present in the soils of the Fimber area, but presently no data are available to test this hypothesis.

The results of the above analyses suggest that the soils on the Wolds have an even more complex history than has hitherto been recognised (Catt 1982). In addition to loess, clays-with-flints, blown sands and tills (or their much weathered remnants in the form of scattered erratics and eluviated clay subsoils) have all contributed to the sedimentary parent material. Blown sands in particular appear to have previously been much more extensive over the northern Wolds at least. These sands may have been derived as a consequence of the interaction of winds blowing from different directions in the vicinity of the region and causing a redistribution of the outwash sediments left by the retreating Devensian glacier in the Vale of Pickering and North Sea (fig. 62). Katabatic winds blowing from the North Sea glacier would have been locally funnelled along the Vale of Pickering, moving loose deposits as they did so - the Sherburn sands as the southern edge of the Vale and the Seamer deposits to the north would have provided much source material. This material was probably carried westwards by these winds. However, ice lying in Eskdale on the northern part of the North Yorkshire Moors may have also generated local katabatic winds - possibly the winter accumulations of snow on the Moors had a similar effect - so that a strong north-south air movement was generated - aided by the regional slope of the Moors and the north-south

Fig. 62 Schematic diagram to show the possible origin of blown sands on the northern and north-eastern Wolds dip slope. Katabatic winds blowing E-W from the North Sea Glacier and funnelled up the Vale of Pickering interfere with winds blowing N-S down the dip-slope of the Northern Yorkshire Moors. The resulting vector winds (N.E. - S.W.), would carry blown sand from the eastern and southern edges of the Vale of Pickering and transport it over the scarp edge and down the dip slope. Some local redistribution of sands derived as outwash from the scarp and northern and eastern fringes of the dip slope may also have been reworked by wind at this time.


YORKSHIRE MOORS
NORTH SEA ICE
NORTHERN WOLDS
Winds from the N. Yorks Moors
Wind direction on the northern Wolds
Seamer Gravels
Winds from the North Sea Ice
Sherburn Sands
Filey moraine complex

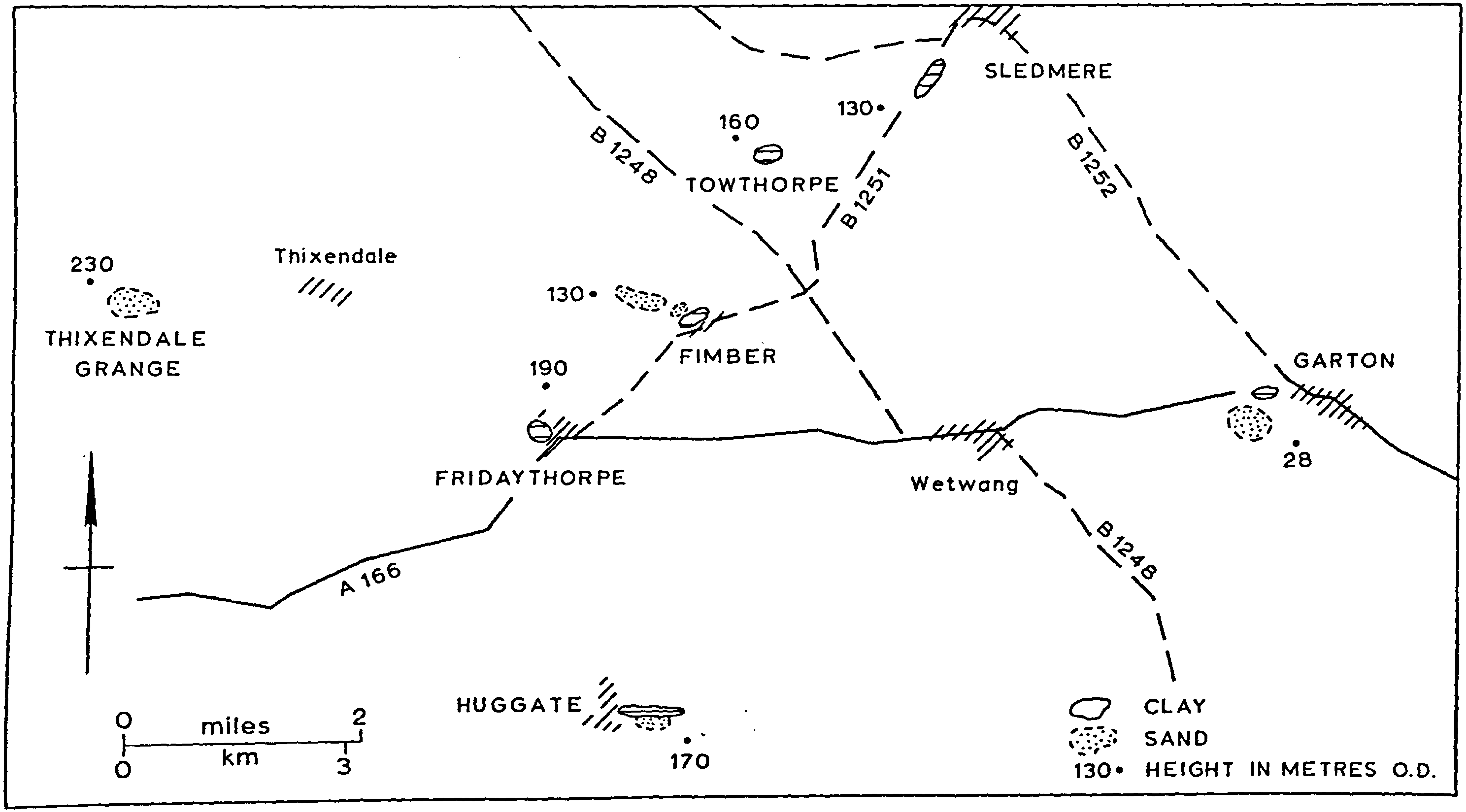
orientation of the local valleys. When the E. - W. winds from the North Sea region met the north-south winds from the Moors, the sands which were being moved around in the Vale of Pickering would have been caught by two major air movements. Thus the dominant direction of movement of the sand would reflect the combination of the direction of the two winds i.e. from N. E. - S. W. Further as the major source of sand seems to have been in the east, the sand would be expected to have been carried furthest across the north-eastern corner of the Wolds, and shorter distances across the dip slope to the west. The predominance of blown sands on the northern and north-eastern edges of the Wolds may also reflect the fact that some material derived directly from glacial outwash was also being redistributed by the wind, (Chapter III). If this process was in operation at the end of the Devensian and the blown sands were transported as far south as Fimber, one possible explanation for their preservation at that site may be because the area was a hollow and the sands were not removed by subsequent erosion from this site.

E. <u>The fissure Deposits of the Dip Slope</u> (fig. 63)

Solution cavities are not very commonly reported in the Chalk, but several are present on the northern Wolds at Linton Whins (SE861699) on the south-west corner of Linton Wold, at Raisthorpe on Vessey Pasture Wold (SE835625: Mortimer 1885, Lewin 1969), Thixendale Grange (SE819608: Wood and Rome 1868, Bisat 1940), Westfield Farm, Fimber (SE883610: Mortimer 1884, 1886, Bray <u>et. al.</u>, 1981, Huggate (SE889551: Mortimer 1884, 1886, Catt <u>et. al.</u>, 1974), Fridaythorpe (SE73591: Mortimer 1684, 1886), and Sledmere (SE927624: Mortimer 1884, 1886). Mortimer (1884, 1886), recorded "red clays" at Towthorpe Farm (901630) and Fimber Field Farm (SE900595). Versey (1937) recorded sands in solution pipes in the Thixendale - Fimber area.

All the old workings in which these deposits were exposed (except at

Fig. 63 Map of the fissure deposits and other scattered drifts recorded on the Yorkshire Wolds by Mortimer (1886) and Versey (1937).


SLEDMERE
130
160
B 1248
TOWTHORPE
B 1251
B 1252
230
Thixendale
130
THIXENDALE
GRANGE
FIMBER
GARTON
190
FRIDAYTHORPE
Wetwang
28
A 166
B 1248
HUGGATE
170
0
miles
2
0
km
3
CLAY
SAND
130 HEIGHT IN METRES O.D.

Raisthorpe which to the author's knowledge, has never been worked), are now long abandoned and overgrown. However, investigations have revealed some interesting facts which seem to imply that more detailed future studies would be worthwhile, although the old workings at Fridaythorpe Village, (fig. 72) Towthorpe Farm (fig. 74) and Fimber Field Farm (fig. 73) are now entirely abandoned and lost. It would seem from the vague descriptions of the deposits that these were accumulations of silty clay subsoils similar to that reported by Matthews and the author on the interfluve areas (Matthews 1975).

The other deposits were studied and the following was found:

i) Linton Whins Chalk Pit (SE861699)

Approximately 170 m south of Rayslack Farm in a small copse (Linton Whins) a chalk pit had been dug next to the West Lutton to Thorpe Bassett Road. This pit is now entirely overgrown with mature trees, and the few sections still visible in the top of the pit show 25 - 40 cm of thin dark grey to dark brown sand or sandy silts with much angular broken chalk and flint fragments. These are typical grey and brown rendzinas which are found on the northern Yorkshire Wolds, but in no part of the pit were silty-clay subsoils found.

In the north face of the pit an important section was excavated, the total height of which eventually reached 4.12 m. This section was photographed and measured (figs. 64 and 65). The section showed the following deposits:

Section	Thickness
Topsoil (brown rendzina) with massive tree roots (15 cm), smaller rootlets and shrubs etc. Whole section totally obscured.	25 cm
A. Small (< 2 cm) angular flint gravel set in a matrix of structureless light yellowish -brown (10 YR 6/4 - dry)	

	Section	Thickness
	silty sand.	
B.	Brown to dark brown (7.5 4/4) silty sand with many rootlets and small (< 2 cm) scattered pale grey angular flints. This horizon was very loose and friable but showed a slightly blocky structure. Formed pockets and lenses between horizons A. and C.	Individual horizons vary greatly in thickness. Combined total thickness = 30 cm.
C.	Strong brown (7.5 YR 5/6, damp) slightly gravelly silty sand, with a well developed blocky structure. No clay was observed on ped faces. On weathered surfaces and on ped faces a fine off-white calcareous (?) coating was observed.	
D.	Mottled dark reddish-brown (5 YR 3/2 damp) to dark brown (7.5 YR 3/2, damp) organic rich, fine silty sand. Scattered angular flints < 7 cm. Homogeneous and very highly compacted.	
E.	Mottled strong brown (7.5 YR 5/6) to brownish-yellow (10 YR 6/6) organic rich fine silty sand. Scattered angular flints < 7 cm. Very highly compacted and homogeneous.	20 cm
F.	Mottled dark reddish-brown (5 YR 3/2) to dark brown (7.5 YR 3/2) organic rich fine silty sand with scattered angular flints < 7 cm. Highly compacted and homogeneous.	40 cm
G.	Very pale brown (10 YR 7/4) silty sand with organic matter. Streaks of black carbonaceous material throughout mass. Small numbers of small (< 2.5 cm) angular flints scattered throughout sections. Highly compacted and homogeneous.	30 - 33 cm
H.	Brown to dark brown (7.5 YR 4/4) organic-rich fine silty	

Section	Thickness
sand with very few scattered angular small (< 1 cm) flints. Very compact, homogeneous.	8 - 23 cm
I. Mottled very pale brown (10 YR 7/4) and strong brown (7.5 YR 5/6) organic fine silty sand. No flints present. Very well compacted and homogeneous.	8 - 18 cm
J. Brown to dark brown (7.5 YR 4/4) organic rich silt with small pebble bed (4 - 5 cm thick) of scattered angular flints (< 2.5 cm) at upper part. Well compacted and homogeneous.	15 cm
K. Mottled brown to dark brown (7.5 YR 4/4) and dark reddish-brown (5 YR 3/4) organic silt. Slightly finer in texture than J. 4.5 cm thick pebble bed of angular flints (< 2.5 cm) at top. In places mottling gives way to streaks of one colour upon a background of the other; black carbonaceous streaks were also present. Well compacted and homogeneous.	12 cm
L. Alternating mottled brown to dark brown (7.5 YR 4/4) and dark reddish-brown (5 YR 3.4) organic rich silty clay, and white (10 YR 8/1 and 8/2) powdery weathered chalk with shattered angular flints _in situ_ in chalk. Both grey and white flints present. Small (< 2.5 cm) angular flints present in darker horizons. A thin (2 - 3 mm) light mauve/grey discontinuous clay band present approximately 18 cm from the top of this horizon. Well compacted and homogeneous.	30 cm
M. Mottled dark brown (7.5 YR 3/2) and dark yellowish brown (10 YR 3/4) organic silty	

Section	Thickness
clay with rare black/very dark brown carbonaceous streaks. Some clay skins present on ped faces. Texture variable with some pockets more clayey and others more silty. Where the clay content was higher the colour became pale brown (10 YR 6/3) with scattered tiny (2 - 4 mm) specks of red (2.5 YR 4/8) clay. Towards the bottom of this horizon blocks (< 10 cm) of sub-angular to sub-rounded chalk were present; they were very weathered and had a high moisture content. The outer surfaces of this chalk were very plastic but the cores were hard. Organic horizon was soft and plastic when wet; loose, earthy and friable when dry. Slight blocky texture.	65 cm
N. Yellow (10 YR 8/6) powdery, friable chalk with much broken angular flints and organic clay filling cracks. Fissures and joints between the chalk blocks. One small (4.5 cm) pebble of reddish-yellow (7.5 YR 6/8) sand with very fine dark brown bonding (probably ferruginous) was recovered from this horizon. This pebble was probably derived from the Dogger or Estuarine sandstone in the Jurassic of the North Yorkshire Moors. Organic material was loose, earthy and friable.	20 cm
O. Yellow (10 YR 8/6) blocks of chalk overlying dark brown (7.5 YR 3/2) to nearly black organic clay. Organic horizon was well compacted and homogenous throughout but showed a blocky nature where the clay content was very high. No flints were present. Some black shaly	

Section	Thickness
fragments were recovered from the base of this horizon.	30 cm
P. Very highly shattered, angular flints (probably tabular flints <u>in situ</u>). Smaller (6 - 10 cm) nodular flints with thick (1.5 cm) patinas. Matrix composed of fine light yellowish- brown (10 YR 6/4) sandy clay, with pockets of dark brown/black loose, friable organic clay.	15 cm
Q. Pasty (wet), powdery (dry) angular to sub-angular chalk blocks approximately 30 cm long. Fissures and cracks between the blocks were up to 23 cm wide, and filled with dark brown (10 YR 6/4) organic clay. This clay was very earthy and friable. The bottom of this horizon was not seen as the section had to be abandoned at this depth.	At least 25 cm

Rootlets of trees extended throughout the whole of the section in the organic/clays and silts, except between the horizons at 1.75 M and 2.65 M where for some reason rootlets were absent. The flints were very pale grey in colour and except where stated above, lacked any patina or other form of weathered faces. Below 2.65 M the clay content of the deposit began to increase markedly; the material below this level was also much damper and generally less compact but was still homogeneous. The chalk blocks in the base of the section were deeply pitted on their sides and undersurfaces, individual pits ranging in size from 2 - 4 cm in diameter and 0.5 - 1.5 cm deep, but the upper surfaces were almost entirely free of any such solution features. Where the chalk had been weathered to a powdery (dry) or pasty (wet) mass, this formed a coating around the larger blocks which was 2 - 5 mm thick, the cores of the blocks being compact and hard. The dip on the blocks of chalk in the base of the section varied

Fig. 64 Diagrammatic section of the fissure fill at Linton Whins chalk pit (SE861699) - May 1977.


DEPTH IN METRES
0
1
2
3
4
HORIZON
ROOT ZONE
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
P
Q
ORGANIC MATTER
LOESS
CHALK
FLINTS
WEATHERED CHALK
SILTY CLAY

Fig. 65 Photographic section of the fissure fill at Linton Whins chalk pit - May 1977 (Photo Mr. B. Fisher).

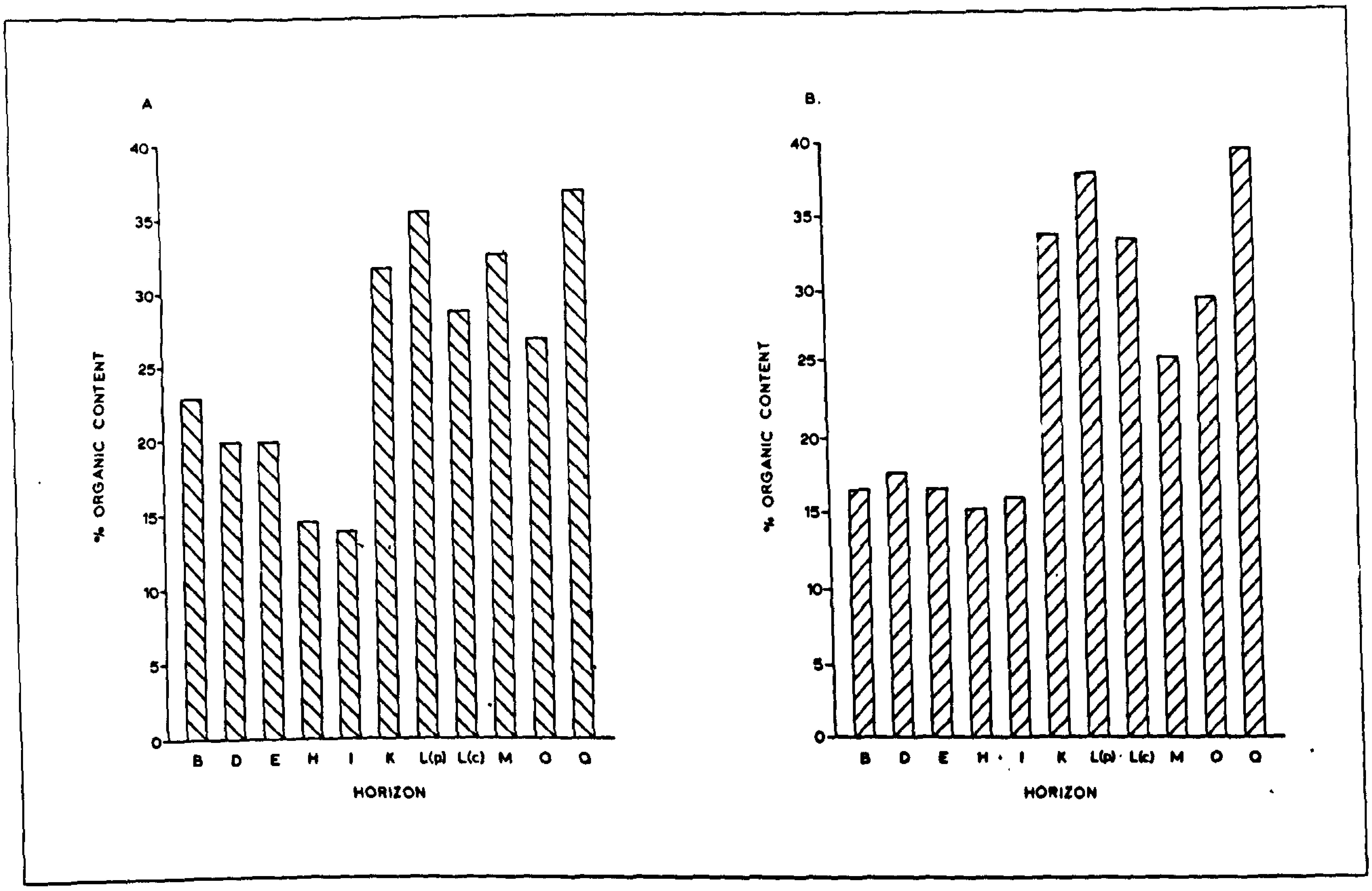
between 30° and 40° north-north-east. The average dip in the rest of this pit was 5° south to south-east.

Initial excavations here showed that a mass of rubble and scree approximately 0.4 m thick overlaid the apparently undisturbed deposits which were excavated to the bottom of the fissure. This enabled a limited 3 - dimensional view of the deposit to be observed. The left (i.e. western) face showed the best detail and is reproduced in part as fig. 64. Within the exposed section there appeared to be the nose of a fold, the outer limbs of which were composed of very broken and weathered powdery chalk and angular flinty organic sandy silt. The core was composed of organic sandy silt which was free of both chalk and flints. The fold structure overlaid dark brown (7.5 YR 3/2) organic silty sand, a well compacted horizon which contained many scattered angular flints especially towards its base. This deposit in turn overlaid a mass of large (> 25 cm) angular to sub-angular chalk blocks which had weathered powdery outer layers with solution pits in the sides and bases of the blocks. Filling the gaps between the blocks of chalk were organic silty sands and clays similar to those in horizon Q although the width of individual fissures rarely exceeded 5 cm. The chalk blocks dipped between 30° and 35° to the north-east and north-north-east. The top of the chalk blocks in the eastern face was at approximately 3 m below the top of the section. This natural disturbance of the basal chalk blocks was thought to be due to solution collapse at the base of the hollow.

The organic content of the different horizons varied considerably. The organic contents of the various horizons as determined by H_2O_2 and loss on ignition are shown in fig. 66. The losses caused by ignition are consistently higher than those determined by the H_2O_2 method and it is suggested that either residual water was left in the samples prior to firing (although all samples had been carefully oven dried beforehand) or

Fig. 66 Organic content of the different horizons in the fissure fill at Linton Whins chalk pit:

a) as determined by firing
b) as determined by H_2O_2


A
B.
% ORGANIC CONTENT
0
5
10
15
20
25
30
35
40
B D E H I K L(p) L(c) M O Q
HORIZON

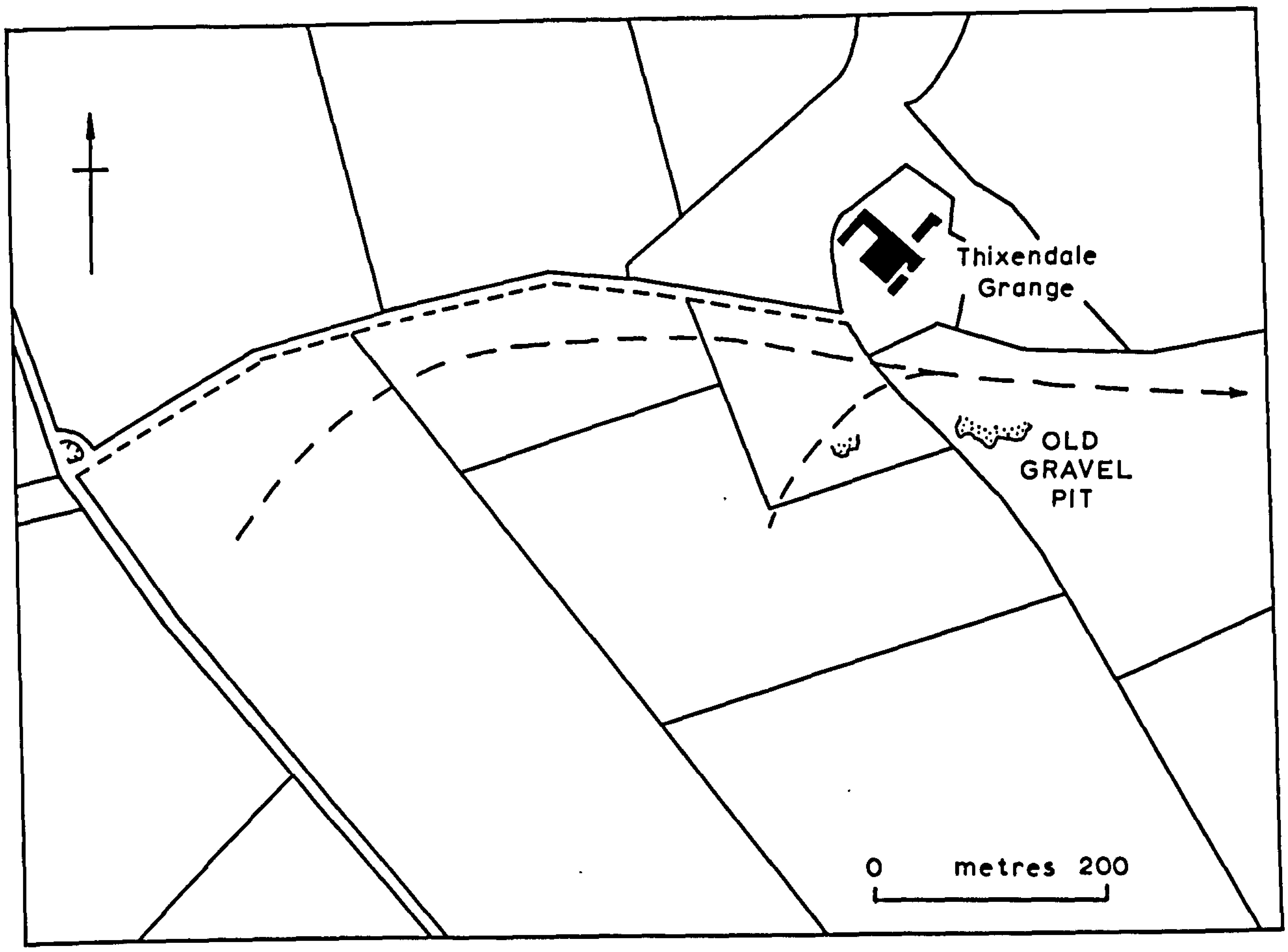
the absorption of water from the atmosphere after firing (again precautions were taken against this by putting the samples into airtight containers with silica-gel). Alternatively there may have been minute quantities of chalk present which would have been reduced to quicklime by the heating and so exaggerated the amount of material lost. However, even the amounts of organiccarbon present as determined by H_2O_2 were far higher than those found by the C_{14} dating laboratory at Belfast which reported the presence of 0.05% organic carbon. The actual content of organic carbon is therefore still unclear, although it is undoubtedly present.

The question now arises: how did this material get into this solution fissure, where did it come from and how old is it? These questions can be dealt with in reverse order: the age has not been determined by C_{14} assay because the dating laboratory could not obtain enough material to get a proper date, and even had they been able to do so there would have been some uncertainty surrounding the date due to the high calcium content brought about by the presence of the chalk. Where the deposit came from is a little clearer. Analysis of the inorganic residues left after H_2O_2 analysis showed that both loess-sized and blown-sand sized material was present in the ratio of approximately 4:3. This would suggest that this deposit probably accumulated as an organic soil on the surface of the chalk during a relatively cold period when the ground would have been frozen at depth (to allow the topsoil to become waterlogged for part of the year during the thaw) which later slipped into a solution hollow in the chalk. The overfolding in the section suggests that perhaps a small cavity collapsed or the deposit sludged in from one side. More soil probably continued to accumulate on the site and solution and enlargement of the original hollow has probably continued since due to the concentration of acidic groundwater in this localised area. Accumulation of the organic material later ceased (due to a further increase in the cold?), and the section was sealed with a loess cover.

ii) Thixendale Grange (SE819608) figs. 14 and 67

On the north-western edge of the Wold escarpment at circa 230 m O. D. occur a group of sands and gravels at Thixendale Grange. These have been referred to and described by several previous authors e.g. Wood and Rome 1868, Bisat 1940, Straw 1964. They were also the subject of the correspondence between Wood and Rome in the early part of 1868 and of a letter by Lamplugh to J. Stather in 1924 (see Appendix A for the scripts of these letters). Rome reported that the sands were at least 3.8 m (21 feet) thick; Catt and Penny proved 4.1 m of sand by augering (J. Catt pers. comm. 1978). The old workings in the deposit are still visible on the ground on the south side of Thixendale opposite the farm, and it would appear from both the narrow limits of the working and the presence of chalk in situ within 3 m of one of the old pits that this sand and gravel occupies a solution hollow in the chalk. Some interesting pebbles have been reported from these deposits - Rome recorded quartzites, sandstones, coal and most interestingly Gryphaea incurva. This author managed to find milky white quartzite pebbles, yellow quartzite, brown chert, Carboniferous and Jurassic gritstone pebbles, and a calcareous shelly sandstone (probably from one of the middle Jurassic limestones) in the gravel. Coal was also present in tiny quantities. The sand and gravels were quite separate entities - much of the coarser clastic material in the gravel consisted of chalk and flints. Versey (1937) carried out a heavy mineral analysis on these and other sands found in pipes at Fridaythorpe, Knapton and West Heslerton etc. (Table 3). He found broad similarities in the mineral assemblages of the Thixendale, Fridaythorpe and Faireystones (Burdale) sands (the latter was extracted by solution of parts of the breccia) but could not correlate them with the samples from the Vale of Pickering. He suggested a late Tertiary or early

Fig. 67 Plan of the sand deposits at Thixendale Grange Farm (SE819608).


Thixendale
Grange
OLD
GRAVEL
PIT
0 metres 200

Pleistocene age for these sands.

The author dug out a small section of old workings opposite the farm and found the following:-

Section	Thickness
Grey to dark grey coarse to medium grained (6 - 10 cm) sub-angular chalk rubble with a sandy silt matrix. This horizon probably represents in part material which had slipped down the slope above the old workings.	30 cm
Fine to medium grained structureless dark yellow sand, stone-free.	8 cm
Pasty weathered white chalk gravel with few small angular flints.	4 cm
Fine to medium grained structureless dark yellow sand which was stoneless at the top of the section but which became ston y towards the base until at the bottom it had the consistency of a fine gravel. Pebbles were from numerous sources including grey flint (well rounded), quartzite, chalk and unrecognisable material.	12 cm
Fine to medium grained dark yellow structureless sand.	12 cm
Light yellow fine to medium grained structureless sand.	20 cm
Dark yellow medium to fine grained structureless sand.	18 cm
Fine well rounded dark yellow sandy gravel. The constituents consisted of chalk, flint, quartz, sandstones and gritstones, etc.	10 cm
Dark yellow medium to fine sandy gravel. In this horizon pebbles of Carboniferous and Jurassic gritstones and sandstones, milky white and yellow quartz, chert, Jurassic sandy limestones, red	

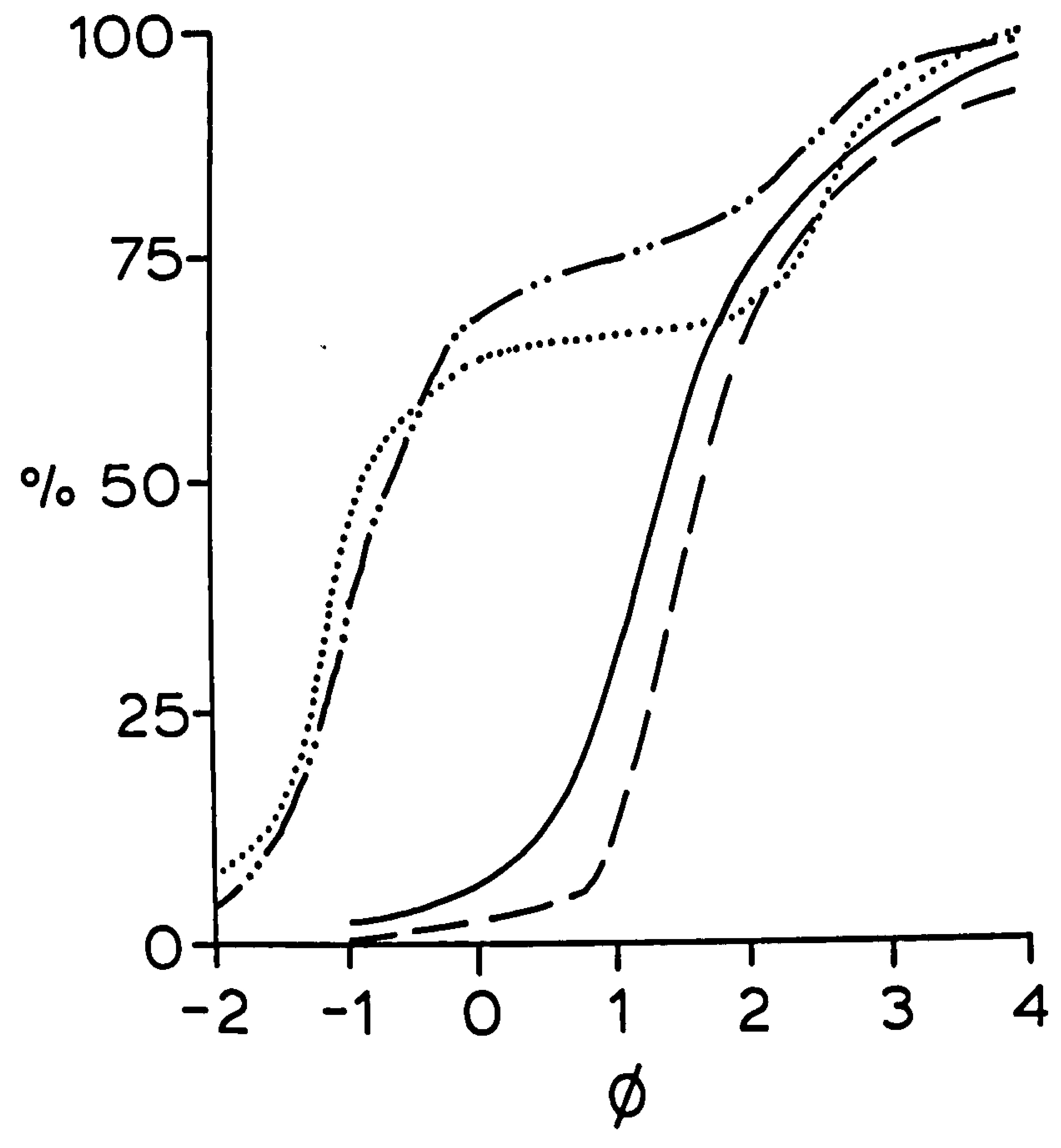
Section	Thickness
igneous (? porphyritic), black fine grained igneous and ironstone were found. Chalk and flints were also present.	15 cm
Light grey chalky flint rubble with a clayey-silt matrix.	4 cm
Chalk, probably <u>in situ</u>.	

The pebbles in the gravels were very well rounded (except the chalk and flints which were angular to sub-angular), one or two of the gritstones and the chert pebbles may have been reworn dreikanter pebbles. No speciments of any fossils were found. The results of the particle-size analysis of the sand and gravel fraction are shown in fig. 68. These show that the sands are broadly similar to those in the Vale of Pickering and on the northern Wolds escarpment, but it is not thought that this has any real significance in terms of age or origin. However, the presence of Jurassic limestone and the generally unweathered nature of these sands was very striking, the sands generally strongly reminiscent of those found on the scarp and in the dry valley at Warren Slack to the east. Versey suggested that these could represent blown-sand derived from outwash in the Vale of York, but the presence of the well rounded gravel with many erratics would still have to be accounted for. It seems more likely that these represent in part at least, either glacial outwash deposits in situ or deposits which have been locally reworked, possibly by both the action of the wind and snow-meltwater, and preserved in a hollow in the chalk. Lamplugh (1924) recorded sands further down Thixen Dale which had once been worked but were now buried under scree from the valley side - it is possible that the sands in the valley represent reworked material from higher up the valley as the latter are found on the valley side and could easily have been eroded by hillwash processes.

Fig. 68 Particle-size distribution curves of sand and gravel at Thixendale Grange Farm. Lines on graph are numbered as follows:-

―――――――― 1
— — — 2
— ·· — 3
·········· 4

See table 13.



100
75
% 50
25
0
-2
-1
0
1
2
3
4
ø

iii Westfield Farm, Fimber (SE883610) (fig. 70)

Mortimer (1886) described a sandy deposit occurring in the fields to the west-north-west of Westfield Farm. Apparently the farm was once known as "Brickfield Farm" after the old sand pits which had been used for brickmaking material. They were also mentioned by Rome in a letter to Wood (see Appendix), Bisat (1940) and extensively surveyed and the mineralogy and particle size data analysed in detail by Bray et. al., (1981). A hollow approximately 350 m x 50 m was found, which was more than 10 m deep. In this hollow were found "coversands" and loess (brickearth), the latter being found between two "coversand" horizons. The deposits had been gently folded into a shallow synclinal structure. The loess sediments were shown to be mineralogically similar to silts described by Catt et. al., (1974) on other parts of the Yorkshire Wolds and at Sewerby Cliff. However, on geomorphological grounds (the site and size of the hollow in which the sediments were found), Bray et. al., suggested that the hollow and its infill predated the Devensian and suggested a Wolstonian or even earlier age for them.

This hollow is the largest found on the Wolds and is comparable with the Raisthorpe Depressions and the fissure at Huggate. The orientation (115°) "does not readily relate to any known structural feature in the chalk" (Bray et. al.), but as with the Raisthorpe Depressions, this author found brecciated and slickenslided chalk at the north-west end of the hollow at Westfield Farm, which indicates the presence of a minor fault or disturbance in the area. It would seem therefore that although this and the Raisthorpe Depressions may well have a solution-collapse origin (Lewin 1969, Bray et. al.), these have occurred along the courses of structural disturbances.

The tripartite division of the sediments and the presence of "coversand-like" material as well as loess is worthy of note, for the Upper Sandy Beds ("coversands") could be contemporaneous with the sands found in the soils in the area to the north, and thus support this author's contention that blown sands are as important, and in some areas more important, than loess in the origin of the Wolds soils.

In Fimber Village the site of the pond was originally the site of another clay pit according to Mortimer. However, there was no indication of any clays when the author investigated the area in 1976 (other than, of course, the lining of the pond).

iv) Huggate (SE889551) (fig. 69)

Both chalk gravels and "clays" used to be worked in the area east of Huggate Village. These old gravel workings are fairly extensive and apparently at one time were quite deep too. A local inhabitant informed the author that in the heyday of the workings up to 10 m of gravel was exposed in the south face of the pits (this was in about 1936 - 1939). The inhabitant also remembered seeing "red clay" beneath the gravel but did not know how thick it was - apparently this clay was not worked at that time. To the east of the largest gravel pit there is a small hollow in the valley side which has a lining of silty clays over 1.5 m thick - it is not known whether the hollow represents the remains of another old pit. In Claypits Wood (SE889551) at the head of Oxlands Dale the old brickpits are nearly 10 m deep. Catt et. al., sampled the sands here and found that they had close affinities to loess - Lill and Smalley (1978) have claimed that the deposits on the Wolds were too thin to represent true loess, but this section and the similar deposit at Westfield Farm are quite thick enough to represent true loess deposits. These sediments, like those at Fimber, tended to be coarsest at the top and finest at the base - in fact the basal horizons had very high clay contents (40 - 45%). This probably represents the effects of illuviation and concentrations of

Fig. 69 Map of the old gravel pits and "clay pit" at Huggate. The latter was shown to be filled with loess (Catt et. al., 1974) - for details see text.

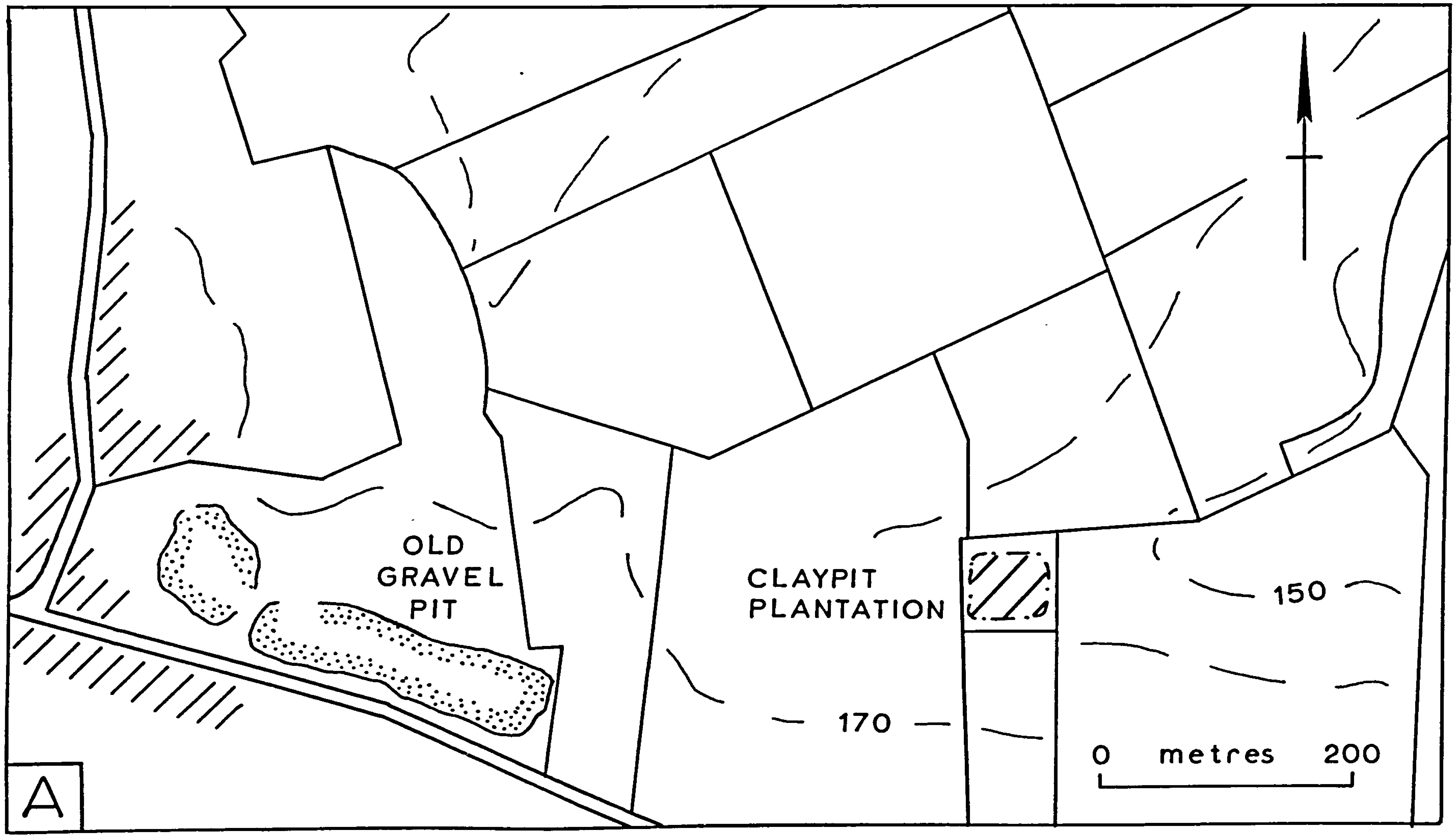
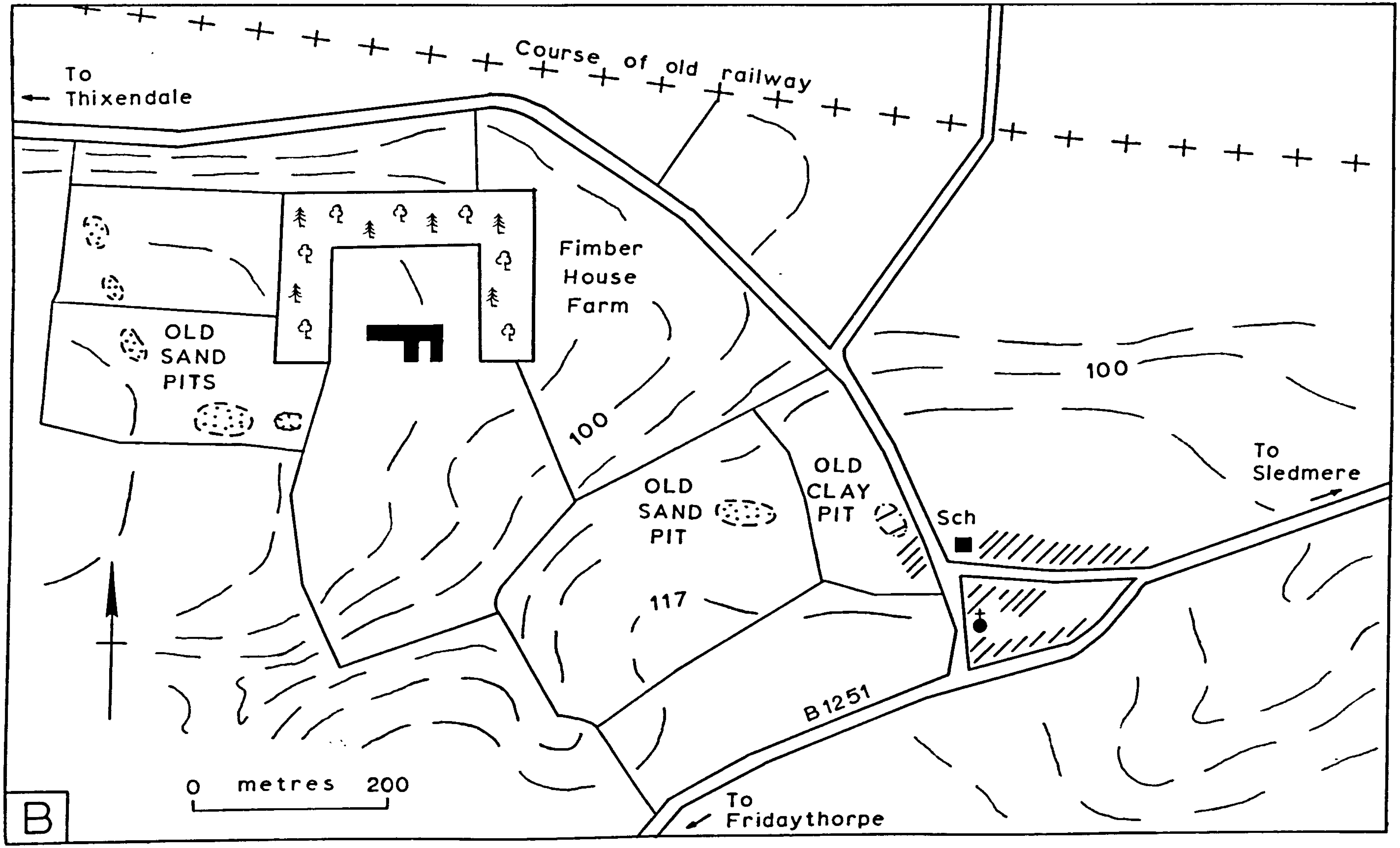

A
OLD
GRAVEL
PIT
CLAYPIT
PLANTATION
150
170
0 metres 200

Fig. 70 Map of old sand pits and clay pits near Fimber and Westfield (Fimber House) (SE883610). Bray et. al., (1981) showed that the sand pits were dug into the surface of a large loess-filled hollow.


To Thixendale
Course of old railway
Fimber House Farm
F
OLD SAND PITS
100
OLD SAND PIT
OLD CLAY PIT
117
Sch
100
To Sledmere
B1251
To Fridaythorpe
0 metres 200
B

clay at the base of profile. The hollow was again very steep sided (> 30°) and terminated abruptly at the western end - the eastern end had a much shallower though somewhat irregular slope. Silty clays were present in the subsoils of the surrounding fields but were quite different texturally from the deposits in the clay-pit. Once again there was a notable lack of coarse material (i.e. gravel) in any part of the deposit.

v) Claypits Wood, Sledmere (SE927642) (fig. 71)

In Claypits Wood on the south-east side of the B1251 approximately 0.7 km from Sledmere Village there is a deposit of clay of variable thickness. The old workings are spread over a fairly wide area but augering failed to prove any clays beyond the limits of the old workings. In a section at the north-eastern end of the wood the author excavated 1.20 m of clay of variable colour:

Section	Thickness
Light greyish brown plastic silty clay. Very few angular flints (< 1 mm) and no chalk fragments.	50 cm
Mottled light greyish brown and bluish-grey plastic clay. Chalk fragments (well rounded) in lower part (10 cm) of section (< 2 mm).	30 cm
Mottled bluish-grey and reddish-brown plastic clay. Mottling decreased in intensity towards base. Few rounded chalk fragments (< 4 mm).	30 cm
Dark yellow fine angular chalk/flint gravel with very little sand matrix.	5 cm
Off-white to white pasty (wet), powdery (dry) weathered chalk.	6 - 8 cm
Compact, rubbly slightly weathered chalk, probably *in situ*.	

The old workings revealed that the clays had varied in thickness locally as some pits were up to 1.5 m deep whereas others were less than

Fig. 71 Map of the old clay pits in Claypits Wood, Sledmere (SE927642). These pits are now filled and planted with trees.

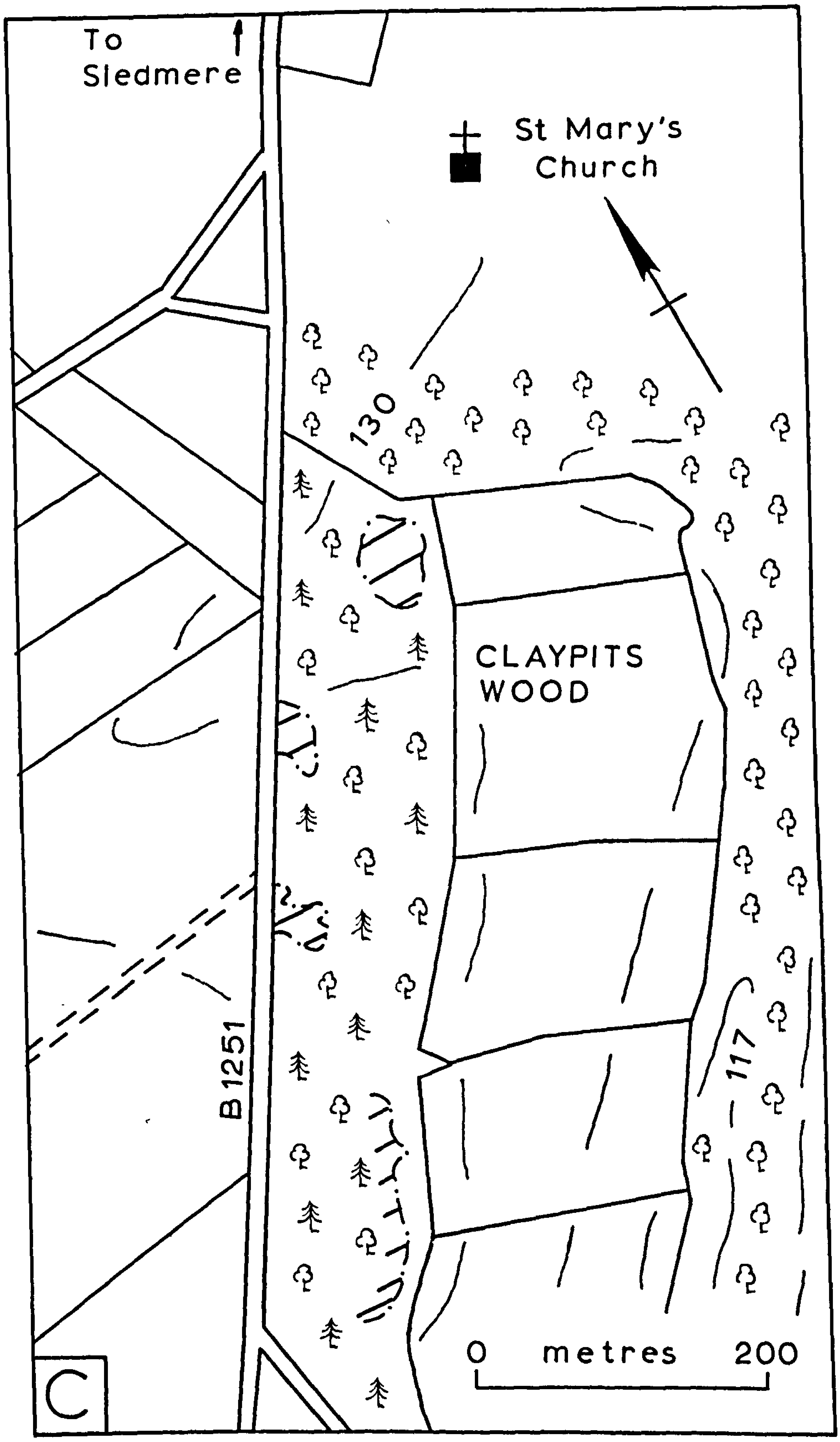

To Sledmere
St Mary's Church
130
CLAYPITS WOOD
B1251
117
0 metres 200
C

Fig. 72 Map of the old clay pits at Fridaythorpe (SE873591) and gravel pit to the south of the village. The clay pits are now occupied by the site of a barn and small pond - the gravel pit has disappeared. No further details were found on this site.

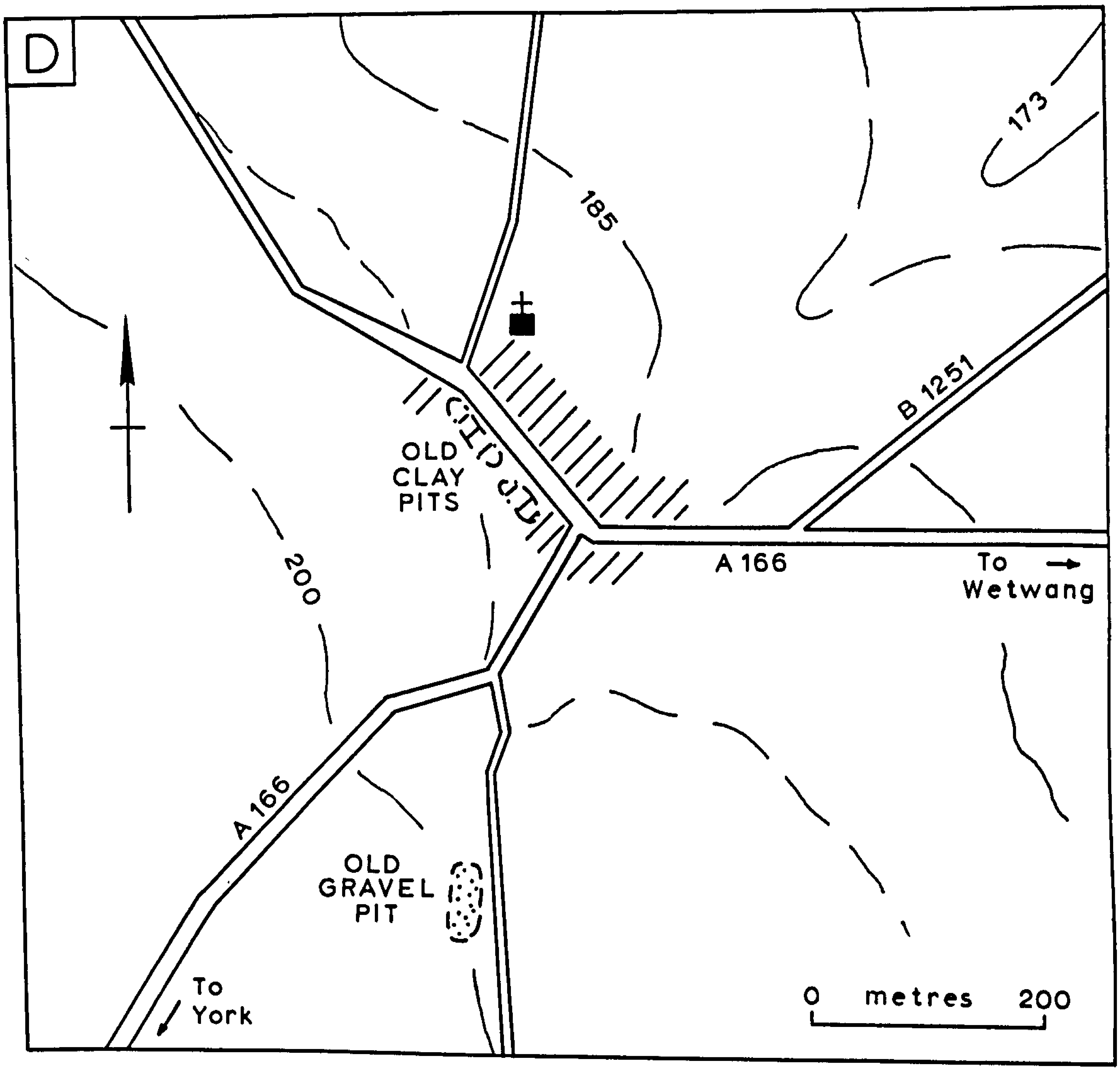
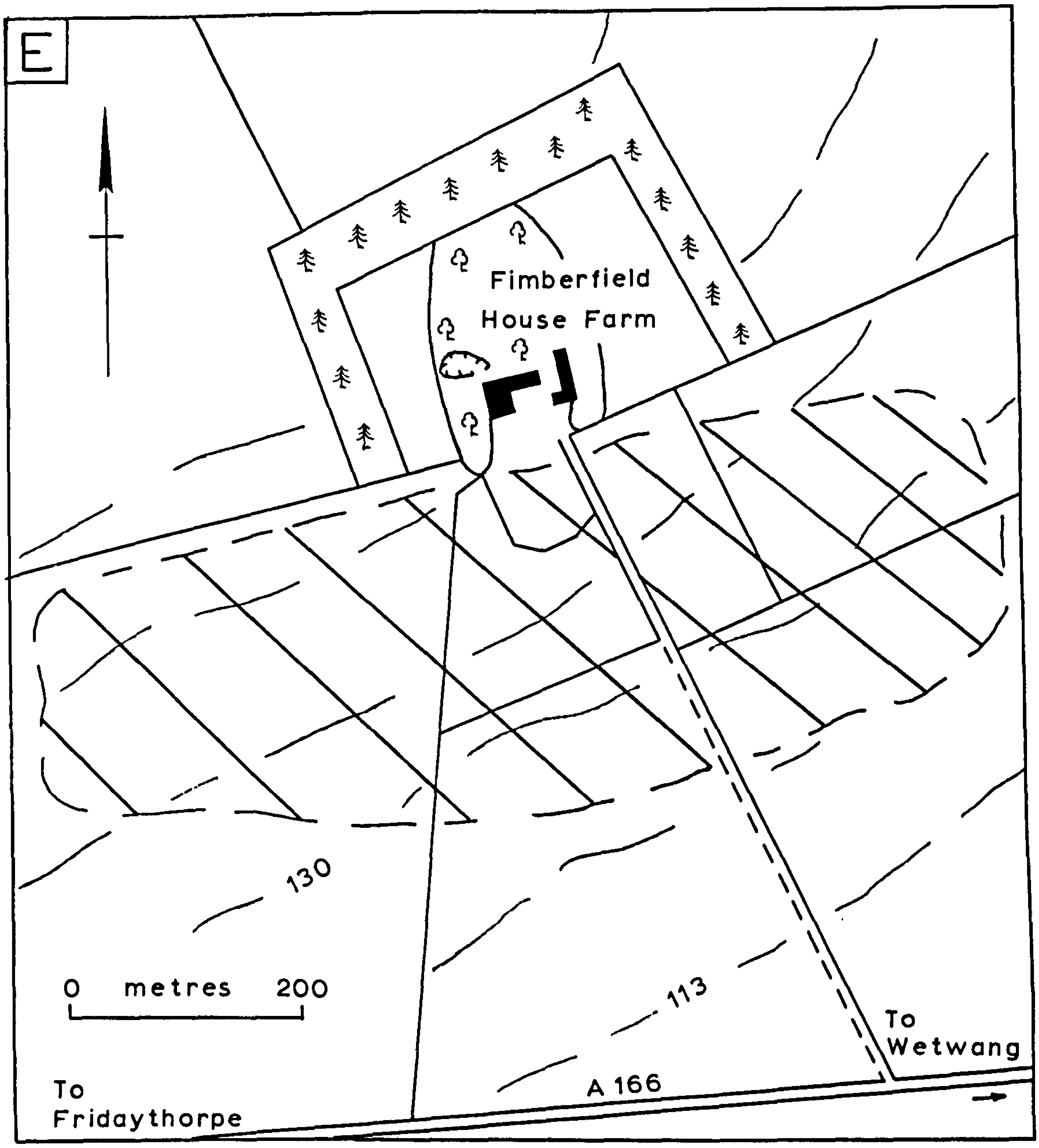
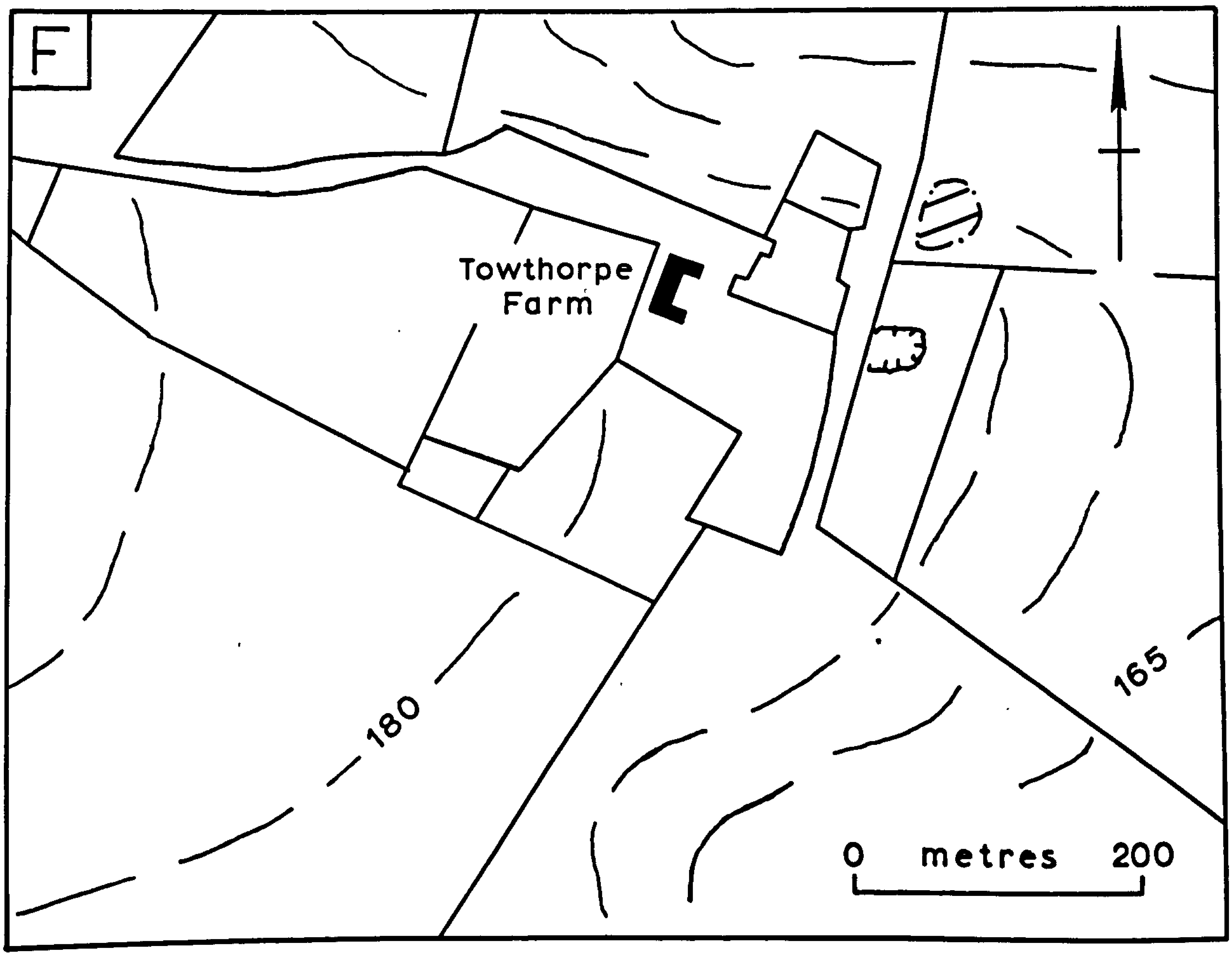

D
185
173
OLD
CLAY
PITS
B 1251
A 166
To
Wetwang
200
A 166
OLD
GRAVEL
PIT
To
York
0 metres 200

Fig. 73 Map of the "clays" at Fimberfield House Farm (SE900595) after Mortimer (1886). Probably this "clay" is similar to the sandy - and silty-clay subsoils recorded elsewhere on the Wolds as no evidence of clay deposits could be found here.



E
Fimberfield
House Farm
130
113
0 metres 200
To
Wetwang
To
Fridaythorpe
A 166

Fig. 74 Clay pit and old chalk pit at Towthorpe Farm (SE901630) after Mortimer (1886). No evidence could be found of the clay pit which has probably been filled and obliterated.


F
Towthorpe
Farm
180
165
0 metres 200

50 cm. The distribution of the yellow chalk/flint gravel at the base was also very patchy and its thickness variable - up to 10 cm thick in places but absent in others. Tiny fragments of well rounded chalk (1 - 2 mm) were regularly found in the basal clay layers, and rare angular flints were found nearer the surface. However, generally the clays were stone-free. The pits were sited on a 2° - 3° slope.

The deposit is interesting because in many respects it resembles the silty clay subsoils found elsewhere on the wolds i.e. the flint content and high clay content. However, the colour and presence of chalk fragments suggests a slightly different origin. Silty clay subsoils are present in the fields to the north-west and it is possible that this deposit represents an accumulation of soliflucted clay which was trapped in a local shallow solution depression. Alternatively this may represent the bottom of a much denuded solution hollow of the type found at Fimber and Huggate. The chalk and flints could have been incorporated either during a period of mass-movement on a slope or by being transported with, and then being cryoturbated into the silty clay subsoils. The lack of any well defined gravel seems to support this latter suggestion and it is thought that this may represent a weathered, reworked and highly disturbed accumulation of silty clay subsoil material.

vi) The Raisthorpe Depressions, Vessey Pasture Wold
(SE835625) (fig. 14)

On the northern flank of Vessey Pasture Dale and Back Dale (often referred to incorrectly as "Thixendale" (e.g. Lewin 1969), there is a series of deep linear depressions which are aligned more or less parallel to the main valley to the south (Mortimer 1886, Lewin). These depressions are also directly in line with part of the Leavening Fault-Thixendale Disturbance. The most westerly of the fissures now forms a short branch of the dry valley which runs perpendicularly to the valley side and meets the trunk valley at the junction of Vessey Pasture Dale and Back Dale. The depression is circa 10 - 12 m deep and has relatively steep sides (20° - 30°). The slope is rather like that of a V with a slightly flattened bottom - apparently there is some gravel present in the floor but augering was not very successful in proving its thickness. Lying to the east of this open depression is a series of 6 en echelon depressions, all of which are filled with a fine to medium grained angular chalk/flint gravel. This gravel is almost certainly of solifluction origin, the lack of fine matrix at the surface being accountable in terms of groundwater washing the fine-grade material down the soil profile into the body of the gravel. (A similar situation existed at Knapton gravel pit where the upper 2 -3 m of gravel was entirely free of fine sandy matrix and did not have to be washed prior to use, but the horizons deeper than this became increasingly sandy and silty the deeper the gravel was excavated). Mortimer dug a trench across one of these depressions to a depth of 13 feet (4 m) apparently without reaching the bottom. The depression was filled with "unwater-worn chalk gravel mixed with various sized pieces of angularly formed chalk, probably fallen from the side of the hill". The side of the depression had a very uneven surface. These descriptions support the thesis that these depressions are largely filled with solifluction debris with smaller quantities of fallen material from the fissure sides. The age of the gravel is not known, but must represent a period of cold and were therefore probably deposited during a peri-glacial phase.

Conclusion

The deposits on the northern Yorkshire Wolds consist of a highly variable group of erratics and erratic assemblages of various ages and origins. Some of these deposits are almost undoubtedly of glacial origin, others may well have been reworked subsequently by ice or snow- meltwater.

Some of the deposits have been redistributed by the wind. The age of all of these deposits is uncertain and even now very little is known about them, especially the remarkable collection of fissure deposits which are found in the north-western Wolds. It is hoped however that this contribution will help to clarify and extend our present knowledge of these sediments and hopefully lead to more detailed analyses of them.

CHAPTER V

THE PERIGLACIAL LANDSCAPE

The landforms and sediments described in Chapter III are largely attributable to glacier ice or meltwater activity. However, beyond the glaciated region (and prior to the advance of the glaciers in the late Devensian) lay a region which was subjected to intense cold and was modified by a different set of processes. This was the zone of peri-glacial activity. The margins of the area which were subject only to periglacial processes during the Devensian vary according to how the evidence of the maximum limits of glacier advance are interpreted: thus the bulk of the Wolds was probably not covered by glacier ice, but some questions must remain concerning the status of the central and western parts of the Vale of Pickering during this period. However this chapter is intended to review all the periglacial landforms and the effects of ground ice in the field area which are thought to have formed at all stages of the Devensian. Thus pre-glacial and post-glacial effects are included.

The results of the peri-glacial activity can be summarised under four headings:

a) solifluction

b) other mass movements

c) ground ice activity

d) the drainage system

It is recognised that the development of large-scale landslips and other forms of mass-movement and parts of the drainage system have been active since the end of the glacial period (i.e. Devensian), but any changes are relatively small compared with the highly intensive activity associated with the peri-glacial environment. However all changes and developments are described here and where it is inferred or known that changes have or continue to occur this will be made clear in the relevant text.

A. Solifluction

The downslope mass-movement of the surface layers of frost-shattered and weathered debris across the scarp and valley sides of the Wolds probably formed an important part of the erosional processes which were active during the Devensian. These processes were probably also responsible for the removal of large amounts of weathered material from the interfluve areas too as solifluction movements are known to occur on slopes with angles as low as 2° (Budel 1937, Washburn 1973). Typical morphological features associated with this and related processes are solifluction terraces, lobes, stone-banked lobes and terraces, stone streams, scree slopes and garlands, but almost no morphological evidence for solifluction has been found in the field area. The reasons for this are probably many and complex. The most important must be the effects of continued downslope mass-movement of material since the cessation of the climatic conditions conducive to solifluction at or just after the end of Zone III times, and the effects of prolonged agricultural influence since late neolithic times. However the apparent preservation of talus slopes in limited areas suggests that the destruction of all the morphological evidence may still be incomplete. It is possible that some morphological evidence has been buried beneath later sediments, especially in the Vale of Pickering where blown sand is ubiquitous. On the other hand the features may be present on degraded remnants which are now very difficult to recognise and which would need to be properly excavated and sectioned before their true nature was discovered. It must remain to be seen if the mass-destruction of all of the morphological evidence for solifluction is complete.

The evidence of solifluction activity from sedimentary deposits is much more widespread, albeit somewhat scattered and in some areas rather scanty. Lewin (1969) claimed that the dry valleys acted as "gutters into which (frost-weathered) material was moved" and Edwards (1978) believed that much of the chalk and flint gravel which is interbedded with the Sherburn Sands in the Vale of Pickering was reworked solifluction debris. It seems highly likely that except for rather isolated hollows or well protected areas at the foot of slopes the solifluction material was transported away from the base of the slope almost as quickly as it accumulated. This would be one factor in explaining the rather patchy nature of the distribution of this material. The presence of large quantities of apparently fluvially-reworked debris in the floors of the dry valleys of the Wolds (and in the Vale of Pickering) would seem to support this.

Sections in undisturbed solifluction deposits have only been recorded from a few sites, although angular gravels have been augered at several localities on the Wolds. The major sections in the deposits were recorded at the following localities.

i) Old Dale (SE914734)

A small gravel pit on the crest of the valley slope on the western side of the dale exposed 2.25 m of alternating beds of medium (2 - 4 cm) and fine (< 1 cm) grained angular to sub-angular chalk and flint gravel. The coarser beds were between 10 and 25 cm thick, were loosely packed and had little interstitial material. The finer gravel beds had much fine-grained chalk mud and a small amount of silt in the matrix. The thickness of these beds varied from two to 10 cm. The fine-grained beds appeared to grade upwards from the underlying coarser material - there was no marked break in grain size from coarse to fine material unlike the transition from fine to coarse where frequent signs of non-sequences and erosion were present. Small normal faults with displacements of up to 15 cm were recorded in the lower parts of the gravel: the upper gravel horizons were unaffected by these. The beds dipped at angles of 10° to 17° east-south-east (i.e. into the valley): exceptional dips of 22° were recorded at the base of the exposure in small fault-displaced blocks. The modern ground surface truncated the upper gravel horizons and no superficial deposits (except an organic silty gravel between 10 and 15 cm thick) were present on the gravels.

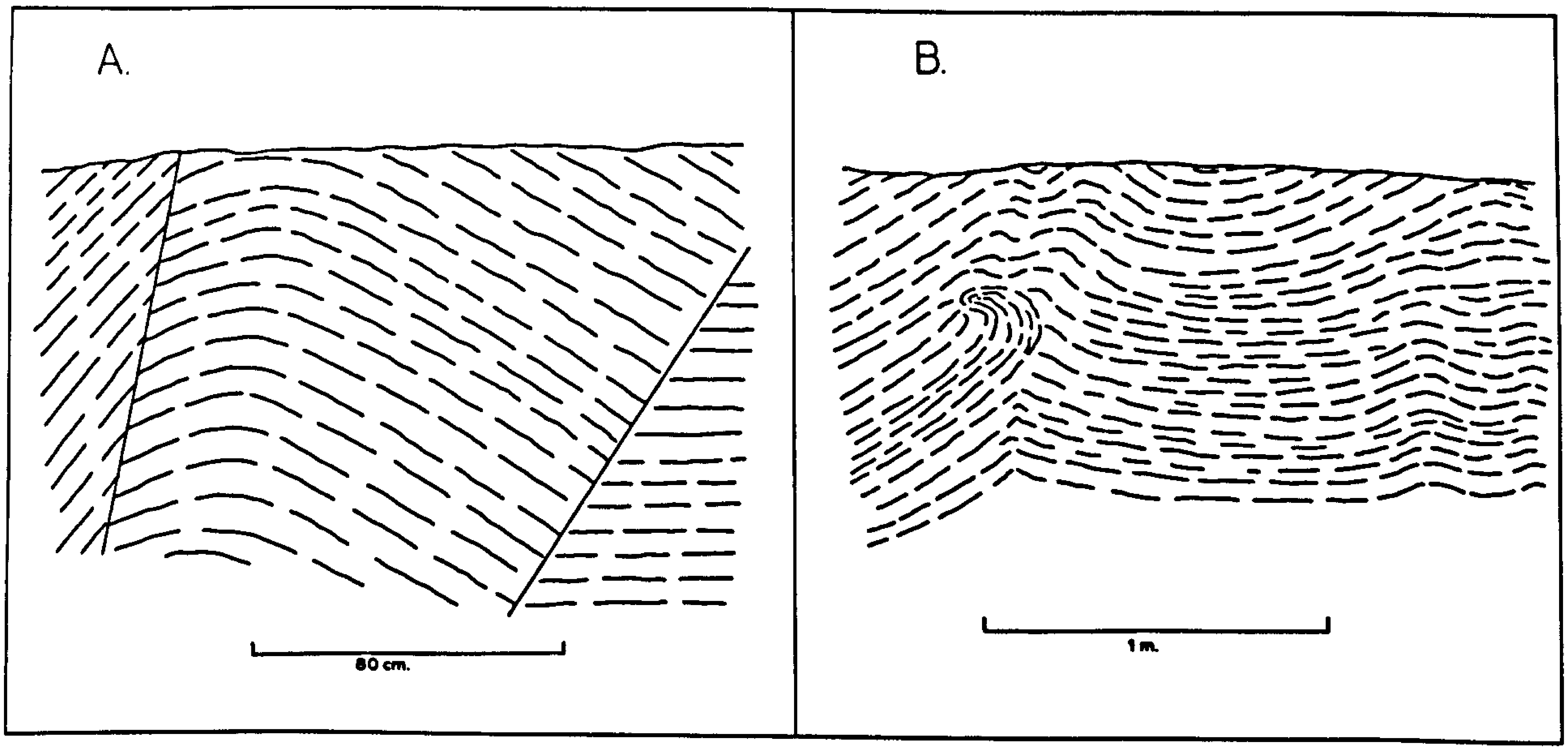
ii) Knapton Plantation (SE896749)

In several temporary sections in the plantation up to 2.5 m of rhythmically bedded fine and coarse chalk and flint gravels were exposed. As at Old Dale the fine beds had larger amounts of matrix than the coarse material which was fairly loosely packed. Small pseudo-tectonic features included a north-north-west to south-south-east trending anticline with normal faulted limbs (fig. 75). Steeply dipping normal faults with displacements of circa 20 cm were also found in other sections of the gravel. The gravels dipped from 4° to 8° to the north except where they were disturbed by the small anticline. Where the gravels were found in contact with the underlying solid chalk there was an intervening layer (between the rhythmically bedded gravels and the chalk) of coarse, angular blocky chalk with clasts 10 cm long. The horizon was between 30 and 45 cm thick and showed a tendency to fine upwards towards the solifluction gravels: this coarse blocky horizon probably represented frost-shattered chalk *in situ* or only slightly disturbed by downslope movement. The upper surface of the solid chalk was very uneven but was not reflected in any pseudo-tectonic structures in the overlying gravels. The gravels were overlain by Sherburn Sands (see Chapter III).

iii) Ganton Dale (TA007753)

Two metres of alternating medium and fine grained angular chalk and

Fig. 75 Diagram of pseudo-tectonic structures (folding and faulting) in solifluction gravel (grèze s litées) at Knapton Plantation gravel pit (SE896749) - March 1976.


A.
80 cm.
B.
1 m.

flint gravels almost identical to those found at Old Dale and Knapton Plantation were found in a small pit on the north side of the Dale. The upper 0.4 m of material was very disturbed (probably by the collapse of rabbit burrows) and did not contain recognisable bed-structures. No pseudo-tectonic structures were present. The pit was excavated in the side of the lower slopes of the valley and appeared to have been cut into an old talus slope. The gravels dipped between 8° and 12° into the valley bottom.

iv) Water Dale (SE908709)

A small pit on the south side of the valley had been excavated into the base of the valley side. The exposed section showed 2.2 m of rhythmically bedded angular chalk and flint gravels which dipped into the valley floor at angles of 10° - 14° . The ends of the gravel beds which reached the modern ground surface had been truncated as the modern slope was steeper (i.e. 20° +) than the dip of the gravels.

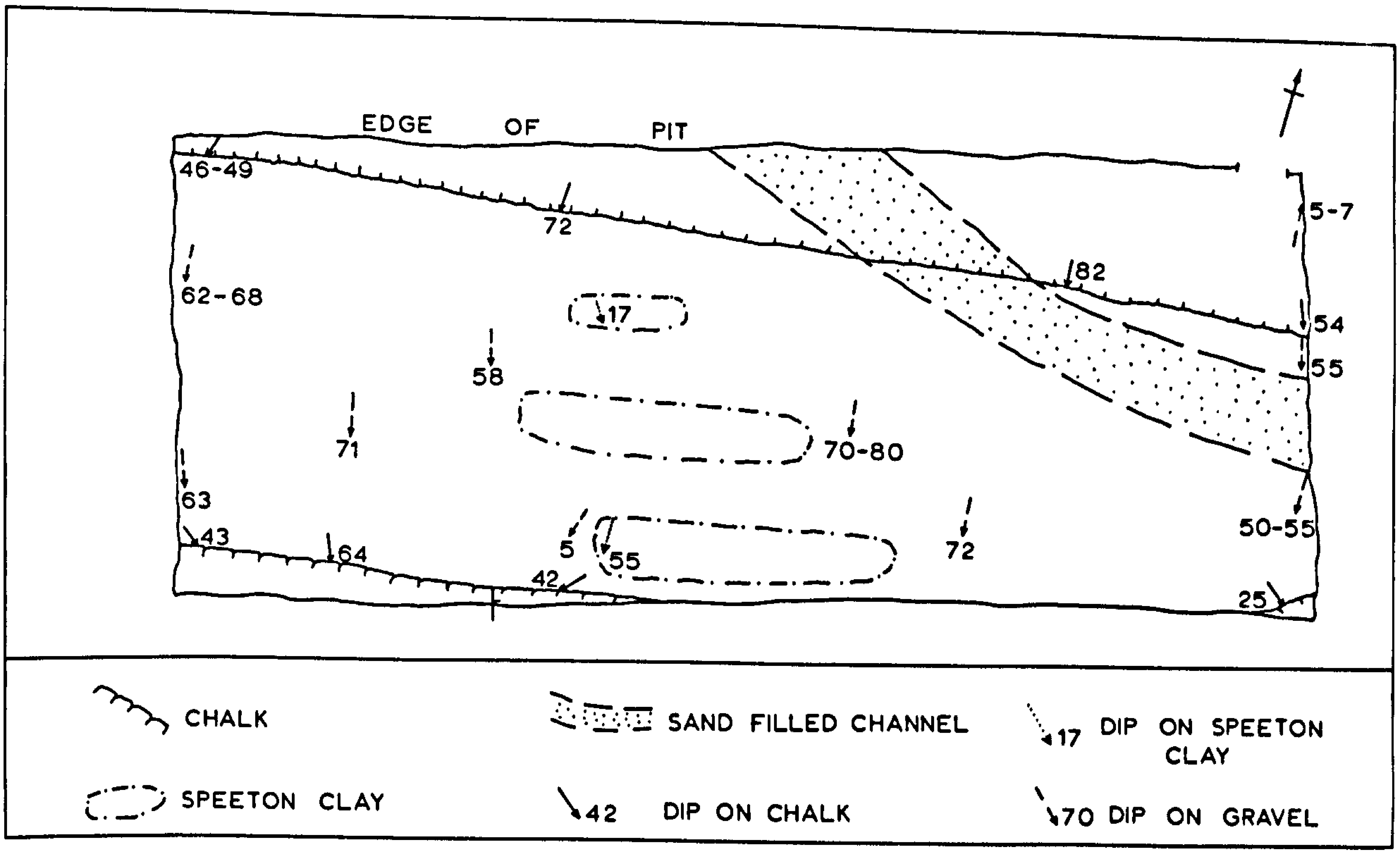
v) Linton Farm (SE908709)

In a section excavated in a bank for the site of a new barn 5 - 6 cm of mixed fine grained chalky gravel with much silty sand and chalk mud matrix, rare scattered large angular lumps of chalk (up to 15 cm long) and many erratic pebbles was exposed (for details of erratics see Chapter IV, p. 116). These gravels overlaid highly disturbed and broken chalk and Kimmeridge Clay (?). The gravels dipped at 17° east-south-east and overlaid a small pocket of loess at the eastern end of the section. The upper edges of the gravels had been truncated by erosion and were disturbed by frost-wedge casts (see Section C below).

vi) Knapton Gravel Pit (SE888749)

The thickest (12 m) and best exposures of solifluction gravels in the field area were exposed between 1974 and 1977. The bulk of the material

Fig. 76 Plan of Knapton gravel pit (SE888749) circa June 1977, showing the walls of chalk affected by tectonic disturbance, the dip of the solifluction gravels (grèze s litées) and the rafts of Speeton clay which were recorded at that time.


EDGE OF PIT
46-49
72
62-68
17
58
71
70-80
63
43
64
5
55
42
72
5-7
82
54
55
50-55
25
CHALK
SPEETON CLAY
SAND FILLED CHANNEL
42 DIP ON CHALK
17 DIP ON SPEETON CLAY
70 DIP ON GRAVEL

has now been worked out so that only small sections in the lower parts of the gravels are now visible. The gravels on this site were originally recorded by Fox-Strangways (1881) who described them as dipping at 54° south. Later Edwards (1978) gave a further brief description. The gravels appeared to occupy a linear depression which trended east-south-east to west-north-west which was bounded on the northern and southern edges by chalk which had been highly disturbed and faulted (this formed the western end of the Sherburn Wold Disturbances). Aerial photographs of the area showed that the depression may continue for some distance beyond the confines of the pit.

The superficial deposits in the pit can be divided into four major units: the lowest chalk rubbles; the middle gravels; the upper coarse gravels and the Sherburn outwash facies. The Sherburn facies were described in Chapter III and will not be discussed further here.

a) <u>The lower chalk rubbles</u>: these consisted of coarse (> 10 cm), blocky, chalk flint, angular gravels with little fine silt and chalky mud matrix. The rubbles varied in thickness (0.2 to 0.5 m) and were found immediately in contact with solid chalk on both the northern and southern edges of the pit. The clasts became rather smaller away from the solid chalk and passed rather abruptly into the overlying finer-grained gravels. The very coarse blocky nature of this material and its proximity to solid chalk suggests that the bulk of this material represents frost-shattered chalk which has not been moved very far by solifluction processes or it could represent a form of locally derived ground moraine. The latter is not a very strong possibility however as no striated blocks have been found and similar coarse blocky material can be found on the Wolds in areas which are not thought to have been glaciated recently.

b) <u>The middle gravels</u>: These formed the thickest part of the succession - over 12 m were exposed at one time without the top (which had been worked out) or base being seen. The gravels consisted of alternating beds of medium (2 - 4 cm) loosely packed, matrix poor angular gravel and fine (1 - 2 cm) matrix rich gravel. These gravels were identical to those found at Old Dale, Knapton Plantation, Ganton Dale, etc., and as with the gravels in the sections described above, local erosion and non-sequences were common. The beds appeared to consist of couplets: a lower coarser matrix poor unit which rapidly graded into a finer matrix-rich unit. The surface 1 to 1.5 m of gravel was reported by the pit owner to have originally consisted of white matrix free gravel. He also reported that as digging operations penetrated deeper into the material the amount of "dirt" (i.e. fine matrix-chalk mud and silt) increased. The dip of the gravels was variable. Fox-Strangways recorded 55° for surface material, Edwards (1978) recorded dips of up to 65° and this author found dips of up to 80° along the basal sections of the northern edge (fig. 76, N.B. All dips were to the south). High angle normal faults with throws of up to 2 m were found in the lower horizons of the gravel: the overlying material was unfaulted and only displayed minor flexures and folds. Along the northern edge of the gravel the upper 0.5 - 1 m of material had been slightly reworked and the dip reversed until it was between 5° and 7° north (fig. 28).

Within the body of these gravels were found large masses and blocks of angular chalk (up to 20 cm). Also found were rafts of "pugged" Red Chalk from 0.5 - 5 cm thick x 5 - 25 cm long: one raft contained a well preserved specimen of Terebratulata sp. Towards the lower parts of the exposed gravels were also found large rafts of Speeton Clay, one of which had a small quantity of Carstone and Red Chalk attached. The clay rafts were of uncertain size but one was 40 m long x 3 - 4 m thick and 10 m wide - its full dimensions could not be ascertained as it was still partly buried. Specimens of belemnites of unknown affinities were found in the rafts which also showed signs of crude laminar bedding. It is not known how many rafts of clay were originally present but four were recorded. The contact between the gravels and clays showed that the gravels were not disturbed by the emplacement of the clay and that the clays had hardly been eroded when the gravels were deposited over them. The upper surface of the largest clay raft dipped 50° south and was overlain by coarse rubbly chalk 8 cm thick and then the more usually rhythmically bedded material which dipped 5° south (see fig. 28).

c) The upper coarse gravels: These were only found in the eastern edge of the pit where they filled a shallow depression in the middle gravels (figs. 29 and 30). They consisted of up to 1.2 m alternating beds of coarse angular blocky chalk and flint gravel (2 - 8 cm) and finer angular material (0.5 - 3 cm). The matrix of both gravel types was largely composed of Sherburn Sand (fig. 31). Edwards (1978) described these gravels as consisting of two solifluction lobes which displayed distal coarsening. However, if a pair of coarse and fine beds is taken as evidence of a solifluction lobe then five lobes are present in this section (see fig. 24). The distal coarsening is only present in two of the lobes and was apparently caused by the termination of downslope movement of the lower lobes by the northern rim of the hollow. Within the hollow the solifluction material was found to lie on both Sherburn Sand and the middle gravels, but further to the south the upper gravels rested directly upon the middle gravels.

vii) Other sites

Long abandoned and overgrown gravel pits were found on Wintringham Brow (SE885744), at Abbey Plantation (SE907755) and Sherburn Brow (SE957748) on the northern Wolds escarpment, and at Huggate (SE884551: fig. 69) and the western side of Bessingdale (SE913603). No sections were observed in any of these pits but digging and augering showed that similar material to that recorded in the sections above was present. The pits at Huggate were once dug to a depth of up to 10 m. Small patches of this type of material are commonly found in old burrows and in slipped terracettes on the northern escarpment and on some of the dry valley sites not mentioned above: again no adequate sections were visible but these scattered findings do show that this material is fairly widespread on the Wolds.

In Camp Dale (TA058743) there is a dramatic break of slope at the foot of the western side of the valley. Similar breaks of slope may be observed in Ganton Dale near the old gravel pit and in several other dry valleys in the field area (e.g. Water Dale, Thixendale). In the case of Ganton Dale and Water Dale the sections observed in the gravel pits show that this break of slope is in part explained by the presence of the solifluction gravels described above: in the case of Camp Dale and other sites where no exposures are available it is thought that a similar explanation for the break in slope angle applies. It is not certain whether these lower angles at the foot of the valley sides should be considered to represent morphological evidence for fossil screes or talus slopes however as in a few observed sections it has been noted that the modern ground surface truncates the bedding in the gravels. However it is clear that these lower slopes are in many cases underlain by gravels so that these could be considered to represent some form of morphological evidence for ancient screes or talus slopes, which have been modified by erosion and agricultural practices in post-glacial times.

viii) <u>Origins and Age of the Soliflucted material</u>

Periglacial slope deposits which are well stratified and consist of alternating beds of coarse and fine debris have been called 'grèzes litées' by Guillien (1951) and have been described from other parts of southern

England (Kerney 1965, Kerney et. al., 1964, Paterson 1976) and northern Europe (Dylik 1960, van der Hammen 1952). The exact mode of formation of these deposits is still unclear, Cailleux (1963) showed that permafrost is not necessary for their formation - seasonal frost or snow would allow them to form. Emble ton and King (1968) suggested that the coarser layers may represent winter or early spring debris which slipped down the local slope and which was followed by finer slope-wash during the spring and summer snow-thaw. The very marked rhythmic layering suggests that a seasonal influence may have been responsible for their formation. The general lack of very coarse material in these deposits suggests that either the effects of frost-weathering were very powerful or that the coarsest material was carried beyond the slopes on which the finer material has been preserved. The exception to this rule - in the east face of Knapton gravel pit - could represent a mass of coarser solifluction debris that was fortuitously trapped in a small hollow and which has since been preserved there. Alternatively the coarser gravels at Knapton could represent a different type of periglacial slope deposit associated with a slightly different climatic regime.

The angles of dip recorded in the bulk of these deposits agree with the angles recorded elsewhere in similar material (e.g. Soons 1962, Watson 1975), except at Knapton gravel pit where the dip and orientation of these gravels is most unusual. Edwards suggested that the reason for the southward direction of dip in the gravels was that the whole hillside had undergone massive rotation slipping on the underlying Speeton Clay. This hypothesis can be disproved on two lines of evidence and is made doubtful by two more:

a) the presence of slickenslided and brecciated chalk in large quantities in the vicinity of this pit and the presence of faults of considerable throws in the chalk on the south side of the pit suggest that the chalk had been disturbed by tectonic earth movements. The alignment of the chalk on the northern side of the pit with the western extension of the Sherburn Wold Disturbance would seem to add weight to this tectonic argument;

b) the angle of dip of the chalk on the northern side of the pit is excessively high to be associated with normal rotational slip (rotationally slipped blocks rarely have dips > 50°). The very high angles are characteristic of dips associated with tectonic structures described elsewhere on the Wolds however (see Chapter II);

c) if this thick mass of gravel had undergone rotational slipping much more evidence would be expected in the form of folds, faults and other dislocations and disturbances in the gravels which would indicate this period of movement. Furthermore the Speeton Clay rafts would have been actively emplaced into the basal gravels and the latter should show signs of distortion and disturbance - such evidence is lacking. Lastly the gravels near the southern wall of chalk would dip northwards into the hollow left by the rotating mass if Edwards' hypothesis is correct: they did not do so;

d) if the mass of gravel was rotated back through circa 80° to 90° so that the material dipped northwards at circa 15° - 20° a very large embankment of gravel would result which would stand well above the modern ground surface. Explanations would need to be found to account for the erosion of the gravels from the surrounding areas which were not affected by this rotational slipping - Edwards offers no such explanation.

Thus an alternative hypothesis still has to account for the rafts of Speeton Clay and Red Chalk, the southward dip of the gravel gravels and the origin of the hollow in which the deposits have been preserved. One hypothesis could be that these deposits are partly or even wholly reworked solifluction debris:

a) the hollow in which the gravels are preserved could have originated either as an extension of a tributary of the main Pickering buried valley, or as a sub-marginal glacial channel which was excavated along the line of weakness in the chalk caused by the disturbance and faulting associated with the local disturbance (fig. 77a).

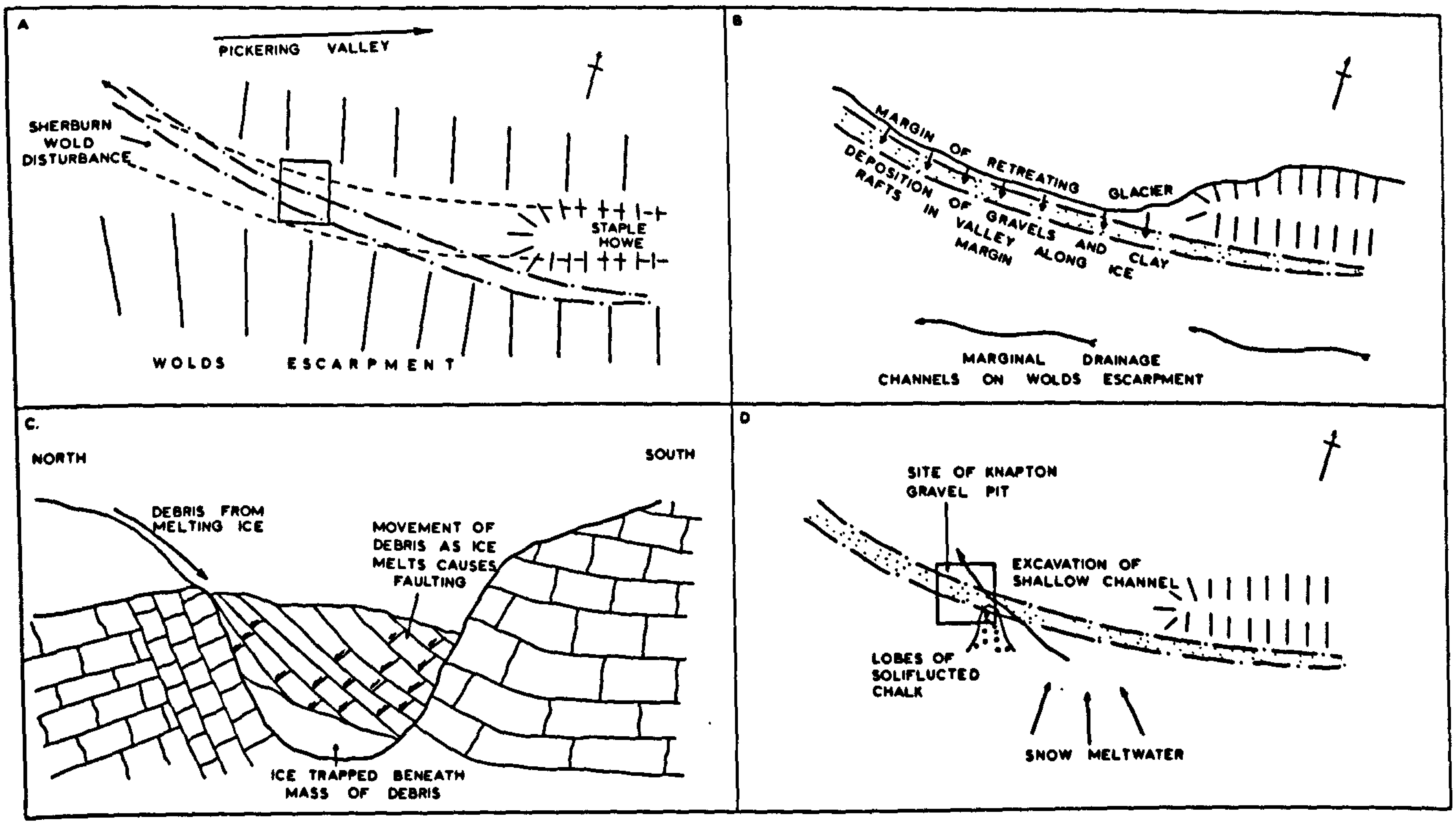
b) when the margin of the Vale of Pickering glacier had retreated past the old sub-marginal channel the supra - and englacial tills (which in this part of the ice consisted of reworked solifluction debris, rafts of chalk and Speeton Clay), began to sludge down the margins of the ice into the abandoned channel (fig. 77b). Initially the northern wall of chalk in the depression was laid under contribution but this was rapidly buried. The large rafts of Speeton Clay sludged or slid down the slopes as discrete solid frozen masses.

c) small scale normal faulting occurred in the gravels while they were being deposited due to the melting of trapped and buried masses of snow and ice. The faulted masses of gravel were rapidly buried beneath more debris which consequently were unaffected by the pseudo-tectonic structures.

d) the upper horizons of the gravels were eroded away by snow-meltwater streams which probably followed an ill-defined hollow which broadly followed the incompletely filled channel. This new fluvial channel was partly filled by Sherburn sands the bulk of which was removed just prior to the advance of at least five solifluction lobes into the channel. These solifluction lobes were in turn buried by more Sherburn sands probably derived by snow-meltwater which was reworking deposits which were originally left higher on the Wolds scarp. Some reworking of the top of the second phase solifluction lobes also occurred at this stage.

At the stage during the period following the cessation of deposition of the middle gravels at Knapton gravel pit and the deposition of the

Fig. 77 Plan and section to show the possible evolution of the deposits at Knapton gravel pit during late Devensian times (for explanation see text).


A
PICKERING VALLEY
SHERBURN WOLD DISTURBANCE
STAPLE HOWE
WOLDS ESCARPMENT
B
MARGIN OF RETREATING GLACIER
DEPOSITION OF GRAVELS AND CLAY RAFTS IN VALLEY ALONG ICE MARGIN
MARGINAL DRAINAGE CHANNELS ON WOLDS ESCARPMENT
C.
NORTH
SOUTH
DEBRIS FROM MELTING ICE
MOVEMENT OF DEBRIS AS ICE MELTS CAUSES FAULTING
ICE TRAPPED BENEATH MASS OF DEBRIS
D
SITE OF KNAPTON GRAVEL PIT
EXCAVATION OF SHALLOW CHANNEL
LOBES OF SOLIFLUCTED CHALK
SNOW MELTWATER

blown sands which are found overlying all the deposits at this site, the upper horizons of the middle gravels on the northern edge of the pit were re-orientated down the modern slope (i.e. they dip to the north, not the south as in the case with the bulk of the middle gravels). This phase of re-orientation may have occurred during the excavation of the hollow in the middle gravels (stage d above) or during the second solifluction phase (also in d above).

The above hypothesis can be criticised on the grounds that no solifluction material seems to have entered the uncovered sub-marginal hollow from the south - almost all of the material was derived from the margin of the glacier which lay to the north. This seems unlikely in view of the fact that a long chalky slope would have been left uncovered, especially as chalk is particularly susceptible to frost shattering. Also the explanation of the origin of the clay rafts is not wholly satisfactory.

An alternative is that these deposits represent material derived from a chalk ridge which originally lay to the north of the depression which has since been removed by erosion and weathering. This would increase the possibility of these gravels being earlier than Devensian in age, but as was argued by Edwards the lack of weathering and dissection would then be difficult to account for.

The age of these deposits both at Knapton gravel pit and the other sites described is difficult to determine with any degree of accuracy or certainty. A Devensian age would not seem unreasonable in view of the relationship of these deposits to the remainder of the landscape, but a pre-Devensian glacial maximum seems likely in view of the fact that such stratified deposits are rare in the marginal drainage channels and chutes etc. Also the section at Luttons Lane is remarkable in that it is almost entirely free of any covering of stratified gravels. However stratified gravels are not reported in any quantity at either the Sewerby or Hessle raised beached where other late interglacial and early or middle Devensian deposits have been found (Lamplugh 1887, Catt and Penny 1966, Boylan 1967, 1977). Similar deposits are also absent beneath the tills at Eppleworth (TA021324) and Ruston Parva (TA069617) chalk pits, although loessic silts are found in the matrix of chalky muds underlying the tills (Catt et. al., 1974). Silty loessic material is also a common constituent in the matrix of the stratified gravels, so if Catt et al., are correct in their dating of a middle Devensian loessic phase in Yorkshire the stratified deposits could be broadly contemporaneous with or slightly later than this phase of loess deposition. One further line of evidence which suggests that the stratified gravels may not be earlier than mid or late Devensian is that they are only affected to a small degree by ground ice features (see below for a full description of these). It is argued below that what evidence for ground-ice activity there is in the field area is largely of Zone I or III age and the pre-Zone I and III cryoturbation phenomena would have been more fully developed in response to the more severe climatic regime.

Thus it would seem that at some stage in the past solifluction and the deposition of stratified drifts was an important process in the Wolds area. However it is not known just when this phase of solifluction occurred; it may not have been contemporaneous with the glacial maximum as temperatures would have been too low to allow freeze-thaw processes to break up the chalk and allow the sludging of the weathered material. Alternatively it may have occurred during a period when the ground was only subjected to seasonal freezing and thawing at some stage prior to or after the Devensian glacial maximum.

B. Mass-wasting

Mass-wasting attributable to processes other than solifluction includes soil creep and landslipping. The products of soil creep are very difficult to distinguish from those of solifluction in many cases as the latter is to a certain degree a form of soil creep. Stripping of the natural vegetation cover during late Neolithic and early Iron Age times probably led to a marked acceleration of creep and related soil erosion processes (Manby, pers comm. 1977). Certainly the results of soil creep are fairly widespread. Creep of frost-shattered debris is a process which is still active on steeper poorly vegetated slopes today and is described in those area where it has been recorded by the author.

i) Soil creep and related processes

The erosion of soil from the interfluves and valley sides has been accomplished by three major processes: wind, gullying and soil creep. In the valley floors between one and 2.5 metres of stony colluvial deposits are found which are probably the result of long-continued creep on valley sides and the accumulation of this material in the valley floors. This process would seem to have been largely confined to the surface soil horizons and the interfluves and valley sides, but the fact that the soilfluction gravels have been truncated (e.g. at Ganton Dale and Water Dale) is evidence that these have also been subject to erosion. The best sections which display the results of creep on hillsides were found in the Wintringham valley between Shardale and Ladyhills Farms (SE904724) and on the south-western edge of Towthorpe Field (SE907614). Both sections probably represent the result of either soil creep following the stripping of the natural vegetation and may also be due to accelerated erosion due to agricultural practices:

The section in the Wintringham valley showed:

Section	Thickness
Dark grey organic-rich sandy top-soil with many fine rootlets.	7 cm
Fine-grained (1 - 2 cm) sub-rounded chalk gravel with angular flints in matrix of light grey fine sand.	25 cm
Dark brown to very dark brown stoneless medium to fine-grained sand.	15 cm
Discontinuous pebble bed composed of sub-angular chalk with scattered grey flint.	2 - 4 cm
Dark brown stoneless medium to fine-grained sand.	40 - 50 cm
Medium to fine-grained (1 - 4 cm) sub-angular to sub-rounded gravel with scattered angular grey flints in a dark brown sandy matrix.	20 - 35 cm
Dark brown to brown stoneless medium to fine-grainned sand.	30 cm
Coarse (< 6 cm) sub-angular blocky chalk gravel with angular flints.	10 cm (base not seen)

A similar section was found in a second road cutting approximately 200 m south of the above.

Section	Thickness
Dark grey to very dark grey organic-rich sandy topsoil with many rootlets.	15 cm
Fine to medium grained (1 - 3 cm) sub-rounded chalk and angular flint gravel in matrix of grey to light grey medium to fine-grained sand.	15 cm
Dark brown to very dark brown stoneless medium to fine-grained sand.	15 cm

Section	Thickness
Medium and fine-grained sub-angular chalk and angular flint gravels in a matrix of dark brown medium grained sand.	8 cm
Dark brown medium grained stoneless sand.	20 cm
Fine-grained (1 - 2 cm) sub-rounded chalk and angular flint gravels in a matrix of dark brown medium to fine-grained sand.	5 cm
Dark brown medium and fine-grained stoneless sand.	10 cm
Medium and fine-grained (2 - 5 cm) angular and sub-angular chalk and angular flint grav el in a matrix of dark brown medium to fine-grained sand.	10 cm
Large (> 10 cm) angular blocky chalk and flint.	12 cm exposed - base not seen

When traced down the hillslope it was found that individual lenses of sand and gravel thickened and thinned considerably. The upper gravel bed disappeared 60 m downslope (SSE) and was replaced at the base of the section by another gravel and sand horizon. Samples of sand taken from the lowest sand lens showed that the bulk of this material was composed of blown sand.

Further examples of sections which exposed the effects of soil creep were not found on the Wolds. However it is suspected that much material of this kind is present on the Wolds and that continued searching will find new exposures in the future.

Downslope creep of coarser grained material - essentially frost-shattered chalk - was also observed in several areas of the Wolds. This was especially notable on the western side of Thixendale (SE878618) on a north-eastern facing slope. Between late September 1976 and mid-March 1977 over 0.5 m of frost-shattered rubble accumulated at the foot of this slope, and the following winter more was added to this. The slope had originally been overgrazed and the vegetation further suffered in the prolonged drought of 1976 so that eventually bare rock slopes were being subjected to frost action. Slopes on the northern and north-western side of Thixendale (at SE859621 and SE880620) were also affected by frost-weathering and erosion and small screes were beginning to form at the base of the valley slopes. In Ganton Dale (TA011748) similar phenomena were observed.

ii) Landslips

Considerable parts of the northern Wolds scarp between the western edge of Thorpe Bassett Wold and Leavening Brow have been affected by large rotational landslips (fig. 14: Mortimer 1869, Matthews 1975). Rotational slips are also found on some of the dry valley sides in the north-western Wolds where Mesozoic clays crop out in the lower valley sides and floors (e.g. the small valley in which Wharram Percy Village was situated). Fox-Strangways mapped landslips east of Thorpe Bassett Wold (Sheet 54 - 1881) and it has been claimed that Mortimer described landslips in this area, (Foster and Milton 1976 , Versey 1937); and Lewin (1969) also described "land-slipped" strata east of Thorpe Bassett Wold. In fact Mortimer did not describe landslips east of Thorpe Bassett and a comparison of aerial-photographs of areas east and west of Thorpe Bassett Wold shows that the morphology of the northern escarpment is different and that the features are attributable to quite different causes (fig. 14 and 41). The scarp east of Thorpe Bassett Wold has been described previously (Chapter III).

Features associated with rotational slipping of the chalk upon the underlying Mesozoic clays in the the area west of Thorpe Bassett Wold are quite distinctive on aerial-photographs (e.g. fig. 14 and 45) and on the ground. They are as follows:

i) the appearance of large scallop-edged depressions in the chalk above and behind the edge of the escarpment or valley sides (fig. 45).

In some areas, e.g. Settringham Brow, only a single line of such cracks have formed; in other areas failure of the slope on several occassions has led to the formation of a series of such depressions and an associated stepped profile (as on Leavening Brow).

ii) the stepped morphology of the scarp profile which resulted from the repeated failure of the slope is quite different to that east of Thorpe Bassett Wold where the scarp is dominated by lithologically controlled benches and marginal drainage channels. Whereas the benches in the east can be traced as recognisably continuous features the slopes in the west which are affected by landslips have no such laterally extensive benches, but consist of a series of benches at different levels and with different slope angles.

iii) the width of the benches produced by failure by landslipping are much greater than the benches which were cut on marginal or sub-marginal glacial drainage channels. Furthermore whereas the channels have been dissected by gullies (see below) the landslip scars have not been so dissected.

The factors which control the degree of landslipping and period during which it occurred in this area of the Wolds are not properly understood. Fluctuations in the water-table levels may affect the stability of the lower slopes and the shear strength of the Mesozoic clays: in this case it is thought that a very high water-table level may be partly responsible for failure in the shear strength of the clays. Mortimer (1884, 1885) described movements on Birdsall Brow which occurred in the 1860's following an exceptionally wet summer and autumn. However the very wet autumn of 1976 and the following wet winter of 1976 - 1977 did not appear to induce slipping in this area. Perhaps then the slipping on Birdsall Brow in the 1860's resulted not just from heavy summer and autumnal rains but from the decrease of the furze vegetation during the

autumnal rains but from the decrease of the furze vegetation during the
agricultural reformation in the preceding decade, (this was suggested by T. Manby, pers. comm. 1977). Oversteepening of the slopes by glacial erosion may also have occurred; after deglaciation the release of pressure by the melting of the ice caused the hillslopes to become unstable and start to slip. Whatever the causes of these landslips however, it is thought that during the period of thaw towards the end of the late-glacial period landslipping on this escarpment would have been a more frequent occurrence than today as large quantities of meltwater would have induced failure in the clays underlying the chalk.

c) <u>Ground Ice Activity</u>

Direct evidence of ground ice in the field area is fairly widespread but is confined to a limited number of phenomena. The majority of these phenomena also appear to show that the ground was not frozen to any great depth. The evidence can be summarised under the following:

i) <u>Frost-wedge casts</u>: these features, which result from the cracking of frozen ground due to contraction and the infilling of the cracks firstly with ice and later with surface-derived material as the ice melts away, have been recorded at the following sites:

East Heslerton gravel pit (SE919766): Edwards (1978) recorded the presence of wedge casts in the sand at the northern end of the pit penetrating to depths of 8 m. This author has found no evidence of such features in this end of the pit and believes that Edwards' "frost-wedges" are due to liquid sandy mud flowing down the surface of the sand face, distorting the bedding which was exposed in the face at the time. The evidence for this is that all of the "frost-wedges" of this nature which this author has investigated have no "depth" i.e. they appear to be confined to the surface of the sands only. The frequency of occurrence of these casts was also noted to be greater in the winter months (especially when snow was lying on the ground) than in the summer. Edwards also recorded the presence of frost-wedge casts in the gravels in the northern edge of the pit. Seven such casts were recorded by the author in April

1975 - the largest was 0.95 m deep x 30 cm wide at the top. The smallest was 0.4 m deep x 8 cm wide.

Knapton gravel pit (SE888749): Edwards (op cit.) recorded one wedge in the northern edge of the pit which was 1 m deep x 0.5 m wide at the top. Two smaller casts were exposed in later workings in the same area of the pit - the casts penetrated the sand and gravel facies of the Sherburn outwash sands.

Knapton Plantation (SE895759): in temporary sections in the gravel workings several frost wedge casts were recorded. These penetrated the grèzes litées gravels to depths of up to 90 cm and were from 5 to 12 cm wide at the top. All of the casts were filled with dark brown blown sand and small angular flint pebbles.

Linton Farm (SE908708): a total of 13 frost wedge casts were recorded in the sections in the blank behind the new barn. They were concentrated in two groups, one of five at the western end of the section consisted of rather shallow (0.6 to 0.8 m deep) and narrow (7 cm - 10 cm wide at the top) casts, and a second group of seven at the eastern end of the section which were deeper (from 0.7 to 1.1 m) and wider (9 cm to 13 cm at the top). All the casts were filled with very dark brown blown sand with scattered pebbles of angular flint (fig. 51).

Warren Slack soil pit 2 (SE98857460): a possible wedge cast 35 cm deep x 12 cm wide at the top was exposed in the outwash sands in the base of the pit (Chapter IV).

Muston Wold Farm (TA077785): in a small unploughed field east-south-east of the farm a series of frost-wedge polygons were visible on an aerial-photograph taken by the R. A. F. in 1951. Traces of the polygonal features were just visible in some of the surrounding fields. No trace of these features was visible on photographs taken over the same area in 1967 and 1972. The soils in the Muston Wold Farm area consist of boulder clays 1 m thick.

ii) Involutions and festoons

East Heslerton gravel pit (SE919766): the gravels in the northern end of the pit had all traces of original bedding and sedimentary structures destroyed by involutions and festoons which penetrated the gravels to the base of the exposure and beyond, (fig. 26). In the sands at the southern end of the pit no evidence of these phenomena was found.

Boythorpe Gravel Pit (SE998719): involutions and festoons in water-laid gravels were common in the upper 0.5 to 0.7 m of gravels. The involutions and festoons again destroyed all traces of bedding and sedimentary structures in those parts of the gravels which were so disturbed.

Garton Slack Gravel Pit (SE940600): the upper 0.35 to 0.5 m of gravels were intensely deformed and disturbed by involutions and festoons. The base of the disturbed horizon, as in the sections at Boythorpe, was very irregular with small pockets of undisturbed gravel surrounded by wreaths of deformed gravels near the base of the involuted horizon.

iii) Other frozen ground phenomena:

The most important of these includes the shattering and splitting of chalk near the modern ground surface which is exposed in the numerous old and modern chalk pits on the Wolds. The intensity of the shattering is greatest near the surface of the "solid" chalk where the degree of shattering can be so advanced that the rock has the appearance of a frost-rubble at first glance. However these "rubbles" do display preferential vertical and horizontal joint patterns which suggest that they are almost unmoved. The degree of shattering decreases with depth but even in the deepest pits in the chalk (e.g. at Flixton Hill: TA047778) the effects of widening of joints by frost activity was present. (N.B. R. Mortimer pers. comm. (1976) reported that on the South Downs the width and density of joints in the chalk suddenly decreased at depths of between 55 m and 61 m below the ground surface: this is thought to represent the maximum penetration of permafrost in this area. However the opening of joints at this depth could have occurred during any of the Pleistocene glacial periods and it is unlikely that Devensian permafrost penetrated to this level). Other evidence for ground ice activity which had directly affected the surface layers of the chlak was found at the site of Wharram Percy mediaeval village where archaeological excavations had cleared the soil to the rock level. The surface of the chalk was seen to be highly disturbed with many pebbles with their long (or in the case of platy fragments, intermediate) axes in vertical or near vertical positions. T. Manby (pers. comm. 1977) has informed the author that this is a frequently found phenomenon under archaeological sites on the chalk of the Wolds. He also informed the author that when the major trenches for the North Sea Gas pipelines were dug across the Wolds in the late 1960's many sections revealed what appeared to be evidence of stone stripes and other forms of sorted ground phenomena.

The lack of surface evidence for stone-stripes (or any other forms of patterned ground except that at Muston Wold Farm) is one of the minor mysteries of the Wolds. It is possible that due to cultivation the evidence has been destroyed: however the author has noted on numerous occasions the presence of bands of gravelly soil in fields on shallow slopes which could represent highly disturbed stone stripes. Until proper sections are made however no firm conclusions may be drawn from these observations. Possible stone-stripes were recorded on the eastern slopes of the small northern tributary valley of Cotton Dale (at TA024768). The "stripes" consisted of alternating bands of coarse (2 -4 cm) and fine (> 2 cm) angular chalk and flint gravel which run down the slope. The bands were of unequal width: the coarse parts were between 25 and 45 cm wide and the finer bands between 50 and 70 cm wide. The finer material appeared to be slightly more elevated than the coarse gravels but this was not measured in the field. The stripes were not clear when viewed from a distance of more than 10 to 15 m but were visible if studied at closer quarters. No sections were excavated but further work may prove to be fruitful in establishing (or refuting) the presence of the stone stripes.

On the eastern side of Luttons Lane 11 saucer-shaped depressions were recorded. The depressions on the upslope side were wider and shallower than those downslope and were filled with dark brown and very dark brown medium to fine-grained blown sand (fig. 53). The lower slope depressions were filled with fine to medium grained angular and sub-angular chalk gravel. The "risers" between the depressions consisted of large and medium grained angular blocky chalk and flint gravels: some of the long axes of the material in the risers were nearly vertical.

Other cryoturbation phenomena in the form of sandy pockets and lenses which had apparently been intruded downwards into underlying gravels were recorded at Knapton Plantation, Knapton Gravel Pit and Linton Farm. In addition disrupted pebble beds (with some pebbles with their long axes vertical or nearly vertical) were recorded in the upper metre of sand in a pit at White Cottage, West Heslerton (SE899754).

Mr. S. King (pers. comm. 1977) recorded the presence of a possible fragipan near Wykeham on the northern side of the Vale of Pickering at a depth of circa 0.8 m.

iv) <u>Age and significance of the ground-ice features</u>

The above evidence for ground ice activity can be divided into two distinct groups: the evidence which indicates deep (i.e. $>$ 5 m) penetration of the ground by frost and the evidence for shallow ($<$ 5 m) penetration. The evidence for the deep penetration is confined to the chalk in the form of opened and enlarged joints, which as stated above, may penetrate as much as 60 m in southern England and might be expected to penetrate to similar or greater depths in the Wolds. Much of the evidence for deep permafrost penetration is probably a fossil relic of pre-Devensian glaciations however, when the severity of the climate and hence the penetration of the ground by frost was much greater than appears to have been the case during the Devensian. Dimbleby (1952) and Edwards (1978) have described frost-wedge casts on the Northern Yorkshire Moors which penetrate to depths of up to 3.1 m and which have Basement (i.e. pre-Devenisan) till in them. This means that on the Northern Yorkshire Moors at least the depth of penetration of the permafrost must have been greater than 3 m, although at what stage this depth of penetration was achieved is not certain: the time of the maximum limit of advance of the Devensian ice seems most probable.

In the Vale of Pickering and in the superficial sediments on the Wolds the average depth of penetration of the frozen ground phenomena is much more limited. Depths greater than one metre are uncommon and greater than 1.5 m rare. This would seem to imply that either the period when these features formed was not during a phase of such intense cold as that which was responsible for the ice-wedge casts on the Northern Yorkshire Moors, or that it was not as prolonged. A phase of cold which would fit these requirements, both in terms of length of time and the severity of the climate would be Pollen Zone III (Younger Dryas) which occurred after the main retreat of the Devensian glaciers in this area.

If the ice front ran from Wykeham to Ganton the depth of penetration of ground ice beyond the margins of the glacier and Lake Pickering (as envisaged by Kendall) would probably have been in excess of that actually observed. In fact ground-ice was present during Zone I and/or Zone III times in the area under study as shown by the presence of frost-wedge polygons in Devensian tills north of Hunmanby.

It is therefore concluded that much of the frozen-ground phenomena described in the Vale of Pickering and on the Northern Yorkshire Wolds above is probably of Late Glacial age. This excludes the bulk of the solifluction deposits, especially the "grèzes litées" found on the northern escarpment and on the dip slope of the Wolds. If this dating is accurate it would lend support to the hypothesis that the superficial deposits affected by the frost-wedge - casts and involutions are of late Devensian age because they have not been disturbed by the deeper ground-ice activity of the Early and Middle Devensian and the Devensian glacial maximum.

d) The Drainage System

The peri-glacial drainage system of the area is considered to consist of the buried valley of the Vale of Pickering and the dry-valley system on the dip slope of the Wolds. Neither is probably the result of exclusive peri-glacial erosion but it is considered that both played an important part in the drainage of the area during the Devensian peri-glacial phases. The Pickering valley system has been described in as much detail as is currently known (Chapter III) and will not be further mentioned here.

The dry valleys of the Yorkshire Wolds have been the subject of a relatively small amount of discussion in the past compared with similar features in central and southern England: the most recent review is that of Lewin (1969). However, Lewin's descriptions and analysis of the drainage system was based upon the whole of the Wolds region and thus much small but significant detail was omitted from his study. Much controversy has existed in the past concerning the origin of the dry valleys in the chalk (and other limestones and non-limestone areas) which has not been helped by the fact that no areas of chalk are now found in the periglacial zone of the Arctic or Antarctic regions. Hence much of the argument about the origins of these features has been centred upon theoretical considerations although some of the more recent publications have been based upon more substantial field evidence. This author cannot, and does not intend to try to provide the necessary mass of data which would be required to re-assess and revise our theories concerning the evolution of the dry valley system, but hopes to contribute some new information which should help to construct a more viable and more accurate theory.

Theories of origins of Dry Valleys in Chalk Landscape

The origins of dry valleys in the chalk is a problem that has generated much discussion in the past that no description of a chalk landscape can avoid the ensuing controversy. Lewin (1969) recently reviewed some of the literature and the different theories which have been put forward to explain the origin of the dry valleys, but in view of the evidence presented in Chapters III and IV concerning the possible influence of glacier-ice and meltwater a more complete review is now thought to be necessary. The various schools of thought concerning the origin of dry valleys are:

a) Tectonic activity: Mortimer (1885) believed that large scale earth movement which caused cracking of the ground during the period of Tertiary uplift of the area were responsible for the dry valleys. This is a view which is not held any longer as it is generally accepted that valleys are excavated by erosional processes, even if agreement cannot be found as to what these processes were.

b) Solution: Cole (1887) proposed that solution was the main agency involved in the origin of dry valleys - a view of which is rather extreme but which has a large degree of truth in it. Lewin (1969) has pointed out that some valleys may form through the collapse of solution hollows. It is true that linear steep-sided hollows do exist on the Wolds, one of them (at Huggate) in line with the head of a modern dry valley. However, the importance of valley extension by this process is very difficult to estimate, especially as there appears to be a lack of much suitable evidence indicating solutional collapse.

c) Glaciation: This theory was first proposed by Higginbottom (1947) to explain the origin of scarp dry valleys in southern England. Lewin suggested that Wolstonian or Anglian glaciers must have overriden the Wolds and may have caused a large amount of erosion of the chalk which was then deposited as the "chalk boulder-clay" of central England and East Anglia. If Matthews' (1977) proposition that the clays-with-flints found on the Wolds are of Tertiary origin is true it would seem unlikely that much chalk debris could have been derived from this area. If, however, the sandy clay subsoils are the weathered remnants of a former till the chalky boulder clay could have been eroded and removed prior to the deposition of the later tills. However, it is still very difficult to assess the importance of glacial erosion on the development of the drainage pattern.

d) Spring-sapping: This is the first of two major hypotheses forwarded to explain the existence of dry valleys. Its proponents envisage irreversible processes (i.e. widening of joints by solution) which cause the drying-up of the springs and streams which were responsible for excavating the valleys. The supporters of this hypothesis claim that the "steep headwalls" of the valleys are good evidence in support of the theory. Lewin modified the idea by claiming that spring sapping under colder and wetter conditions than those at present were responsible for the major phases of dry valley formation. This school of thought may be attacked on four major lines of weakness: first too much reliance is placed upon a process about which very little is actually known: secondly the main line of morphological evidence used in its support (i.e. the steep valley heads) may be explained by alternative theories; thirdly not all dry valleys have steep headwalls or even marked breaks of slope in the shape of the long profile which would indicate the position of old spring sites. (Lewin's hypothesis may be specifically attacked on the grounds that it seems likely that permafrost conditions existed in this area during much, if not all, of the Devensian, thus forming an effective seal to rising or moving groundwater. Secondly the modern climatological data suggest that the climate of eastern England during the Devensian was probably slightly _drier_, not wetter than present (Lamb and Woodroffe 1970, Coope _et. al._, 1971). Fourthly, the evidence from southern England indicates that even under peri-glacial conditions without continuous perma-frost old spring sites were probably no higher in the past than they are today (Kerney _et. al._, 1964).

e) _Peri-glacial processes_: This is the second of the major schools of thought which concentrates on dry valleys as part of a peri-glacial landscape. Peri-glacial processes, such as snow-meltwater erosion are thought to be the most important factor (although on the Northern Wolds at least some glacier-ice meltwater may also have been involved), and much evidence has been forwarded in the past in support of this theory (Kerney _et. al._, 1965, Kerney 1964, Paterson 1970, 1976). So far only scarp-face valleys have been analysed and described, yet this seems to be the strongest contender with the most and best supportive evidence.

The dry valleys of the Northern Wolds are considered to be a typical example of a chalk drainage system, both in terms of pattern and very probably in their overall development. The drainage system may be conveniently divided into two sub-units;

a) the trunk dry valleys (which were briefly discussed by Lewin);

b) an important secondary system hitherto unrecognised in Yorkshire which consists of a large number of low order channels.

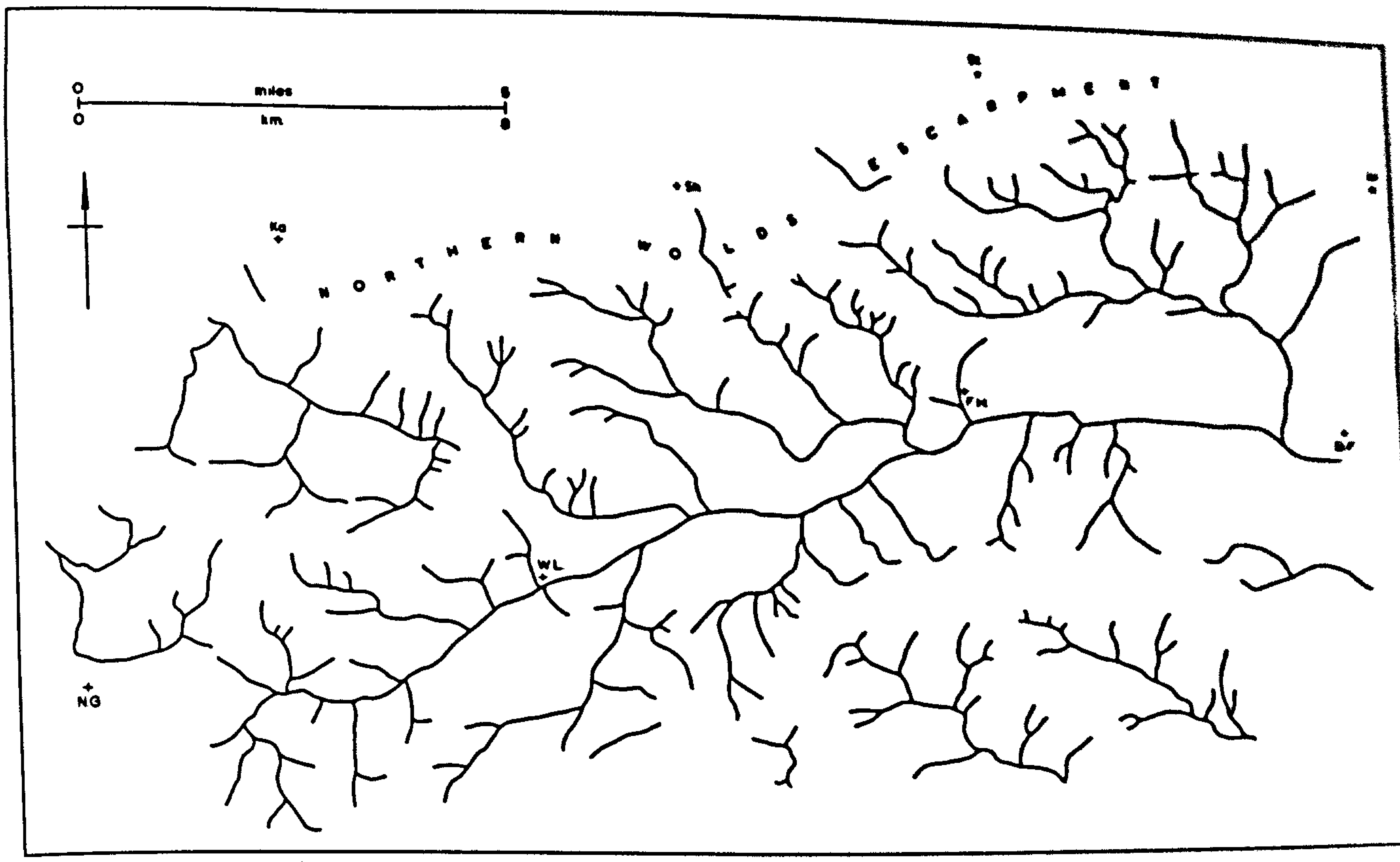
The secondary system has almost certainly been superimposed upon the first (trunk valley) system under conditions which no longer exist today, and which may help to elucidate some of the details of the formation of the larger dry valleys.

a) The Trunk Dry Valleys

The major dry valleys are here defined as those described by Lewin (1969, p. 38) who stated that a dry valley existed where two contours made a V one above the other. This is one of a number of methods of determining channel length, but it is highly subjective, the more so when the drainage system under study is a fossil relic, (Gardiner 1975). The problems which arise from Lewin's definition of a dry valley will be discussed more fully below; in the meantime his definition and the valleys marked by him on his map of dry valleys of the Wolds are considered here as the main "trunk valley" system (fig. 78).

Lewin calculated the drainage density of the Wolds using the above method of determining channel length and found that the density value varied from between 1.5 and 1.7 km/km^2. This survey was based upon a system of calculating area using random-quadrat s. This method eliminated the effects of movement of underground water from one basin to another, a factor which Lewin believed may have affected the density of individual

Fig. 78 Map of the trunk dry valleys of the northern Yorkshire Wolds (based on Lewin 1969).


0
miles
5
0
km
8
NORTHERN WOLDS ESCARPMENT
Ka
Sh
FM
WL
NG

drainage basins and thus would present a distorted image. This author has returned to the individual drainage basin as the areal unit for calculating density on the grounds that:

i) the processes by which these valleys formed was probably dominated by surface-water flow and underground water movement was not greatly significant if indeed it affected the systems at all.

ii) the Wolds valley system is now dry (except for the Gypsey Race which is the product of highly unusual hydrological conditions) and can thus be considered as a part of a system where the individual drainage basin comprises the basic unit.

Lewin calculated that the drainage density varied from 1.5 to 1.7 km/km^2 depending upon the size of the quadrat used. Calculations of drainage density of individual basins showed a variation from 0.2 km/km^2 (Low Mowthorpe Slack (E): 23) to 2.4 km/km^2 (Galloping Slack: 27) with an overall mean of 1.49 km/km^2 (Table 14). In fact, this value is probably not a true reflection of the drainage density as will now be shown.

b) The Secondary Drainage System

This consists of all the shallow valley head and valley side channels and gullies which can be readily observed in the field and on aerial photographs (figs. 10a and 44a). This secondary drainage system was mapped directly from air-photographs and is shown on fig. 79. When this secondary system was added to the trunk dry valleys the drainage density calculations showed a very marked increase. The range now extended from 0.92 km/km^2 (High Mowthorpe Slack; 0.2 km/km^2 for trunk valleys) to 19.2 km/km^2 (Low Mowthorpe Slack; 2.4 km/km^2 for trunk valleys). The mean density of the two systems is 3.45 km/km^2 (previously 1.49 km/km^2 a figure much closer to the average for world densities quoted by Strahler (op. cit.), but now greatly in excess of the average for temperate basins calculated by Langbein (1.65 km/km^2 : Langbein 1947). This mean density

Fig. 79 Map of the combined dry valley and dry gulley network on the northern Yorkshire Wolds as mapped from air-photographs. Compare with Fig. 78.


0
miles
5
0
km.
8
St.
H
Sh.
Ka
F.H.
B.F.
W.L.
N.G.

value (3.45 km/km^2) is in excess of figures given by Pinchemel for the Picardy region (0.74 km/km^2 : Pinchemel 1957), for the Dove Basin (0.06 km/km^2 : Gregory 1971) and for an area of mixed sandstones and marls in Devon (2.67 km/km^2 : Gregory and Walling 1973).

The composition of the new drainage network may provide some clues concerning its origin and circumstances of formation. The first point is the extremely large numbers of low order (Shreve 1964) channels, and their concentration either at valley heads or along valley sides (fig. 81). Further they are not evenly distributed within any given basin e.g. on the western side of Old Dale, there are large numbers of channels, whereas on the eastern side there are very few. Similarly on both sides of Helperthorpe - Weaverthorpe Slack the gullies are very closely spaced, whereas on Phillip's Slack there are relatively few valley side gullies and these are widely separated. The reason for these distributions are probably due to the following factors:-

1. Angle and length of slope: if slopes are relatively short (i.e. < 100 m) then they have to be relatively steep (> 10°) for channels to have formed. If the slope is longer the channels will form on lower angle slopes although they then tend to be shallower and wider (e.g. at Wold Newton (TA 03-0472) on the north slope of the Great Wold Valley the average slope is circa 7° ; long shallow and wide channels are found here).

2. Area of interfluve catchments: this seems to have a bearing on the number and total length of gullies present. Where catchments are fairly large and low angle (< 2° - 3°) but are incised by steep sided (>10°) valleys, large numbers of gullies are present (Weaverthorpe Slack) whereas if the interfluve tends to be a longer gentler slope lacking a significant low-angle catchment area, the channels frequently do not occur at all (e.g. Phillip's Slack).

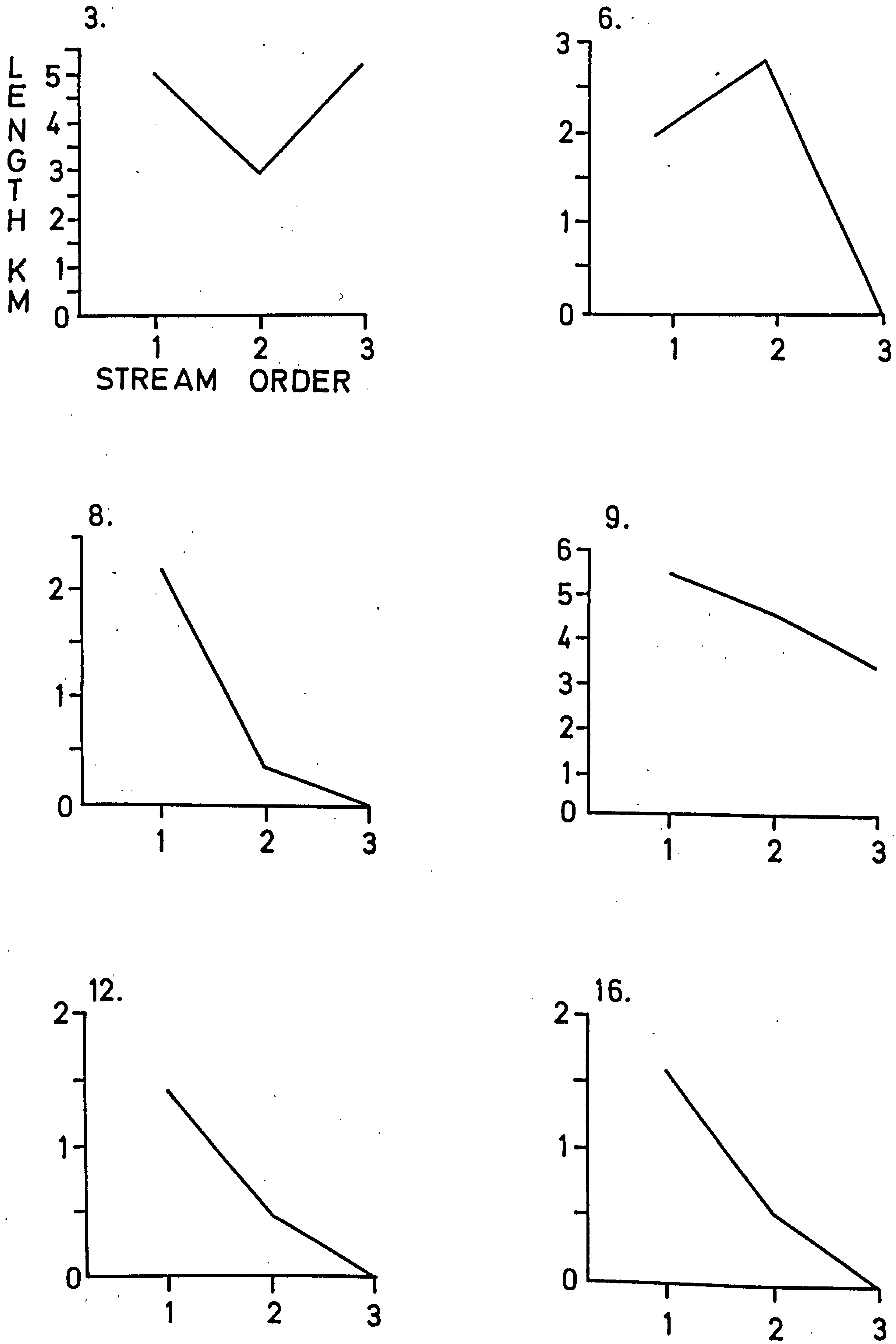
3. Permeability of the subsoils on the catchment: if the sandy and silty clay subsoils (described in Chapter IV above) are present over extensive areas of the interfluves, these will almost certainly help to increase run-off under high precipitation conditions (Foster 1978). It is noteworthy that these subsoils are most widespread on low angle (i.e. < 3°) slopes on interfluves and are rare or absent on longer gentler slopes where they have either been removed or were originally lacking. Therefore high and concentrated run-off conditions would be expected on lower angle slopes and would tend to lead to the formation of more gullies - an hypothesis which seems to be supported by the evidence from the two basins discussed above (i.e. Weaverthorpe Slack where sandy and silty clay subsoils are present, and Phillip's Slack where they are not).

The number, density and low-order values of the majority of the gullies seems to indicate that they were cut very rapidly in conditions which were relatively short-lived, and they were superimposed onto a pre-existing, larger drainage system (discussed in section a above and by Lewin (1969)). To test if this hypothesis was correct a number of small experiments were carried out:-

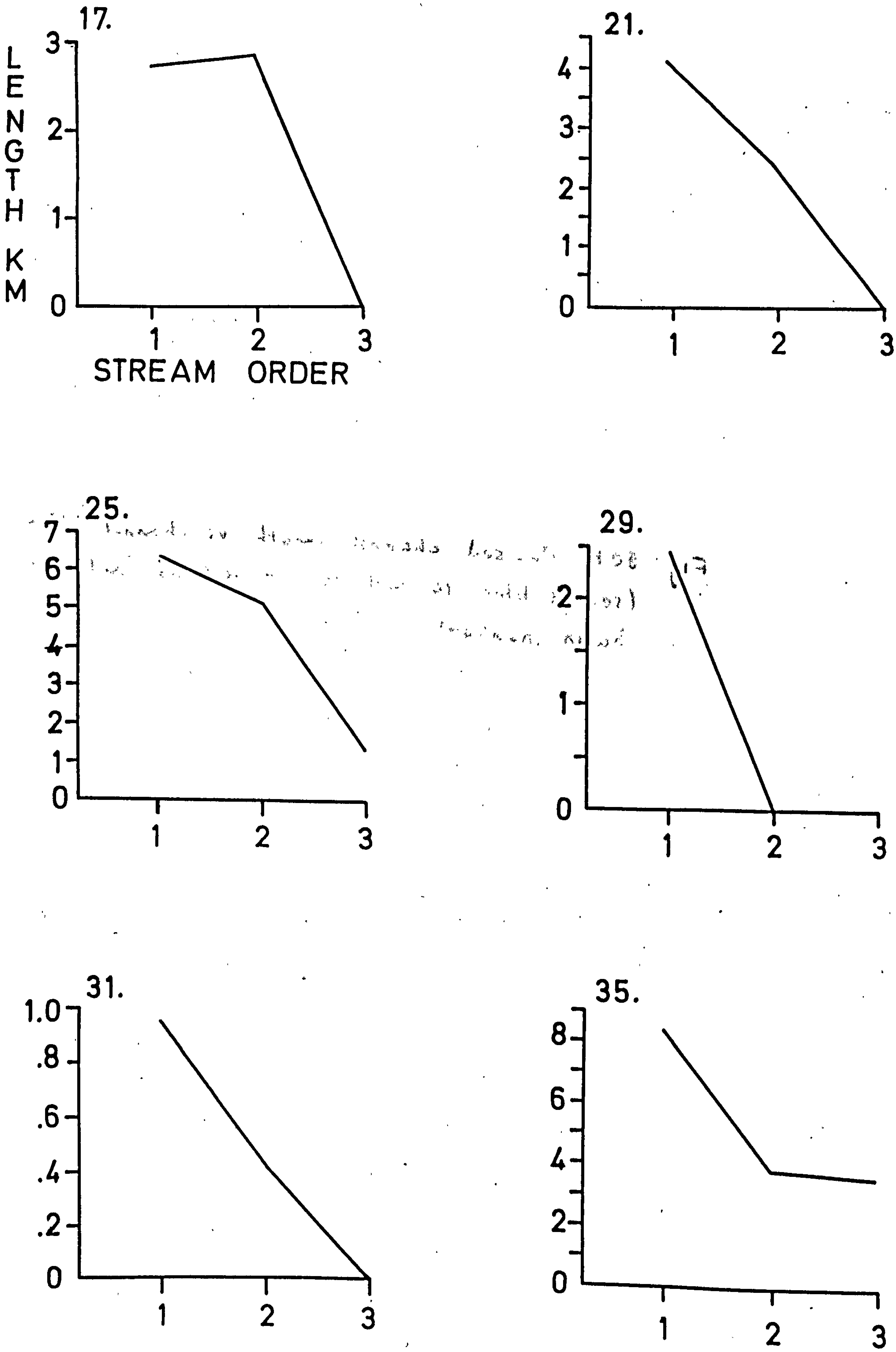
1. Channel order: as stated above, the bulk of the gullies are of first or second order channels only. This is clear if the length and order of the drainage system as described by Lewin is compared with the reviewed data from air-photographs. Twelve basins were selected to range from the smallest ("Foxholes Dale" and "Fordon Dale") to some of the largest (Old/Haverdale and Crake/West Dale). The lengths of each channel order were then measured and compared (table 14). The first significant factor is the evidence in the number of the highest order channel for all but two basins in the sample ("Foxholes Dale" and Cotton Dale/Well Slack, when the new data are included in the calculations. Furthermore there is a very large increase in the total lengths of 1st order channels (ranging from

Fig. 80a and 80b Graphs of channel length vs. channel order for 12 randomly selected drainage basins on the northern Yorkshire Wolds. (To identify individual basins see text and table 14).

80a Channel length as calculated by Lewin vs. channel order. See table 14 for basin numbers and table 16 for data.

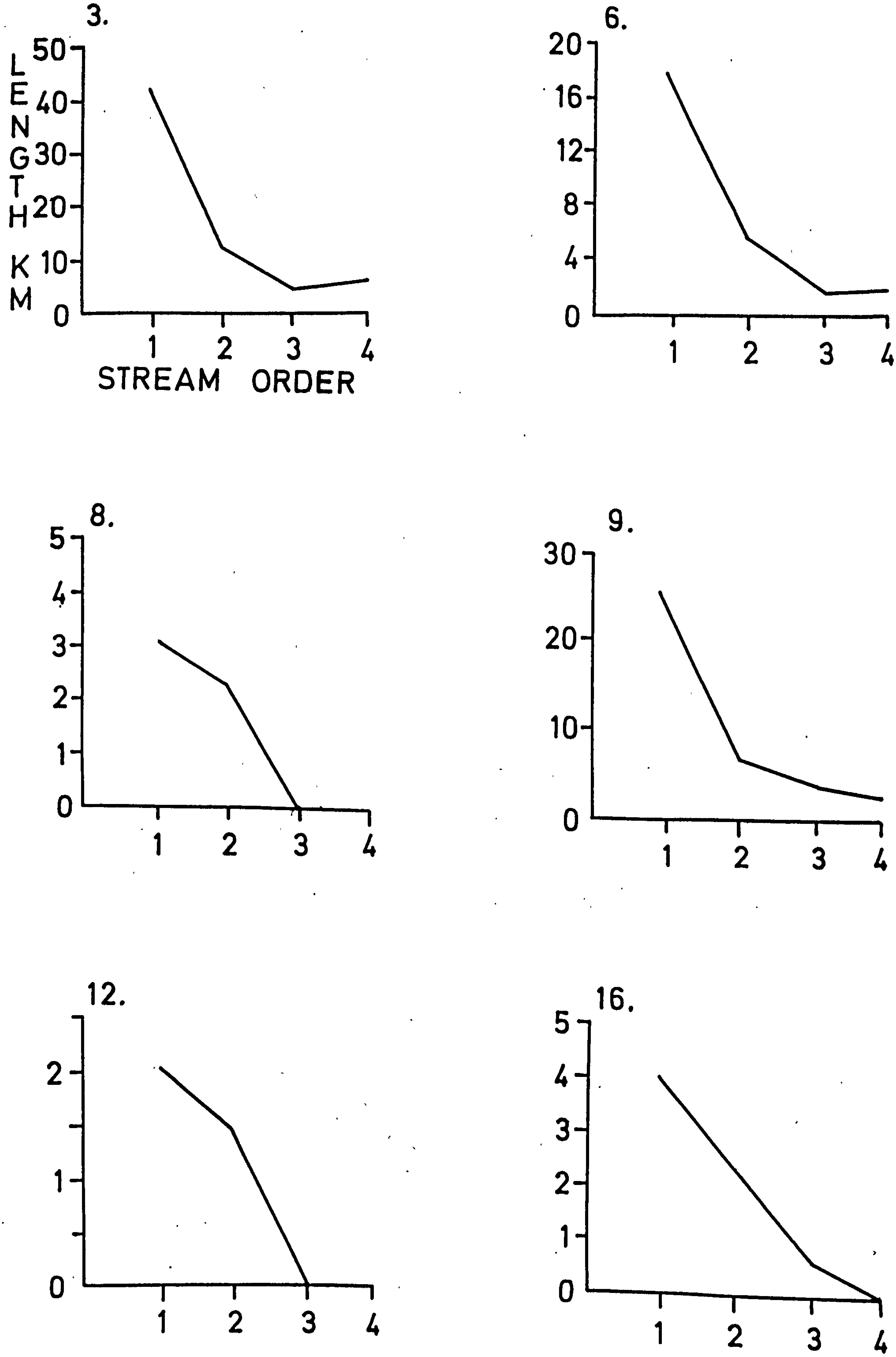


3.
LENGTH KM
0
1
2
3
4
5
1
2
3
STREAM ORDER
6.
0
1
2
3
1
2
3
8.
0
1
2
1
2
3
9.
0
1
2
3
4
5
6
1
2
3
12.
0
1
2
1
2
3
16.
0
1
2
1
2
3

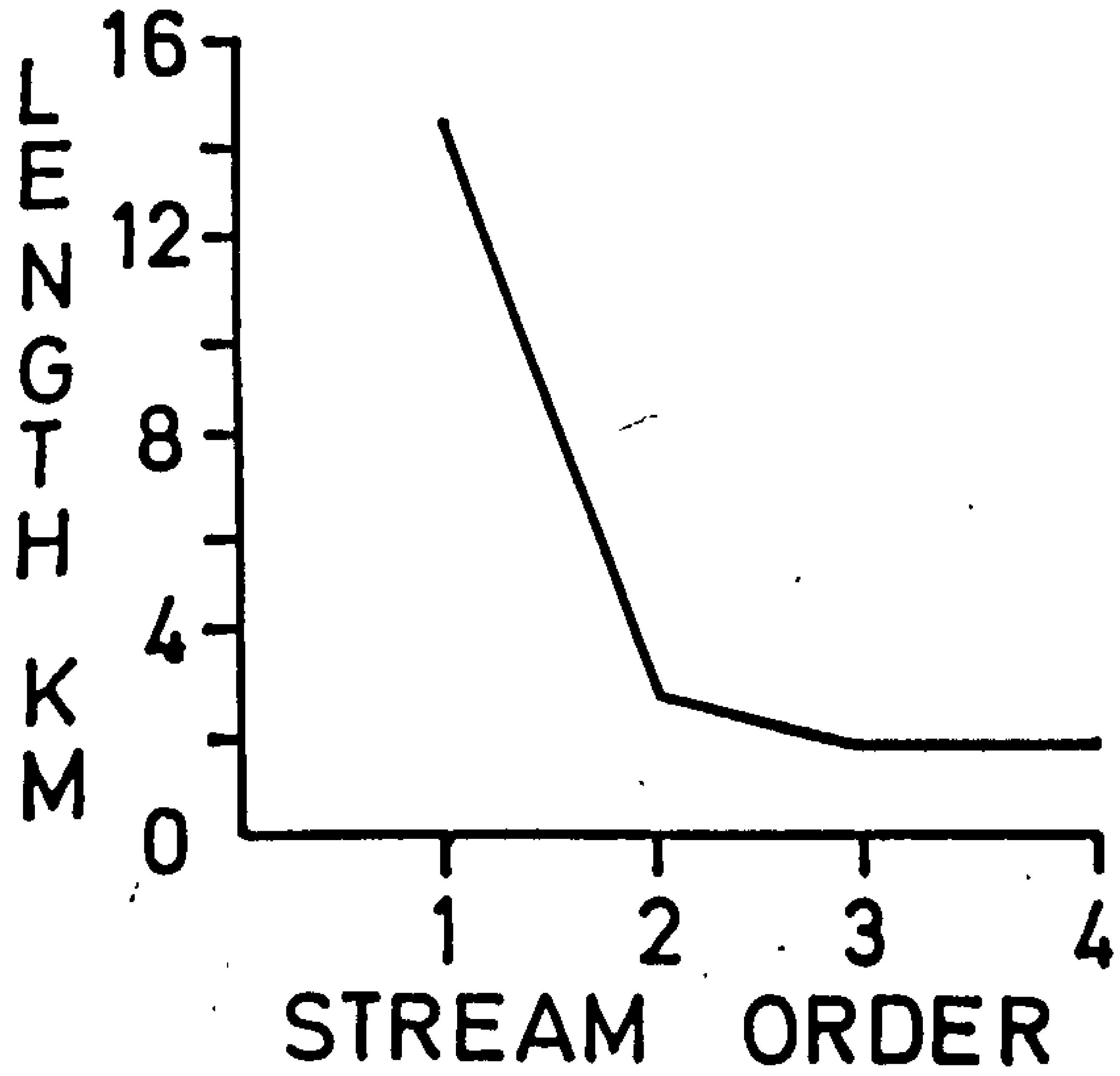


17.
21.
25.
29.
31.
35.
LENGTH KM
STREAM ORDER

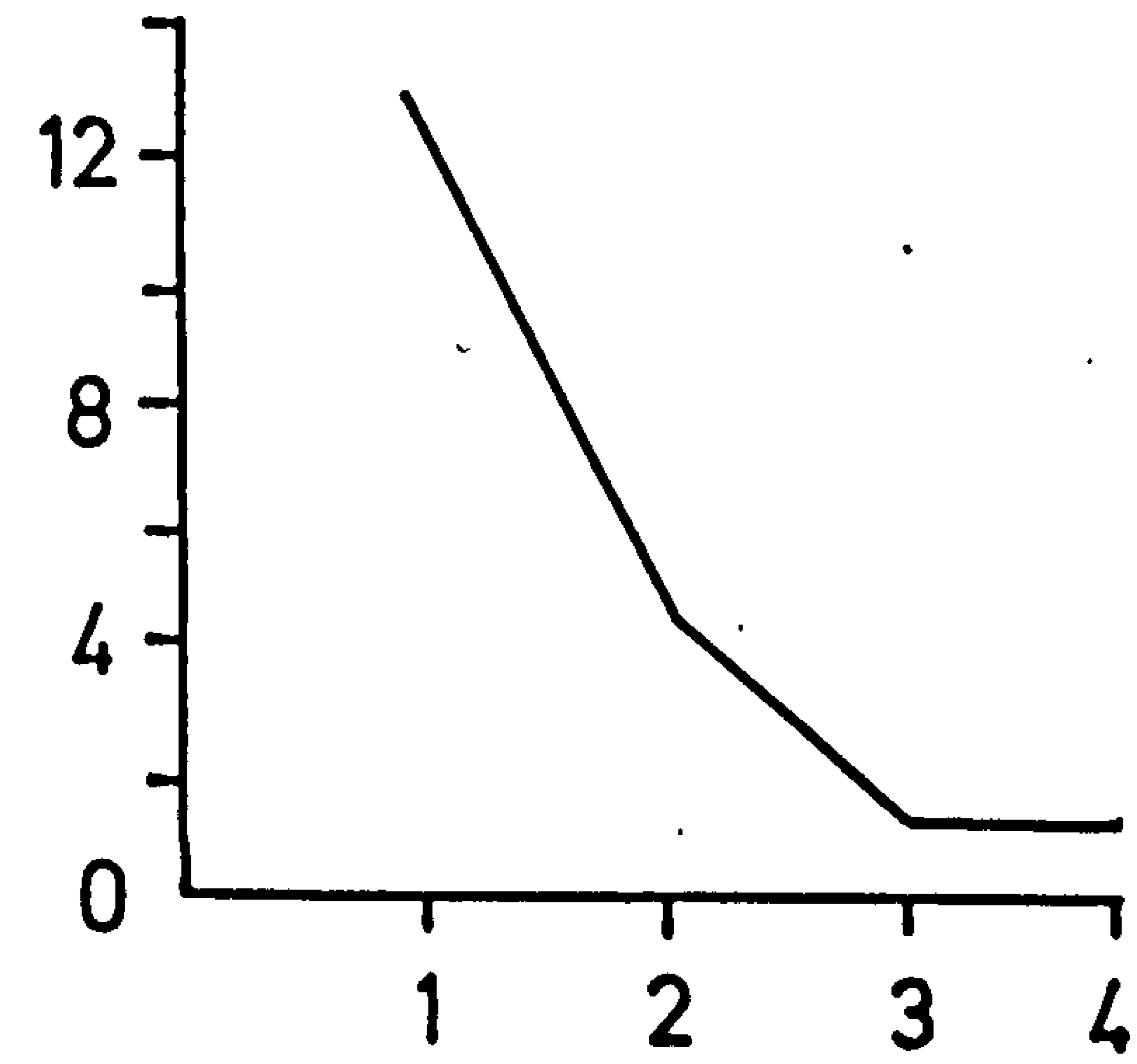
Fig 80b: Revised channel length vs channel order. (see tables 14 and 16 for details and for basin numbers).


3.
LENGTH KM
50
40
30
20
10
0
1 2 3 4
STREAM ORDER
6.
20
16
12
8
4
0
1 2 3 4
8.
5
4
3
2
1
0
1 2 3 4
9.
30
20
10
0
1 2 3 4
12.
2
1
0
1 2 3 4
16.
5
4
3
2
1
0
1 2 3 4

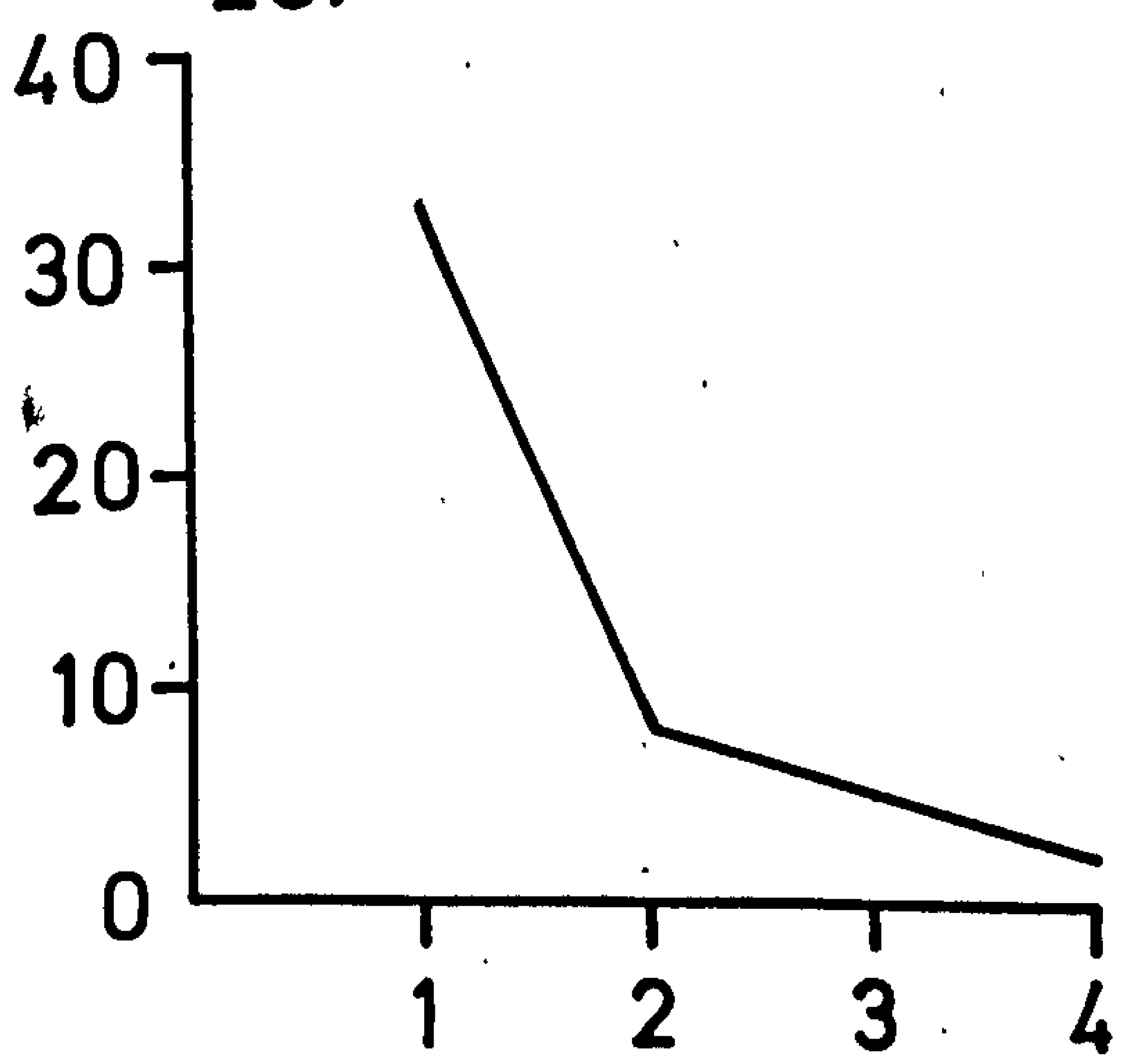
17.



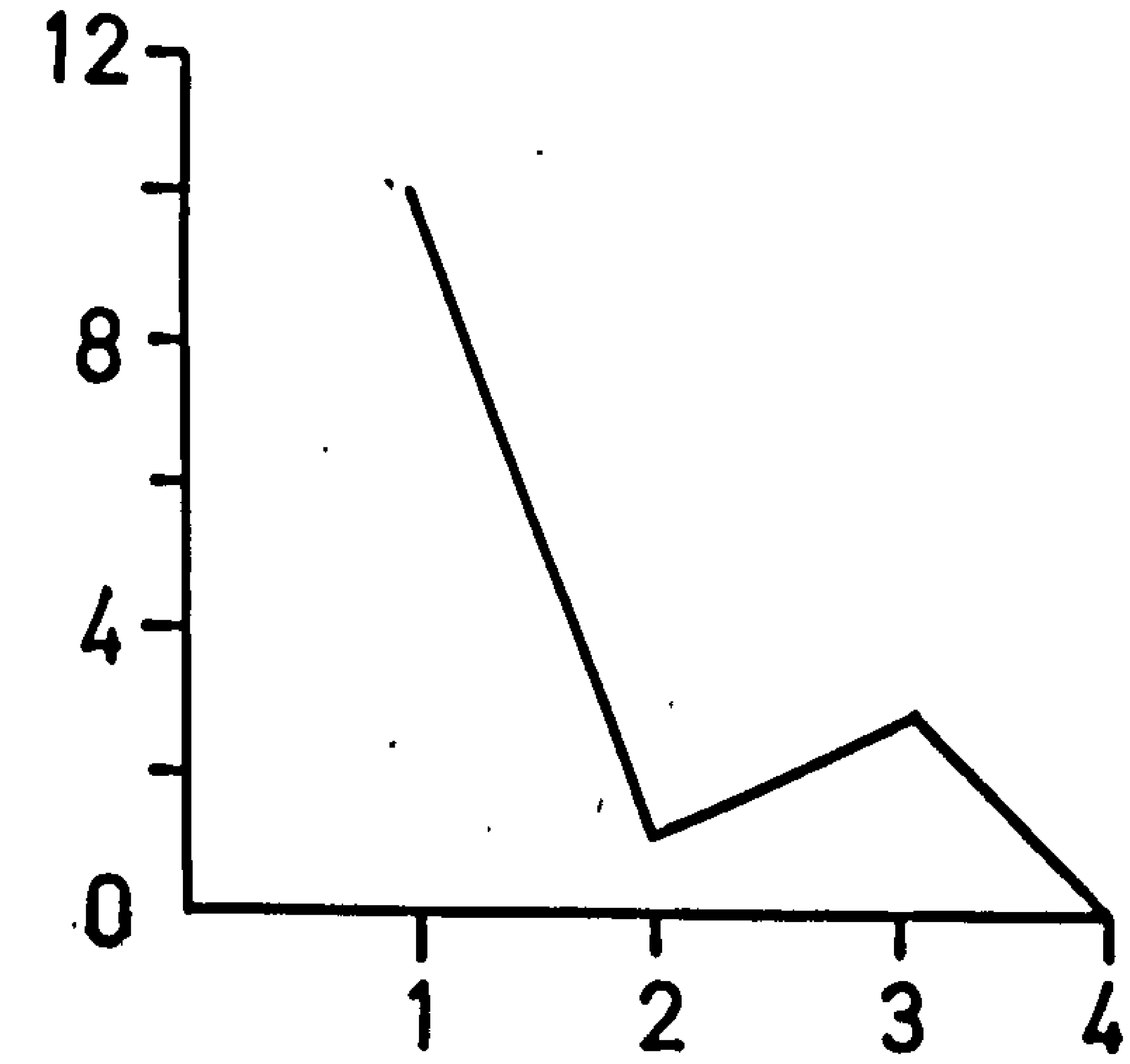
21.



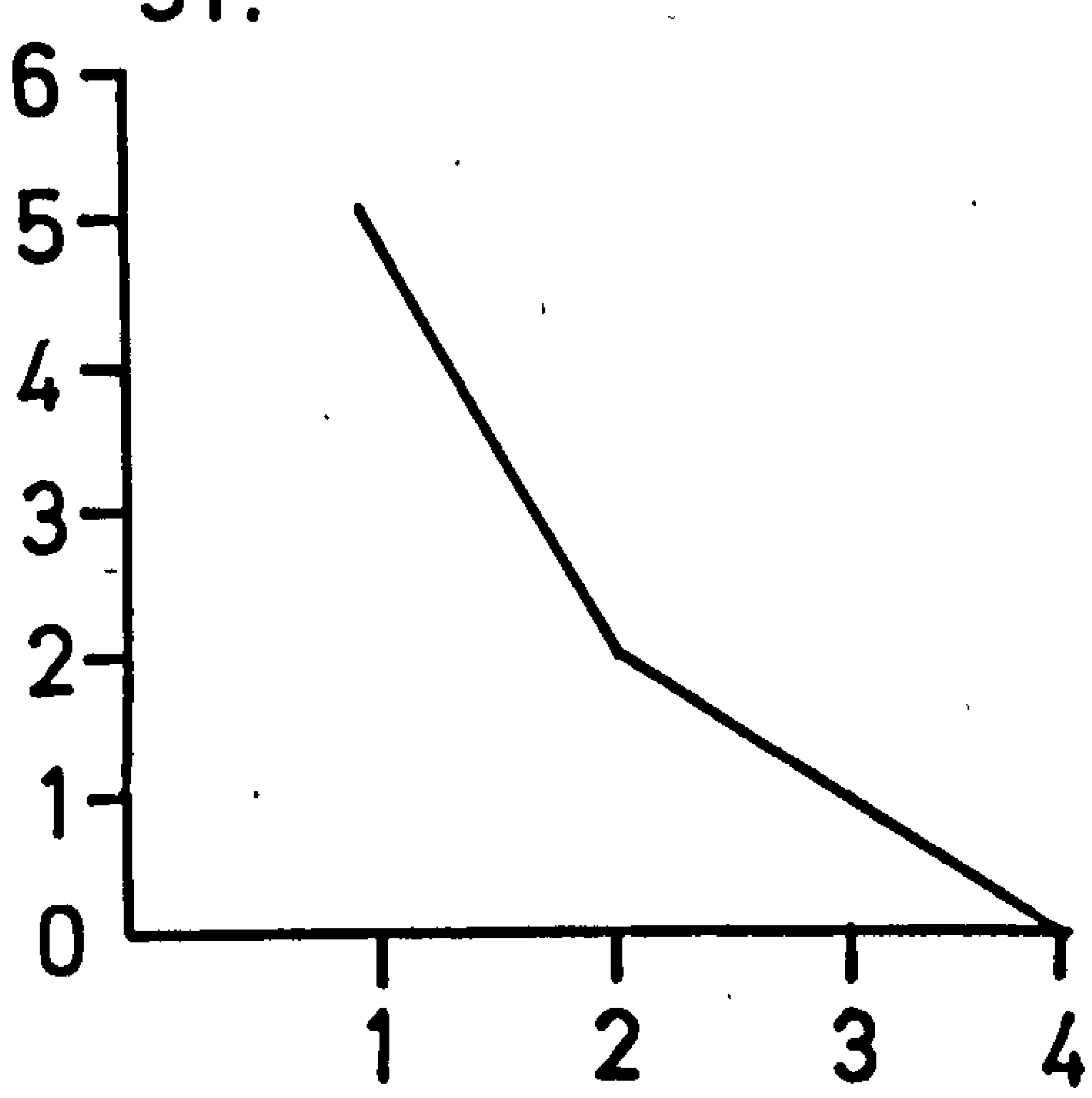
25.



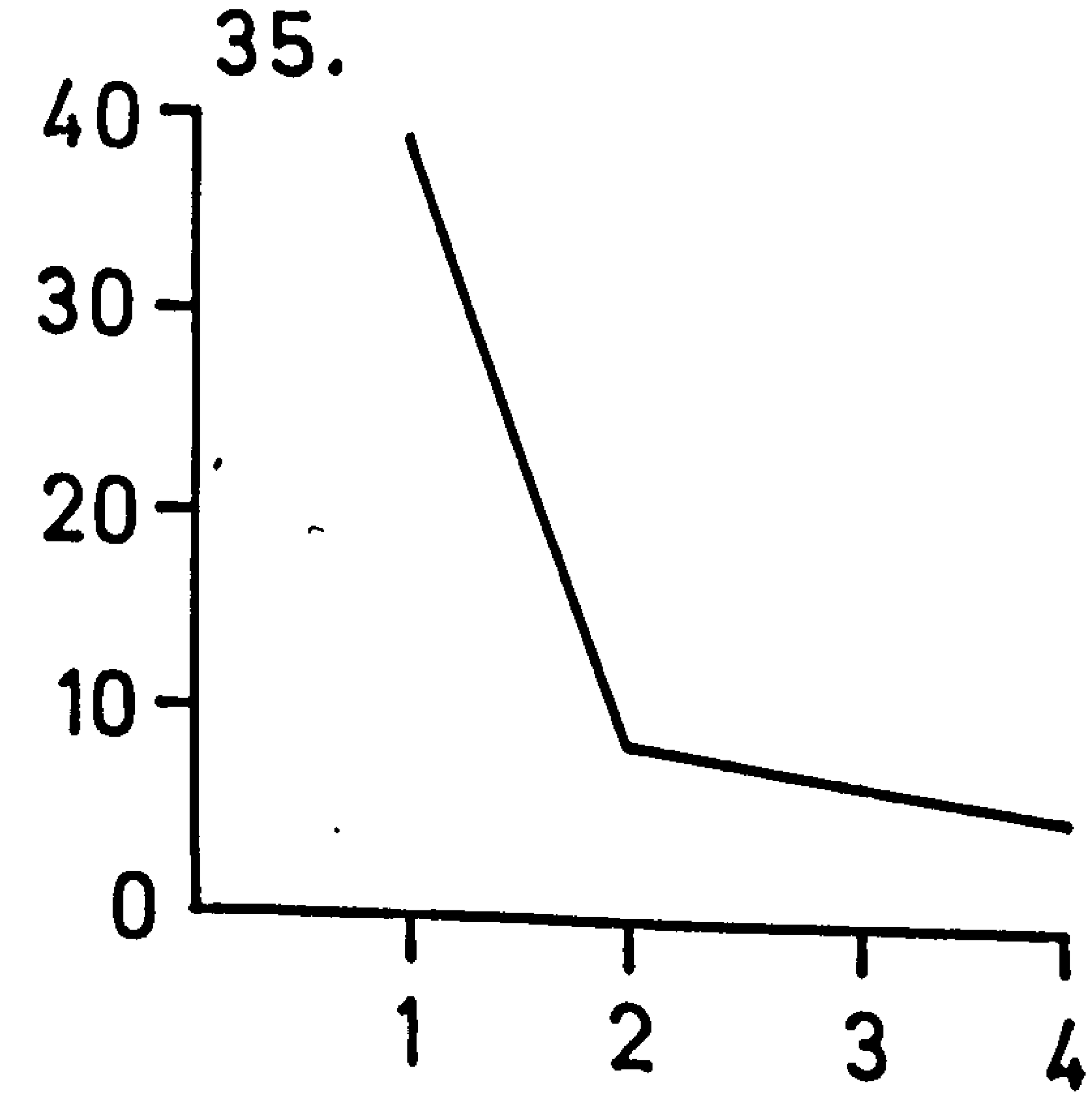
29.



31.



35.



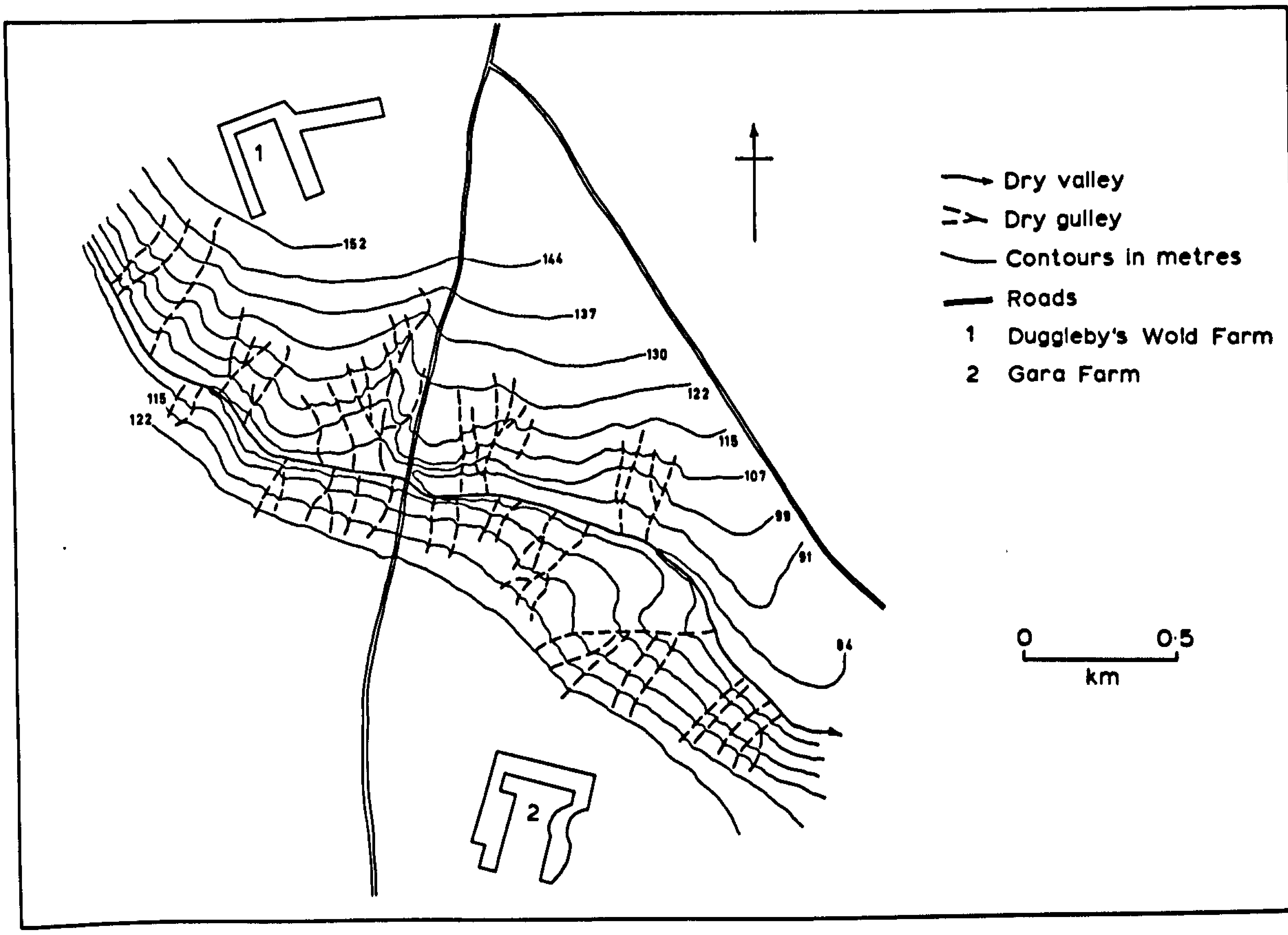
0.5 to 10 times - average increase = 3.46) and 2nd order channels (ranging from 0.5 to 7 times - average increase 2.75 - fig. 80a and b). This shows that the gullies on the valley heads are poorly integrated with the main dry valley network and have probably been superimposed during a late, short-lived phase of development.

b. Local channel orientation: If the gullies had been cut during the formation of the trunk dry valley system they would be expected to show some deferral of junctions - i.e. the angles of junctions between the gully and the dry valley would be fairly low. This is because as the drainage system develops, angles at confluences tend to decrease slowly.

To test the angles at which the gullies join the mainsystem, three separate and different areas were mapped from 1:25000 air photographs using a kern PG2 stereoplotter to draw in accurately the local contours, gullies and dry valleys (figs. 81 and 82). The angles of confluence of the gullies and dry valleys were then accurately measured (table 16). The results show that for gullies which occur along a length of trunk valley (Sunningdale/Weaverthorpe Slack fig. 81), 50% of the confluences occurred at angles between 85° and 90°, and only 10% at angles less than 70°. For a valley head with gullies on one side only ("Butterwick Dale", fig. 82) 25% of confluences were between 85° and 90° and 18% were less than 70°. For a dendritic gully network at the head of a valley (Old Dale, fig. 82), no junctions occurred between 85° and 90° and 35% occurred at angles less than 70°. For 30 randomly selected confluences of trunk dry valleys, 32% of junctions occurred at angles between 85° and 90° and 66% at angles less than 70°.

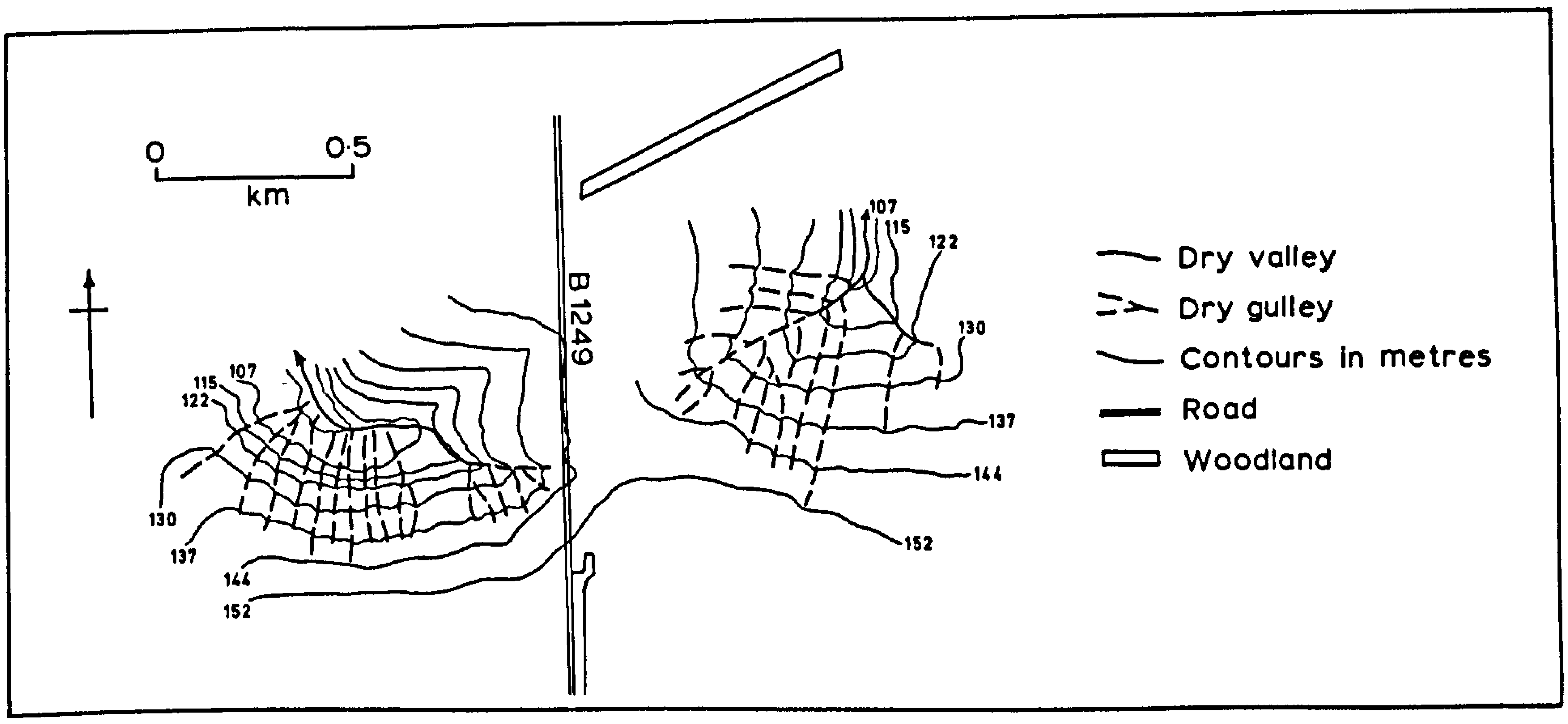
Thus it is clear that in the case of those gullies which occur on valley sides, the evidence of confluence angles suggests that they are of recent origin. In

Fig. 81 Detail of the dry gulley system on the sides of SunningdaleWeaverthorpe Slack (SE 957731 to SE 985720) based on mapping from aerial photographs. Low order (1 and 2) channels run down the valley sides at angles close to 90° , indicating a late stage of development.



Dry valley
Dry gulley
Contours in metres
Roads
1 Duggleby's Wold Farm
2 Gara Farm
0
0·5
km
152
144
137
130
122
115
107
99
91
84
115
122
1
2

Fig. 82 Detail of the dry gulley system at the head of "Butterwick Dale" and Old Dale (Octon) (TA 0170/0270 and 0071/0171) based on mapping from aerial photographs. In these valley heads the dry gullies lead northwards from the interfluve across the steep valley side (i.e. south slope) of the head of "Butterwick Dale" and form a dendritic pattern at the eastern branch of this dale. The Old Dale system forms an alternative and denser drainage network to the main dry valley head - the remainder of the valley has few tributaries.



0
0·5
km
B1249
107
115
122
130
137
144
152
Dry valley
Dry gulley
Contours in metres
Road
Woodland

the case of the gullies found at the heads of dry valleys, the gullies appear to run down the local slope into the dry valley, the angle of confluence being low in some cases, because of the shape of the local valley sides. In all cases however, the gullies run at, or nearly at, right angles to the local contours, which further shows that the gullies formed after the local slope and that they passively developed upon those slopes.

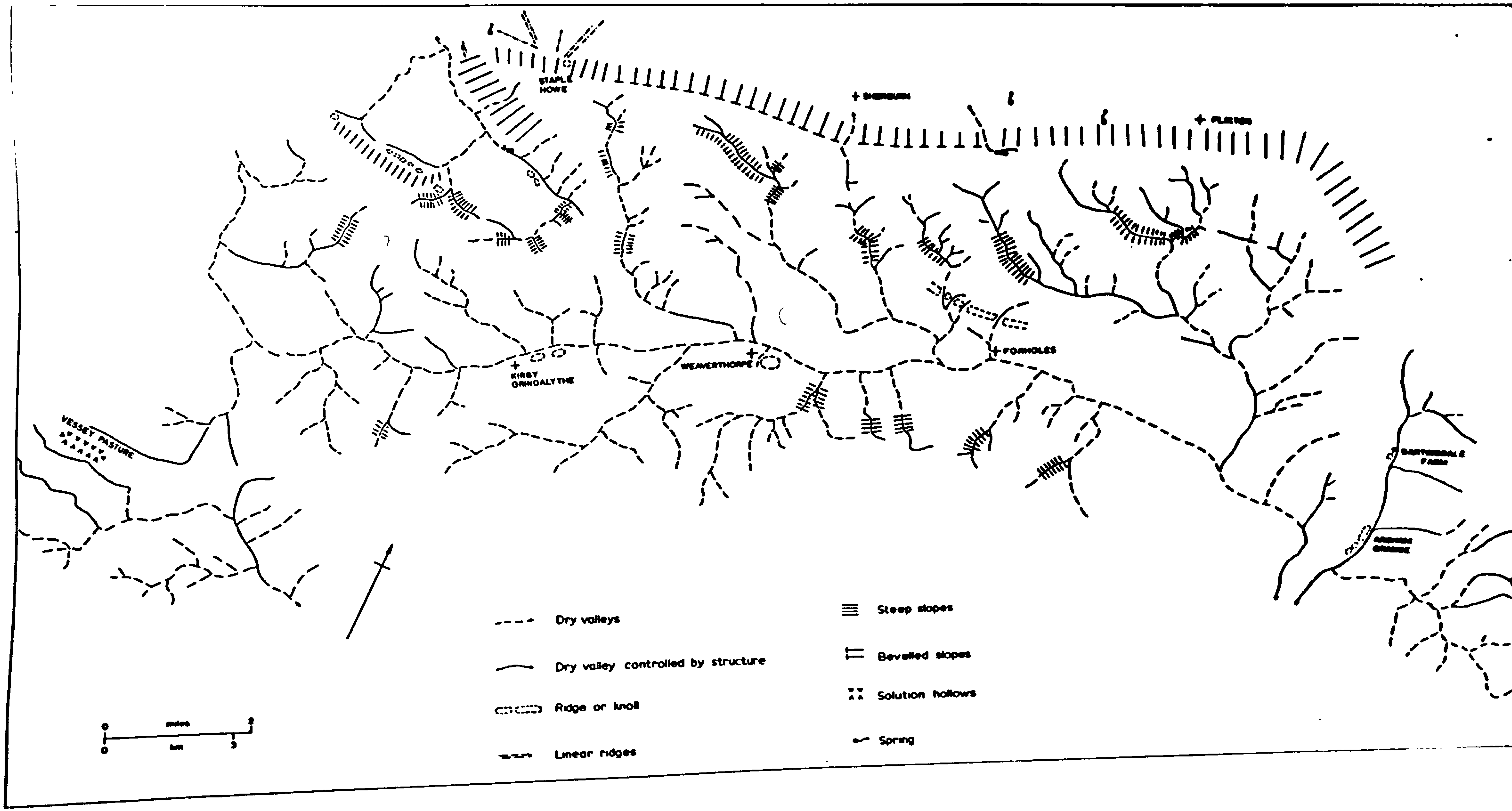
a) The relationship between tectonic structures, joints and valley patterns

Lewin (1969) claimed that a statistically significant relationship existed between the orientation of the dry valleys and the joint pattern in the Chalk. This conclusion is tendentious because firstly Lewin did not have a statistically viable sample of joint orientation data with which to calculate any meaningful results; secondly a regional joint pattern has yet to be proved to exist in the Chalk of the N. Wolds. There is a further problem that even if a regional pattern was shown to be present, the effects of the disturbances in the northern Wolds would have to be taken into account, as these are known to have an effect upon joint orientation (see Woodward and Buckley 1976 and Chapter II, p. 29).

The relationship between the geological structures and joint patterns of the Chalk and the pattern of the dry valley system is such that only in small areas can segments of valleys be said to be related to the underlying structure with any degreeof confidence (fig. 83). It seems highly probable that the disturbance zones of the Wolds are a relatively late feature (Walbank 1970, Kent 1974), but it is not known what, if any, posthumous effects these disturbances had upon the joint pattern of the Chalk prior to their formation. Whatever influence the disturbances may have had the overall result does not seem to have been very great. A notable exception to this rule is the junction of the three valleys at TA0476 where the influence of structures is firmly imprinted on the drain-

Fig. 83

Geomorphological features on the Northern Yorkshire Wolds which are related to the disturbance zones in the chalk (for discussion see text).


STAPLE HOWE
SHERBURN
FLIXTON
FOXHOLES
WEAVERTHORPE
KIRBY GRINDALYTHE
VESSEY PASTURE
Dry valleys
Dry valley controlled by structure
Ridge or knoll
Linear ridges
Steep slopes
Bevelled slopes
Solution hollows
Spring
miles
km
0
2
0
3

age pattern (fig. 41). However, as a general rule the evidence which is currently available cannot be said to support the hypothesis suggested by Lewin that there is a strong degree of joint control of the valley system, as much more data concerning joint patterns are desirable.

ii. The problems of headward erosion and erosion surfaces on the Chalk:

Lewin suggested that the major process by which the drainage system on the Wolds evolved was by headward erosion caused by spring sapping. The spring sapping process caused the gradual dissection of a number of erosion surfaces which had been left exposed by a regressing Late Tertiary or Pleistocene sea. However no evidence was offerred to show how successively exposed surfaces were less dissected than the uppermost surfaces; no evidence was offered in the form of nick-points etc., to show how the effects of successive rejuvenation had affected the trunk and older tributary valleys; nor was any account taken of the fact that if the sea was regressing the old established drainage pattern found on the highest (and first exposed) surface would extend across the successively lower surfaces.

iii. The Valley Long Profiles: This line of evidence has been used by all of the authors who support the spring-sapping hypothesis. (Sparks and Lewis 1957, Small 1958, 1961a, b, 1965, Lewin 1969). These authors argue that the "steep backwalls" of the valley heads are the products of spring-sapping and spring-recession maintaining and undercutting a steep slope. The weakness of this arguement was pointed out by Kerney et al. (1964) but this point seems to have been missed by Small and Lewin. In fact Lewin weakened the case for spring sapping by explaining that the reason why some of the dry valleys on the Wolds did not have steep head-walls was because the backwall slopes had been modified and reduced in steepness by the erosive effects of snow-meltwater. No explanation was offered as to how snow-meltwater could selectively reduce the steepness of some backwalls and not others, even though such diverse valleys are found in close juxtaposition. Furthermore there seems to be a general misconception concerning the number of valleys which actually have steep headwalls. If the long profiles of all the dry valleys and their tributaries are surveyed and plotted to a common scale three conclusions may be drawn: first it is very difficult to find and define a valley with a "steep headwall"; secondly that a series of graduations exist between what may be defined as "steep" and that which is supposed to be "gentle"; thirdly that the steepest part of a valley long profile is rarely found at the valley head, (fig. 84).

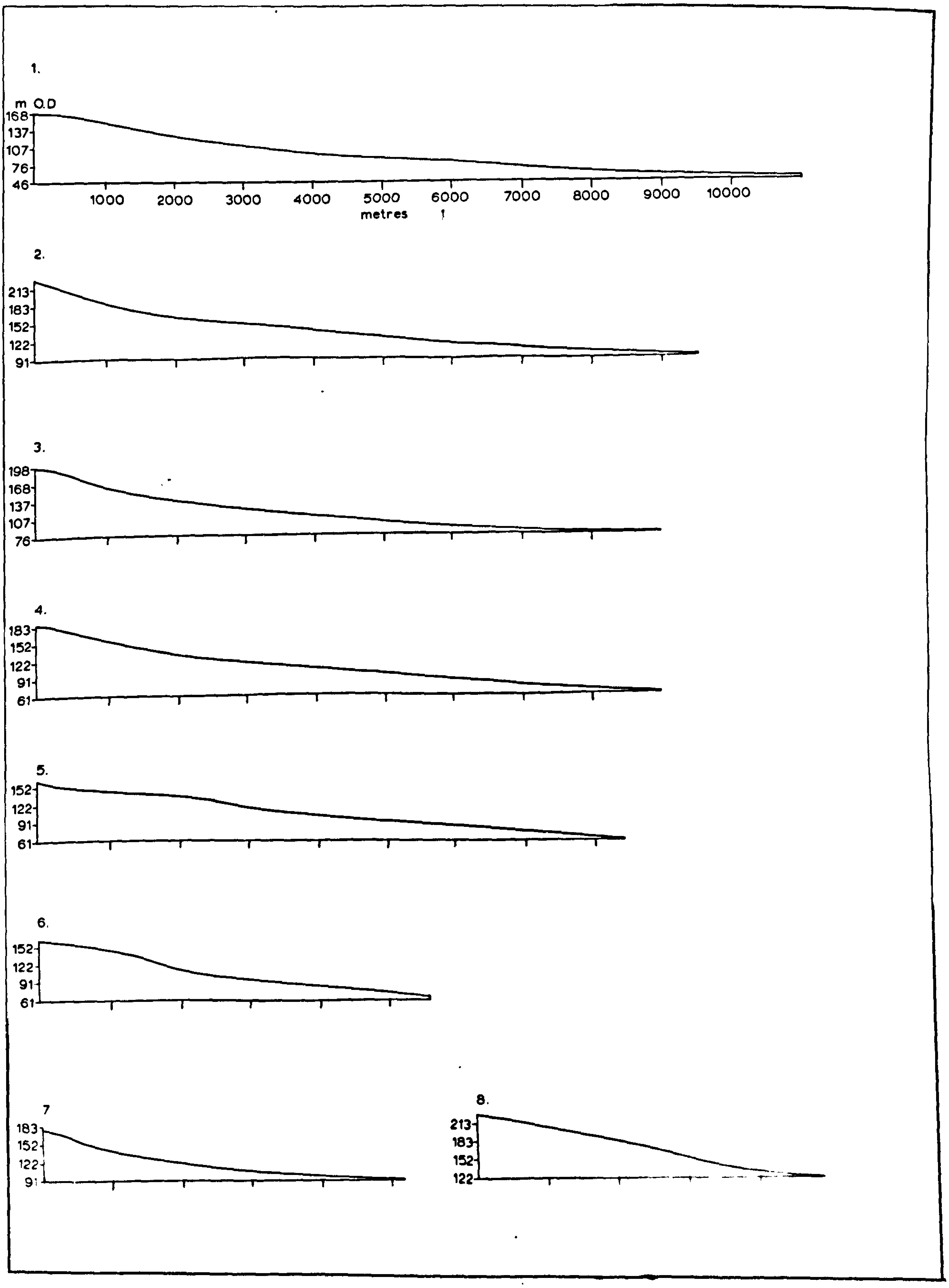
Even allowing for a liberal interpretation of the concept of "a steep backwall" (i.e. a slope of greater than 15°), 28% of the valleys could be said to have such a steep slope in their long profile but 82% could not. It is also notable that few of the "backwalls" of the valleys are as steep as the surrounding valley-side slopes. If the spring sapping hypothesis was correct the backwalls of the dry valleys should be at least as steep as, if not steeper than the valley sides because it was at the foot of the backwall that the most active erosion was supposed to have occurred. Kerney <u>et al</u>. (1964) also showed that the plan of the scarp dry valleys on the North Downs tended towards a V shape in plan rather than an open U as is most commonly assumed. The V shape would have resulted from the flow of meltwater down the backwall rather than spring-sapping at the base. On the northern Wolds similar V shaped plans are found to be coincident with the steeper parts of the valley long profiles, e.g. Horseshoe Bank, Fairley Dale, Burdale, Cow Dale etc.

c. <u>The probable origin of the dry valleys of the Northern Yorkshire Wolds</u>

From the evidence discussed so far, it is clear that the valley network has developed in two distinct phases, the first involving the

Fig. 84a Long profiles of the Yorkshire Wolds dry valleys:-

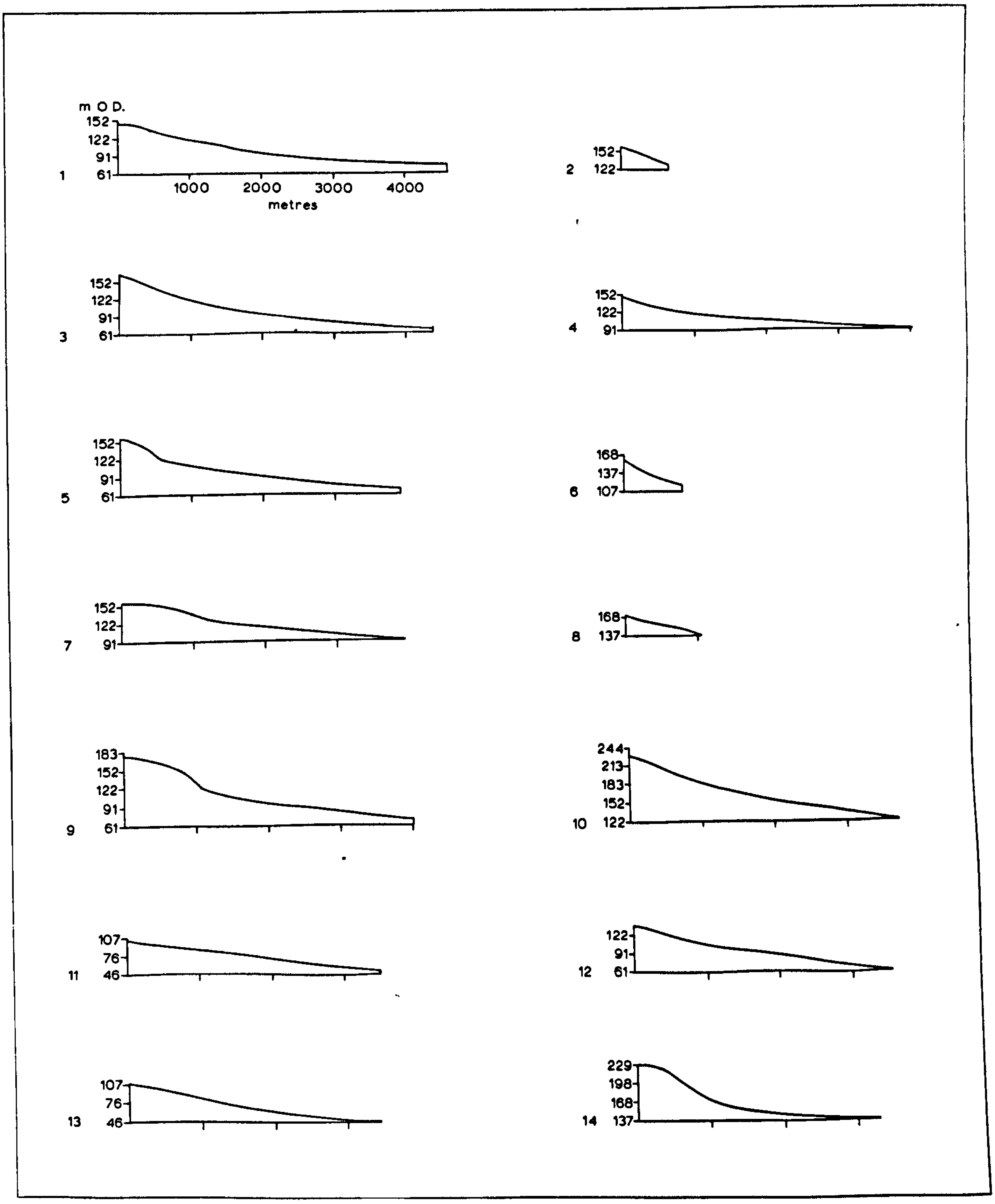
1. Ganton Dale
2. Water Dale
3. Croom Dale
4. War Dale/Weaverthorpe Slack
5. Old Dale/Haverdale
6. Galloping Slack/Rabbit Garth Slack
7. Old Dale, Kirby Grindalythe
8. Wharram Dale



1.
m O.D
168
137
107
76
46
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
metres
2.
213
183
152
122
91
3.
198
168
137
107
76
4.
183
152
122
91
61
5.
152
122
91
61
6.
152
122
91
61
7
183
152
122
91
8.
213
183
152
122

Fig. 84b Long profiles of the Yorkshire Wolds dry valleys:-

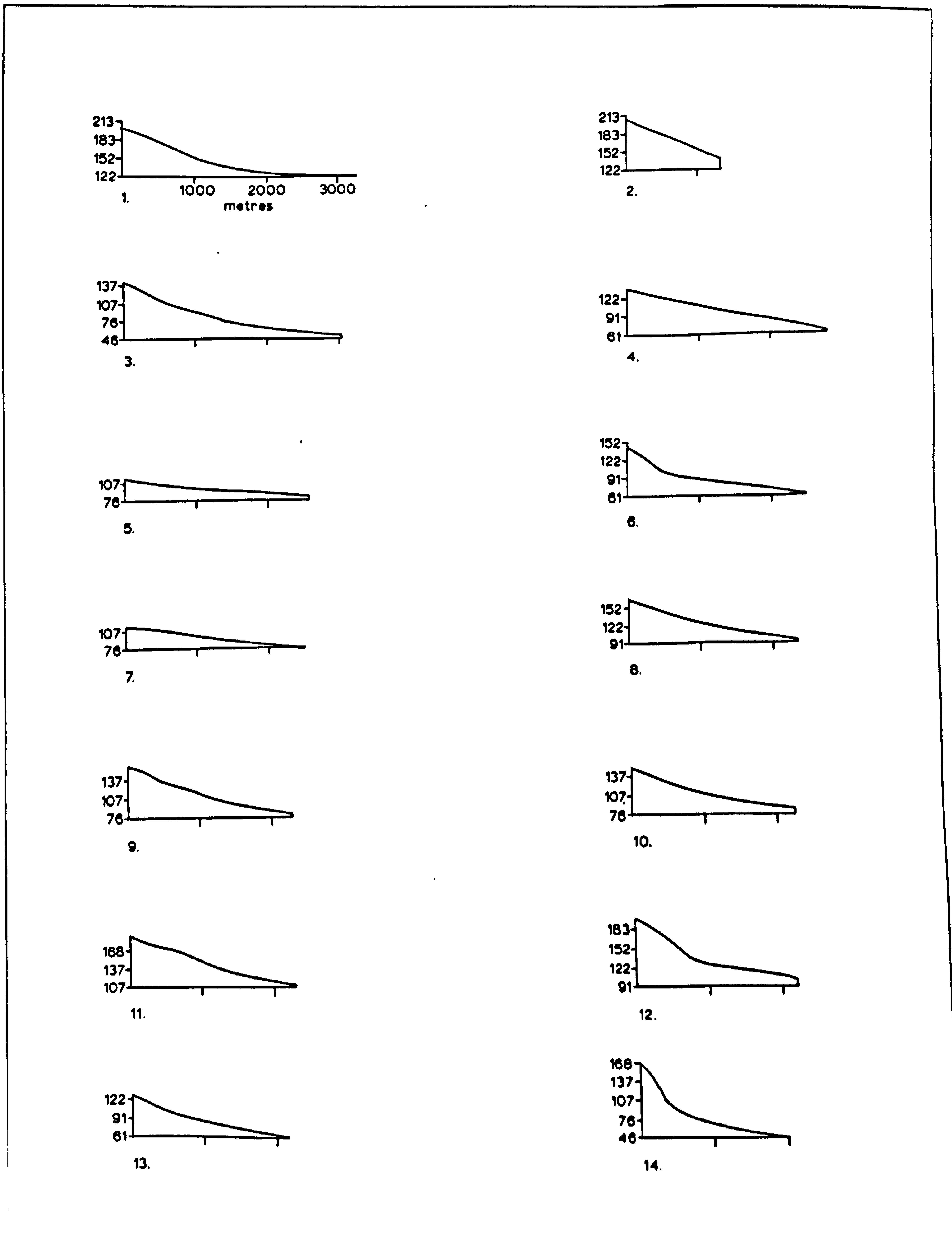
1. Merry Dale
2. Merry Dale (west head)
3. Warren Slack
4. Croom Dale
5. Cooper's Bottom
6. Cooper's Bottom (east head)
7. Well Slack
8. Well Slack (east head)
9. Wad Dale
10. Vessey Pasture Dale/Back Dale
11. South Dale
12. Camp Dale
13. Syn Dale
14. Thixen Dale



m O D.
1
152
122
91
61
1000
2000
3000
4000
metres
2
152
122
3
152
122
91
61
4
152
122
91
5
152
122
91
61
6
168
137
107
7
152
122
91
8
168
137
9
183
152
122
91
61
10
244
213
183
152
122
11
107
76
46
12
122
91
61
13
107
76
46
14
229
198
168
137

Fig. 84c Long profiles of the Yorkshire Wolds dry valleys:-

1. Nova Slack (east head)
2. Nova Slack (west head)
3. Old Dale, Octon
4. Helperthorpe Slack
5. Crook Dale, West Lutton
6. Buttermere Slack
7. Flemming Dale
8. High Croom Dale
9. Belle View Slack
10. Thirkleby Slack
11. Duggleby Dale
12. Low Mowthorpe Slack
13. Syn Dale
14. Ganton Peak



213 183 152 122
1000 2000 3000
metres
1.
213 183 152 122
2.
137 107 76 46
3.
122 91 61
4.
107 76
5.
152 122 91 61
6.
107 76
7.
152 122 91
8.
137 107 76
9.
137 107 76
10.
168 137 107
11.
183 152 122 91
12.
122 91 61
13.
168 137 107 76 46
14.

Fig. 84d Long profiles of the Yorkshire Wolds dry valleys:-

1. Sked Dale
2. Anderson's Slack
3. Fairey Dale
4. Old Dale, Butterwick
5. Stocking Dale
6. Flixton Slack
7. Fordon Dale (west head)
8. Fordon Dale (east head)
9. Ling Hall Slack
10. Weaverthorpe Pasture Slack
11. Green Lane (east head)
12. Green Lane (west head)
13. Kirby Grindalythe Dale
14. East Croom Dale
15. Sledmere Dale
16. Cherry Dale
17. Thixendale
18. Whay Dale
19. Deedle Dale
20. South tributary, Old Dale, Kirby Grindalythe
21. Scramble Bank

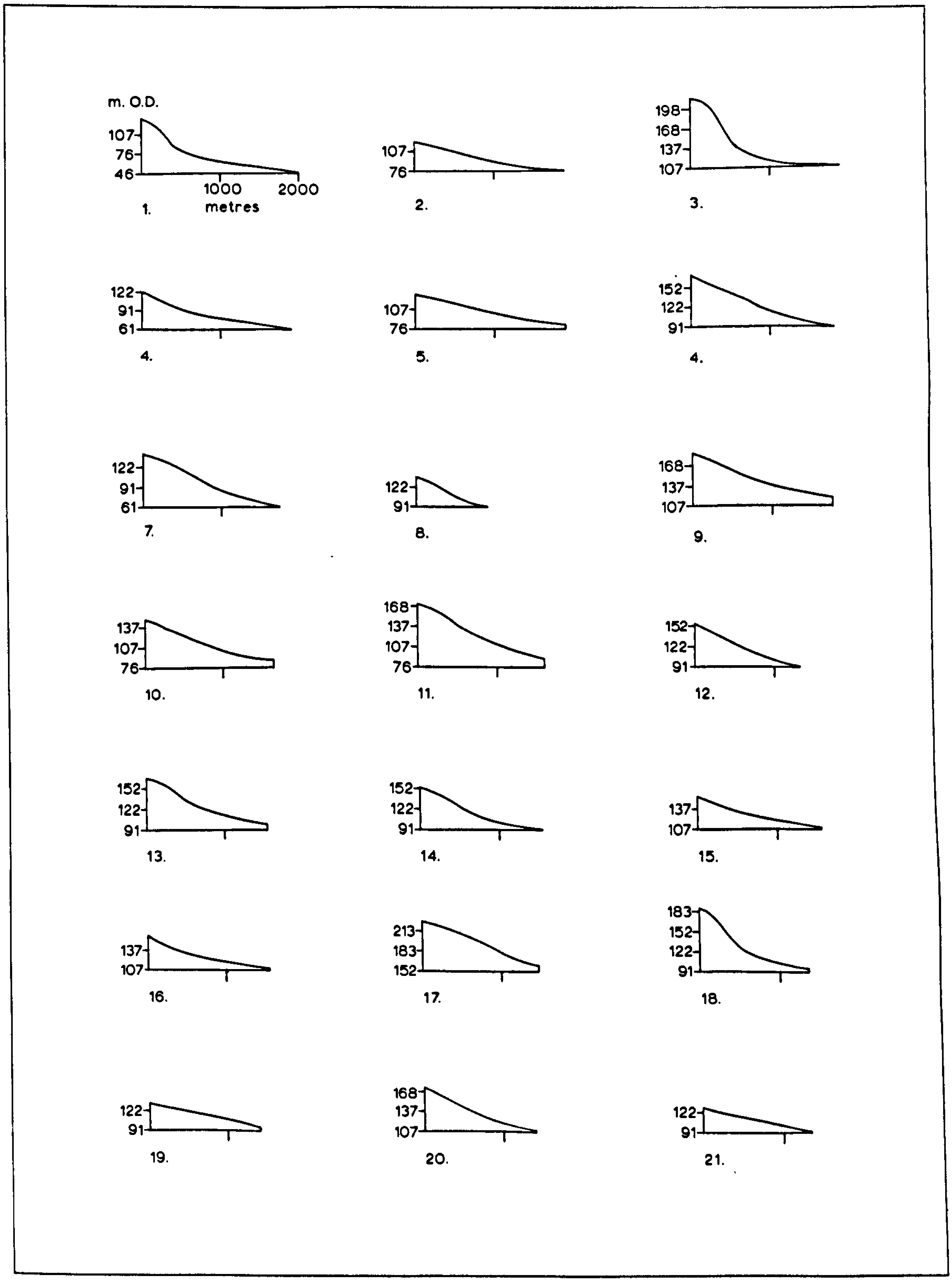


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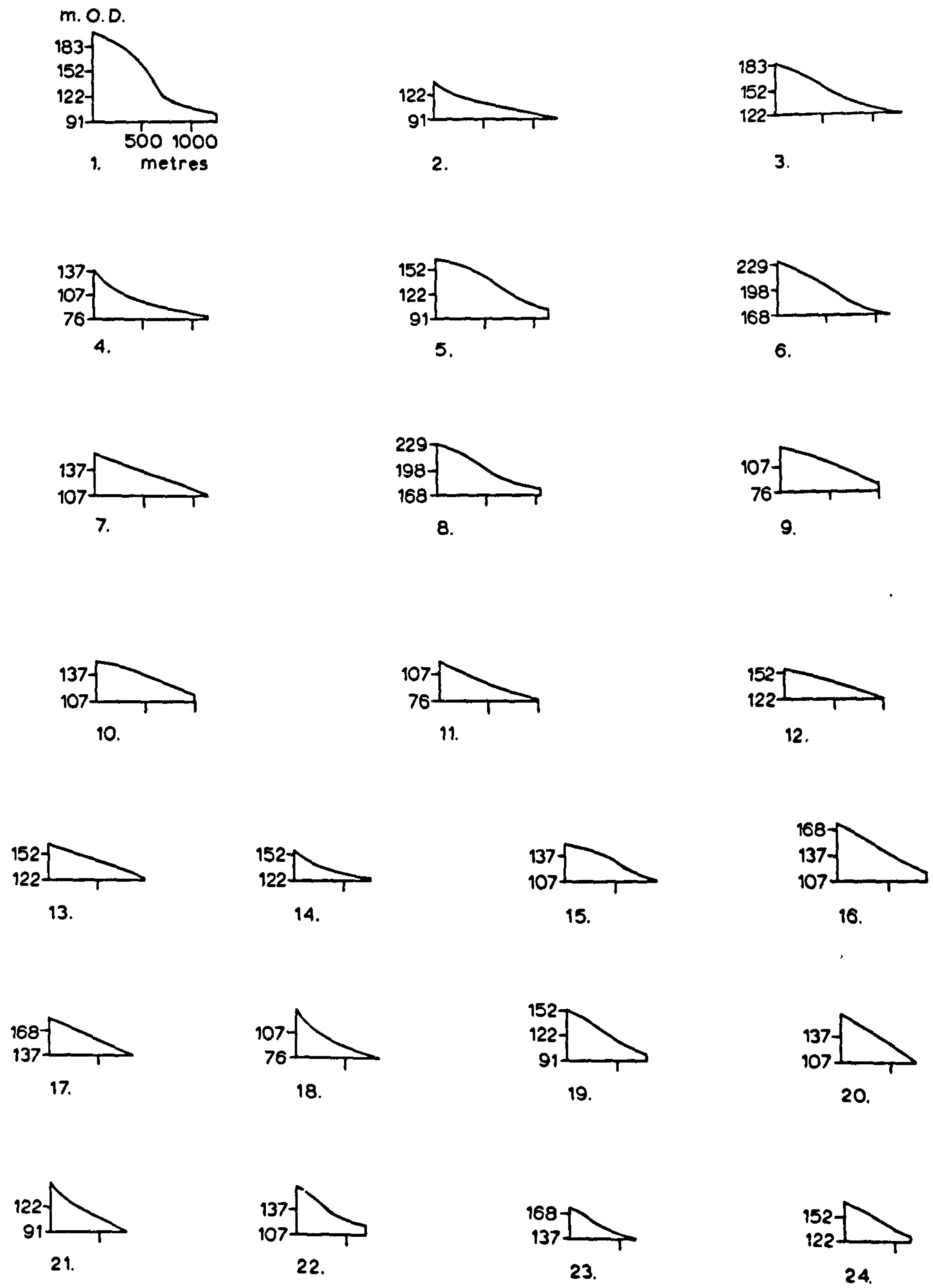
Fig. 84e Long profiles of the Yorkshire Wolds dry valleys:-

1. Middle Dale
2. Croom Slack
3. Crook Dale
4. Weaverthorpe Pasture Dale
5. Owlet Dale
6. Water Dale, southern tributary
7. Mowthorpe Slack
8. Water Dale, north-western tributary
9. Falkener's Slack
10. Several's Slack
11. High Barn Slack
12. Lawson's Slack
13. Rabbit Garth Slack
14. Prodham's Slack
15. Raven Dale
16. Western tributary, Cotton Dale
17. Ling Hall Slack, western tributary
18. Cotes Slack
19. Haverdale Slack
20. Whin Moor Slack
21. Larkhill Slack
22. Cotton Slack
23. Low Mowthorpe Slack, east tributary
24. Ling Hall Slack, eastern tributary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excavations of the trunk dry valleys, the second involves the cutting of the low order tributary channels which are common in the area.

The trunk dry valley: the reasons for the rejection of the spring-sapping and related hypothesis have been discussed at length above, but nonetheless the excavation of the dry valleys must have been a prolonged affair and may well have involved periods of excavation and periods of stability when no erosion occurred, as at present (Jones 1981). There are four possible explanations for the origins of these valleys:-

i. they may have been superimposed from an impermeable cover (Catt and Hodgson 1976 - see above p. 186). In Yorkshire the evidence for a former thick wide-spread cover of clays-with-flints or any other late Tertiary impermeable cover is lacking, but it is possible that such a cover may have existed in the past but has been almost completely stripped away in the successive glacial and peri-glacial phases of the Pleistocene - the exceptions being isolated solution hollows on the interfluves (Matthews 1977).

ii. an extension of this theory could be that an impermeable cover (on the interfluves at least), was provided by a former till sheet derived from Older Drift glaciations. If Bisat's suggestion that the scattered erratics on the Wolds are of Older Drift origin (and many of them may well be so), the former existence of a till cover of low permeability cannot be ruled out.

Either of the above impermeable covers would have greatly contributed to increased run-off and may have led to greater flows of water in what are now dry valleys.

iii. Ineson (1963) has suggested that the valleys have gradually become dry as the joints in the chalk have been progressively opened and widened by continuous solution. If the suggestions concerning impermeable covers on the interfluve catchments are correct, then progressive solution along joints may well be a contributary factor to the dryness of these valleys as the water drainage from the impermeable cover on the interfluves would tend to be unsaturated in carbonates and well able to dissolve more lime: iv. the peri-glacial hypothesis which suggests that the dry valleys were largely excavated during periods when permafrost affected the areas concerned (Bull 1936, 1940, 1942, Reid 1887, 1892), or when conditions were very much colder and frost was much more active in breaking down the chalk to a rubbly mud which could easily be carried away (Kerney et. al., 1965, Kerney 1964, Paterson 1970, 1976), has much to commend it. In the Vale of Pickering there is a large mass of chalk/flint gravel north-east of Sked Dale, Sherburn, which, together with the large quantities of chalk and flint gravels found in the Sherburn sands in the southern Vale of Pickering, may originally have been derived by frost-shattering of the chalk (as indicated by the angularity of the material) but has later been reworked by meltwater. (In this case ice-meltwater was probably responsible for the earlier, lower gravels, and snow meltwater may have eroded and deposited the younger, upper gravels). This evidence suggests that Sked Dale was being actively eroded during the mid or late Devensian, as was much of the rest of the escarpment. Secondly, the presence of chalk and flint gravels (up to 12 m thick is a borehole south of Foxholes) which are also angular but undoubtedly in part water-laid (as at Boythorpe: SE998718) suggests that erosion of the dip slope dry valleys was also taking place at this time. The record of 3 - 4 m of "water-laid" gravels in Thixendale (Mortimer 1885) and the presence of even thicker gravels (at least 4 m) at Garton Slack near Wetwang (SE 945601) all support the thesis that the dry valleys and chalk were being eroded in the late Devensian period. The considerable spreads of chalk and flint gravels over the tills of western Holderness around Driffield and at the mouth of the Great Wold Valley show that some movement of this material has occurred since the deposition of the tills was completed - probably a little more than 13500 years B.P. (Catt and Penny 1966). This evidence is further supported by the presence of a large abandoned meander at Rudston in the Great Wold Valley which contains organic material which is at least as old as Zone III (J.R. Flenley, pers. comm.), the meander probably representing the latter phases of high discharges in the Gypsey Race during Zones I and II.

The dating of these gravels is not possible using absolute methods as no organic material has been found, but the mixing of outwash sands and chalk/flint gravels in the Vale of Pickering supports a late glacial age for some of the erosion - the burial of the gravel lens at Sherburn lends further evidence to a late-glacial phase (if it was pre-glacial it would almost certainly have been much more disturbed by the ice and mixed with other materials). On the Wolds dip slope, the presence of shallow cryoturbation structures indicates that either the cold phase which followed their deposition was not particularly severe or short-lived - indeed by comparing these structures with similar ones found in the Vale of Pickering (which are almost certainly Zone III in age), and the structures on the North Yorkshire Moors (Dimbleby 1952, Edwards 1978), which are probably mid-Devensian and very much larger, a very late glacial age is proposed for the structures in the chalk gravels on the dip slope, and consequently a mid to late-glacial age is proposed for all these water-laid gravels.

The presence of these large amounts of fluviatile gravels in the bottoms and mouths of dry valleys, together with their relatively undisturbed state shows that some excavation must have occurred during late-glacial times: Lewin (1969) considered that this represented the weathered residue of the chalk which had slipped or soliflucted into the valley floors from the valley sides. However the undoubted fluviatile features found in these deposits and their extension well beyond the chalk outcrop indicate clearly that reworking by water did occur on a considerable scale, and that erosion of the valley floor and sides cannot be ruled out - indeed it seems very likely that this was occurring on a large scale.

The tributary gullies: The sheer number and density of these channels implies that short-lived conditions occurred when they formed, otherwise they would have become more integrated into the general drainage pattern. They can be fairly closely dated by several pieces of evidence:-

a. they cut the marginal drainage channels on the northern escarpment and are found extending from the chalk onto the Devensian tills in the Hunmanby area. On these grounds they must therefore post-date the last major glacial phase in this region;

b. they are cut into solifluction gravels (as at Old Dale) - they are therefore contemporary with or post-date the last major peri-glacial phase;

c. the gravels in the Great Wold Valley at Boythorpe and Garton Slack near Wetwang are water-laid, yet the surface has been disturbed by cryoturbation. These gullies represent considerable run-off which would be reflected in part at least as bed-structures in the water-laid gravels of the dry valleys - the presence of undisturbed, probable Zone III cryoturbation structures indicates that the main period of erosion and deposition had probably largely ceased by this time;

d. the presence of occasional small fans of material at the bottom of some of the gullies (e.g. in Old Dale and Camp Dale) further indicates a fairly recent origin as these have not yet been destroyed by solution in post-deposition times.

From the above it would seem that the tributary gullies must have been excavated under conditions which were very different to those which exist today. Run-off conditions must have been much higher and flooding (probably seasonal) common. The most suitable (and geologically recent) periods which could supply these conditions would be either the late glacial melting phase and/or pollen Zone III times, when winter snow falls were fairly high and the spring melt phase short-lived. In connection with this it is noteworthy that Gregory and Walling reported that in many modern Arctic areas seasonal dry valleys were found to have developed and become adjusted to spring flood discharges - in their study there was little or no development of permafrost (Gregory and Walling 1973). In the Łodz uplands of central Poland Klatkowa (1965) described large dry valleys which functioned during interglacial as well as glacial periods but were abandoned in post glacial times due to changes in the climate and basin characteristics which altered the drainage network. Smaller gullies (vallons en berceau) or dellen were found on the sides of the dry valleys which Klatkowa showed were of periglacial origin. Similar features were recorded by Gregory (1971) in S.E. Devon, and were also considered to have been formed under peri-glacial conditions. Finally the well known studies of Kerney et. al., (1964, 1965) and Paterson(1970, 1976), on the South Downs and the Chilterns respectively showed that when gully-like coombes developed on the chalk the ground was probably not affected by permafrost but that high run-off conditions did exist during the spring melting phase.

The strong similarity of the secondary (dry gully) system on the Wolds to the dellen found in Poland and the coombes of Southern England is one which cannot be ignored when discussing their possible origins. The exact combination of factors which led to their formation cannot be ascertained with certainty now, but the evidence shows beyond doubt that they formed very rapidly in late glacial times, possibly under perma-frost conditions but equally possibly under conditions of high winter snow fall and sudden spring thaws unaccompanied by permafrost. During this phase erosion was both rapid and highly concentrated and may well have been responsible for the removal of large amounts of loess from the interfluves and valley sides. Other glacial or inter-glacial and pre-glacial sediments would also have been heavily eroded at this time, the material being carried into the dry valleys and the finer particles (especially those derived from loess), carried away in suspension or filtered between the gravels to form a matrix as the seasonal streams dried up.

There remains one group of relatively minor features on the Wolds which have not been discussed. These are the shallow linear depressions found on Settrington and Staxton Wolds and which were described in Chapter III as possible sub-glacial channel relics. It is quite possible that these features are of sub-glacial meltwater orgin, but an alternative suggestion of their origin is that they have resulted from solution along bedding planes and joints in those parts of the chalk affected by tectonic disturbances (R. Evans, pers. comm. 1977). Detailed mapping and surveying of the depressions on Staxton Wold has failed to reveal any evidence which would support or refute the solution hypothesis. However, in view of the presence of probable solution hollows described in Chapter IV this hypothesis cannot be entirely ruled out.

D. Conclusions

From the evidence available from the Northern Yorkshire Wolds it is concluded that the landscape is largely the product of various peri-glacial processes and that it has only been slightly modified since the end of the Devensian. Landslipping and solifluction, combined with the effects of snow and ice-meltwater were largely responsible for the shaping of the present landscape, although the actual origin of the dry valleys is still an open question. The dry valley system could have been superimposed from an impermeable cover of Tertiary or younger rocks, and was almost certainly modified by snow meltwater at the end of the Devensian period.

CHAPTER VI

LAKE PICKERING AND THE NORTHERN YORKSHIRE WOLDS AFTER 84 YEARS

A re-assessment of Kendall's pro-glacial Lake Pickering theory and the evidence used to define the maximum limits of advance of the Devensian ice in the Vale of Pickering and on the Northern Yorkshire Wolds is now possible. However before any revised reconstruction of the sequence of events can take place a chronological framework must be established. The lack of C_{14} dates excludes an absolute chronology, hence only a relative sequence based upon the principles of stratigraphy and where this fails, interpretation of critical evidence, is possible. Opinions may differ as to what constitutes critical evidence and the difference in interpretation may markedly affect the resulting reconstruction of the history of the area. One method by which the variation of opinion may be reduced is to compare the region under study with other broadly similar areas where the local histories have been recently re-interpreted using both absolute and relative forms of dating. Two such areas are the southern Vale of York where absolute dates have provided a fixed chronology (Gaunt 1976a) and the Eskdale area of north-east Yorkshire where some years ago Gregory re-interpreted the history of the area using relative methods of dating (Gregory (1962a, b, 1965). However such comparisons must be used with care and any reconstruction of the history of the Vale of Pickering must still be regarded as tentative until more adequate methods of dating are available.

A. The Relative Age of the Drifts and Landforms of the Vale of Pickering and Northern Yorkshire Wolds

The discussion of the relative age of the drifts and landforms of the study area conforms roughly to the descriptions in earlier chapters.

i) <u>The buried valleys of the Vale of Pickering</u>

The buried valley system must have been cut at a stage of relatively low sea levels and thus probably represent a phase of incision and falling sea levels prior to the advance of one of the Quaternary ice sheets. During this incision phase the local sea level must have been at least 31 m below O. D. even assuming that the coast at that time roughly coincided with the modern coastline - if however the shoreline had receded into the North Sea Basin the relative fall in sea level at this stage may have been lower. This depth of incision is broadly comparable to that quoted by Gaunt for the early-mid Devensian levels in the southern Vale of York (Gaunt 1976a). The result of this deep incision phase was to cause the excavation of a deep and relatively narrow trunk valley which had relatively short but steeply graded tributaries from the south: in the west the level of incision was much less marked as borehole data show that the buried valley floors west of the line Malton-Pickering vary from c + 22 m to +18 m O. D. The northern tributaries which drain the area between Pickering and Seamer must also have been affected by this incision phase but there is no borehole evidence available at present to indicate the extent or depth of erosion. The increase in gradient of the buried trunk valley floor in the area between Malton and Pickering may be due either to a change in the lithology (and therefore resistance) of the clay floor or to the combined increase in erosive power of the several tributaries which drain the western end of the Vale of Pickering.

If this phase of incision is comparable in age with that described by Gaunt in the Vale of York it must represent the greater part of the Devensian period as this phase appears to have lasted from circa 70,000 years to circa 20,000 years B. P. or a little later (Gaunt 1976a, Mitchell <u>et. al.</u>, 1973).

The embayment in the area south of Malton is of interest because it could be evidence for an earlier age of the Kirkham Valley than that suggested by Kendall (1902) - however more detailed borehole evidence from this area and from the Kirkham Valley itself would be required to prove the relative levels of the rock floor in this area. The origin of the channel as a passive outlet from a lake dammed in the Vale of Pickering as suggested by Kendall is also highly unlikely, especially as there are lower outlets in the Howardian Hills to the west (Melmore 1935), but a sub-glacial origin must also be considered unproved at present as there is no evidence to support this and the feature is rather large to have been formed in this way (Edwards 1978). Joint control of the orientation of this valley is the only statement which can be made with any certainty concerning the genesis of this valley (Harrison and Thackery 1940). It is probable that the Kirkham Valley was used as an overflow channel for lake waters and glacial meltwater during the Devensian period, but it is equally probable that other outlets from the area were opened at different times during deglaciation but have since become blocked (see below).

ii) The erratics and gravel deposits of the western Vale of Pickering

The scattered drift blocks which cap the low hills of the western Vale of Pickering and Ampleforth gap were originally dated by Bisat as pre-Devensian (Bisat 1940). This estimate of their age was based largely upon the weathered state of some of the material recorded by Gayner and Melmore (1936) and the apparent lack of any continuous till sheet: the blocks appeared therefore to represent the weathered remanie of an older till. However, Fox-Strangways' record of oolitic material in the soils in several areas of the western Vale and this author's record of similar material in the gravel at Marton could suggest that these deposits may not be as old as Bisat originally suggested. Most of the material in this area is of local (i.e. Jurassic or Cretaceous) origin but its size and topographical location imply that ice may well have been the transporting agency.

Whether this ice was of Devensian or pre-Devensian age is still debatable but if the presence of easily weathered limestones is used as an indicator of age these must represent a rather late deposit (Bisat 1940). The weathered material reported by Gayner and Melmore (1936) from the extreme western end of the Vale could be taken to represent genuine Older Drift _in situ_ or Older Drift which has been re-incorporated into a younger deposit.

The remanié drift capping of the low hills in the Ampleforth gap is very similar to that found in the remainder of the Western Vale of Pickering. Locally derived, fairly resistant Jurassic gritstones are dominant. One gravel deposit in the area south of Ampleforth village did show erratics derived from the Lake District and Pennines however. The latter were considered by Edwards and Harrison to be characteristic of Older Drift deposits on the western side of the Vale of York (Edwards _et. al._, 1940, 1950, Harrison 1936). However, the possibility that Older Drift deposits were being reworked by Devensian glaciers must again be seriously considered in the light of the evidence of the large clay raft at Wath. This raft is hardly weathered and yet is in such a location that it must be presumed that ice was responsible for moving it into its present position. However, if the glacier which was responsible for the emplacement of the Wath erratic was of Devensian age the constantly recurring question: "Where are the other forms of sedimentary evidence, especially tills, to be found ?" once again arises. This question is also very pertinent when considering the age of all the other deposits in the Vale of Pickering west of Wykeham and on the Northern Wolds escarpment west of Flotmanby (see below).

Edwards (1978) stated that the scattered drifts of the western end of the Vale of Pickering were derived from the North Yorkshire Moors by snow meltwater streams which flowed across patches of partially melted firn and frozen lake or lakelets, depositing channel-like spreads of coarse gravels, including that at Marton. This theory has much to commend it. However, the interpretation can easily be extended from firn to ice in the form of the most westerly lobes and tongues of the North Sea Ice or the most easterly limits of the Vale of York ice which penetrated the area via the Ampleforth Gap. The minimum thickness of the North Sea Glacier and Vale of York glacier (200 - 215 m and 130 m respectively) as indicated by evidence of drainage channels, would be quite sufficient to send lobes of ice into the western end of the Vale of Pickering, (due to the influence of gravity flow at the snouts), well beyond the Thornton-le-Dale limit of Edwards (1978) which probably represents a local northern limit of advance in that area, rather than a limit for the whole valley. The uneven nature of the topography of the western Vale would almost certainly have caused the advancing glacier snouts to divide and flow around local obstructions, especially as they would have been close to the limits of their advance. In this way the erratic material may well have been derived from the glaciers flowing around the edges of the North Yorkshire Moors and deposited by meltwater streams flowing from the ice. The clay raft at Wath was almost certainly emplaced by ice during the Devensian, and lends support to the theory that the more resistant material could have been reworked or emplaced by Devensian ice. Small marginal lakelets may well have formed at this time, especially as snow-meltwater from the North Yorkshire Moors would have flooded into this area during spring thaws. These lakelets would have joined together and enlarged as the ice began to melt down and in this way the ancestor of Edwards' (1978) lake in the western Vale of Pickering may well have become established, although this would probably have been an ephemeral feature as is the nature of such lakes. The exact age of the clays recorded by Edwards (1978) is in doubt - the presence of birch twigs suggests that deglaciation was well under way by the time that they were deposited. It seems probable that the Pickering "delta" was built up at an early stage in the history of this lake, - the material would represent gravels gathered by melting firn and snow-fields on the N. Yorkshire Moors (possibly incorporating some melt-water from the Eskdale glacier), which drained via Newton Dale into the Vale of Pickering. Judging from the size of some of the material found there, these meltwater streams must have had a considerable discharge (Sewell 1904a). It is equally possible that the Pickering "delta" was built up in an ice-marginal lake - especially as the level of the lake clays (circa 34 m) is much higher than that found in the main part of the Vale and which probably represent a later lacustrine phase.

The determination of the relative age of the marginal drainage channels above Ampleforth Village depends entirely upon comparisons of morphology with comparable features in other parts of the country, and the general state of preservation of the channels. Comparison of morphology with channels in other areas shows that these channels are very much like Devensian channels in parts of Eskdale, the western Lake District and central Sweden (e.g. Mount Grasidan), and those channels on the northern Wolds escarpment which are believed to be of Devensian origin too. Such comparisons on morphological grounds are of course a very subjective method of dating, but the relatively recent age would tend to be supported by the lack of any significant infill of solifluction or wind blown deposits, both of which could easily have been trapped and would have been well protected from further erosion.

iii) <u>The Thornton-le-Dale Drifts</u>

The sections recorded by Edwards (1978) and the author at Church Lane in the north of the village and by Fox-Strangways in the old railway cutting in the south are so markedly different that some doubts must be expressed as to whether these represent part of the same overall deposit or whether they are parts of two quite separate drifts. The section recorded by Edwards (1978) and the author is noteworthy because of three characteristics: the lack of cryoturbation, deep leaching or weathering, the local nature of the bulk of the clastic material and the ubiquitous presence of oolitic limestone fragments. The outwash sands which overlie the till are noteworthy in that they contain lenses and streaks of finely comminuted coal fragments. In these characteristics there can be found similarities to deposits both to the east and west. The presence of large quantities of locally derived Jurassic sandstones and gritstones is characteristic of the Devensian tills in the eastern Vale, as are the presence of lenses and seams of comminuted coal in the outwash sands. Coal fragments are also common in the outwash sands on the southern side of the Vale and on the Northern Wolds escarpment. The presence of locally derived Jurassic grits and sandstone pebbles, together with rarer oolitic fragments is apparently characteristic of the scattered drifts capping the hills of the western Vale of Pickering. Jurassic material, including oolite, also forms an important component of the non-chalky drift in the section at Luttons Lane on the Northern Wolds escarpment.

Edwards (1978) has also shown that the Thornton-le-Dale till represents a morainic deposit with a characteristic gravel splay in front of it. However, he was uncertain whether this represented the maximum limit of advance of the Devensian ice in this part of Pickering or whether it represented a re-advance stage which is found in other parts of the U. K. and the world (Gaunt 1976a, Dansgaard et. al., 1969, Epstein et. al., 1970, Ericson and Wollin 1956, Emiliani 1966, Griggs et. al., 1970). It seems likely that Edwards' conclusion that the Thornton-le-Dale moraine represents the local limit of advance of the Devensian ice in this northern area is correct, but his assumption that the snout of the ice passed due south to the Wolds scarp is almost certainly wrong, for the reasons explained above and below.

iv) The drifts and marginal drainage channels of the northern Wolds

The drifts and marginal drainage channels of the northern Wolds escarpment appear to be intimately related and are therefore discussed together here. For reasons which will become apparent in the course of the discussion the age of the scattered erratics on the dip slope will also be discussed.

The drifts and drainage channels of this part of the Vale may belong in age either to the Older Drift or Newer (Devensian) Drift. The former view has much to recommend it on first sight. The isolated and apparently dissected nature of the drifts is perhaps the most important line of evidence. There is also the lack of any significant boulder clay deposits and the almost total lack of far travelled material. In support of the Newer Drift hypothesis there is the notable lack of evidence for weathering or cryoturbation, the preservation of uncompacted sediments in extremely exposed positions high on the north-facing escarpment, the preservation of sedimentary structures in the sands, the presence of numerous striated chalk fragments in the section at Luttons Lane, West Heslerton, the presence of coaly fragments in all the sand pockets (except possibly Flixton) and the similarity of the deposits east and west of the Ganton area where the Devensian ice sheet is often supposed to have terminated (Kendall 1902, 1903a, b, Penny and Rawson 1969, Penny 1974). The drainage channels, like all morphological evidence, are almost impossible to date but two facts can be stated with some certainty and without too great a fear of contradiction. Firstly they form a continuous downslope sequence and secondly there are no major variations between those channels to the east of Ganton and those to the west. From this evidence it may be concluded that the channels form part of a coherent, continuous system which was cut in one glacial stage. The discussion must therefore centre on the age of these features.

The strongest argument in favour of the Older Drift hypothesis for the age of the drifts of the northern escarpment lies in the patchy nature of the distribution of the deposits. This could be taken to imply that these represent the dissected remnants of a once semi-continuous or continuous group of deposits which have since been almost obliterated by erosion. The general lack of tills in the Vale west of Wykeham (except on the northern side) appears to support this Older Drift hypothesis. In addition the differences between the sands on the scarp and in the Vale of Pickering on both sedimentological and mineralogical grounds could be said to support the Older Drift hypothesis.

These arguments may be countered by the Newer Drift hypothesis as follows. First the ice which deposited the sediments on the escarpment may not have been carrying a very large load - the thick drifts in the mouth of the buried valley and the shear-clays at Reighton (Edwards 1978) indicated that there was some congestion in this area and that the upper layers of the glacier may well have been overriding the lower, trapped or slow-moving ice. Boulton (1972b) has described how the debris in glaciers in the Barnes Ice Cap is concentrated in the lower 30 - 40 m of ice and that the upper horizons tend to be relatively clear unless material has fallen from above on the glacier. If these conditions applied to the Devensian glacier which entered the eastern Vale of Pickering it is possible that the congestion indicated above could have caused the overriding of the lower ice by relatively clean, debris free upper ice. This latter would undoubtedly have brought some debris with it, possibly derived from the upper horizons of the slow moving or trapped ice in the eastern end of the Vale of Pickering. Locally derived material, especially chalk and rafts of clay would also have been incorporated into the lower horizons of this ice and these would have been carried up the escarpment if or when forward movement by the glacier was prevented by a barrier such as the scarp would present (Boulton 1972a, Sugden and John 1976). The patchy nature of these drifts may be further accounted for by postulating that erosion during the late glacal period by snow and to a lesser extent ice-meltwater removed the bulk of these deposits. It should be remembered that Gaunt has estimated that the southern end of the Vale of York was probably ice-free by circa 16,000 years B. P. and recent evidence from Eskdale suggests that deglaciation was far advanced if not complete by approximately the same time (Gaunt 1976a, Jones 1977). It would seem therefore that the ice which occupied the Vale of Pickering could well have melted away by 15,000 years B. P., leaving a 4,000 year gap before vegetation began to establish itself and prevent further erosion by spring thaw snow-meltwater. The presence of numerous gullies on the northern escarpment testifies that such erosion did occur and these may well have carried away the bulk of the evidence by which we now seek to justify a Devensian (or older) glacial advance into the western Vale of Pickering. The sand and gravel fan at Ganton could have been reworked and deposited at the foot of the escarpment by snowmelt processes described above.

The sedimentological and mineralogical evidence can also be given a plausible alternative explanation which could support a Younger Drift origin. In view of the large quantities of debris which were being worked out of the glaciers in the eastern Vale of Pickering it would seem highly likely that some at least of the finer sediments were carried westwards into the central parts of the Vale, where they were mixed with sand and chalk gravel derived from deposits cn the Wolds scarp. However, the original sands which were deposited on the northern escarpment may have been derived from a rather limited part of the total glacial debris carried by the Devensian glacier (as suggested above). Thus the sediments on the escarpment would be expected to be different from those in the Vale yet they could still represent deposits of the same glacial episode.

There are other weaknesses in the Older Drift hypothesis which must also be examined more closely. Once again the state of weathering and cryoturbation need to be properly analysed. The presence of clear sedimentary structures in some of the pockets of sand on the northern scarp, together with considerable quantities of chalk gravel is noteworthy. The evidence from Luttons Lane suggests that chalk formed an important component of any till or outwash deposit on the escarpment, but as this could also be easily derived by simple frost-weathering of the bedrock this does not lend much support to the Newer Drift hypothesis. The presence of numerous pebbles of striated chalk at Luttons Lane however does give support to a glacially-derived, Newer Drift origin for this deposit. In addition the presence of considerable numbers of fragments and several small rafts of Red Chalk suggests that this deposit has not undergone any severe or prolonged period of chemical weathering: the presence of oolitic limestone and the fresh nature of the deposit generally, combined with the presence of recognisable fossil remains in the clay raft may aso be taken as support for the lack of severe weathering of the deposit. This is in marked contrast to the strongly weathered and deeply leached nature of the Wolstonian or earlier drifts of the Lincolnshire Wolds (Straw 1964, 1969) and the western side of the Vale of York (Edwards et. al., 1940, 1950, Penny 1974, Gaunt 1976a). The apparent lack of well developed cryoturbation structures in these deposits cannot be used as evidence of age but nevertheless it needs an explanation. It would seem that the nature of the deposits is such that groundwater would be able to drain away fairly freely and this, combined with a topographical location where surface water would probably not be able to accumulate would suggest that the lack of groundwater was the prime factor in preventing the development of cryoturbation and frozen ground features. This would be applicable to those deposits regardless of their relative age.

The age of the marginal drainage system on the northern scarp and the presumed sub-glacial system on Staxton Wold can also be disputed. It has been suggested above that the drifts of the scarp appear to be closely related to the drainage channels - most of the sand pockets are found near to or above a marginal drainage channel while the deposits at Luttons Lane appear to fill an old channel. This, of course, cannot be taken as proof of contemporaneity. However the marginal drainage system, as stated above (p. 231) does appear to form a coherent and continuous system both vertically on the escarpment and laterally from east to west. If therefore this represents a pre-Devensian feature the question must be asked - why are there no indications of any change in the shape, depth of cutting, nature or infilling deposits, etc., in those parts of the system which lie east of Ganton compared with those which lie to the west ? The same question arises with regard to the drift deposits - the nature of the drifts east and west of the Ganton area is almost identical - if anything the deposits to the west are rather better preserved than those to the east. The reason for selecting the Ganton area has already been explained, yet the total evidence for the presence of ice in the recent past having abutted against the scarp is not as good in the area to the east of this line as it is to the west. No tills have been found east of Ganton, nor have any clay erratics, yet the marginal drainage system extends from Flotmanby in the east to Thorpe Bassett Brow in the west. (It can also be traced in intermittent sections on the scarp above Muston and eastwards to the coast north of Bempton Cliffs). There are possible traces of a sub-glacial system on Settrington Wold and on Staxton Wold although these could represent snow-melt phenomena as described in Chapter V. The scarp evidence of the drifts and drainage channels is strongly indicative of a single period of formation. If any part of the drifts or channels are accepted as Devensian the remainder of the drifts or channels must be of Devensian origin and the same rule applies if an Anglian or Wolstonian age is proposed.

The soils and scattered drifts on the Wolds dip slope may also help indirectly to date the scarp deposits and channels. The clays-with-flints would appear to be the oldest post - Cretaceous sediments on the Wolds - Matthews (1976) suggest a Late Tertiary or early Pleistocene origin for these - Catt (1982) supported the latter rather than the former age. The bulk of the soils on the northern Wolds appear to consist of blown sands with a subordinate loessic silt component - the latter probably represents a mid-Devensian deposit which accumulated prior to the maximum advance of the Devensian ice sheets when much of the North Sea Basin was dry (Catt et. al., 1974). However these silts were almost entirely stripped away in the field area, either during or just after the glacial maximum when ice and snow meltwater would have been at or near its maximum probably assisted by ice and snow meltwater and strong katabatic winds. Further erosion also occurred during late glacial times when melting snow and possibly firn fields and seasonally frozen ground conditions would have caused high run-off conditions and rapid erosion of the unconsolidated sediments and underlying chalk. The blown sands which now form the bulk of the inorganic content of the soil in this area could have been derived from remnants of glacial outwash deposits on the Wolds dip slope or from outwash deposits in the Vale of Pickering or North Sea area. The exact age of these sands is unclear but a relatively late date is most probable in view of the evidence of erosion of loessic soils prior to this. The filling of hollows in the chalk on the escarpment at West Heslerton, and frost wedges on the Wolds at Linton Farm and Knapton in the Vale of Pickering are also indicative of blown sand movement throughout the whole region. The Upper Sandy Beds of Bray et. al., (1981) at Fimber were also probably deposited at this time. The dominance of blown sands in the colluvial sediments in the dry valleys may also suggest a late glacial or very early post glacial age.

More recent blowing and drifting of the sands may have been caused by clearance of the lands on the southern margin of the Vale of Pickering for agricultural purposes - the archaeological evidence above that this has occurred at least once in post-medaeval times, (Manby, pers. comm.).

The age of the scattered erratic pebbles on the Wolds dip-slope has only been briefly reviewed before (Bisat 1940). Nevertheless this was a good review which ably summed up the evidence known at that time and the broad conclusion, that these deposits are probably very largely derived from Older Drift material, has not been brought into question by the new evidence presented here except in a few cases. The first of these is the area between the edge of the Devensian tills west of Hunmanby and a rough line running from Hunmanby Village to Camp Dale and then northwards via Merry Dale to the northern escarpment. In this region the erratics are too numerous to map individually and the density increases markedly eastwards, giving the impression that either this area was covered with till which has since been largely destroyed by ice and/or snow meltwater or that these pebbles represent the remnants of an outwash sequence. If the former is true, the Devensian ice must have overlapped the Wolds escarpment at least as far west as Snevver Scar which, as has already been described, is thought to represent a sub-glacial chute. Thus meltwater from the margins of the glacier almost certainly contributed to the formation of the dry valleys in this area (e.g. Flemming Dale, Camp Dale) although these valleys do not display any marked differences from any of the valleys further west or south.

The dreikanter which have been found on the Wolds by Matthews were ascribed by him to an early or mid-Devensian periglacial phase (Matthews 1977). However if the argument for the Devensian age of the drifts and channels of the northern scarp is accepted it is possible that some of the dreikanter and other erratics on the scarp and nearby dip-slope areas could represent scattered debris derived from the margins of the Devensian ice. It seems highly likely that many of these dreikanter are very resistant to abrasion and wear because facetted pebbles which have been cut in similar material (i.e. Carboniferous Gritstones) are fairly common in the coarse outwash gravels on the Wykeham complex; such pebbles are also found in the Devensian tills exposed at Star Carr.

The oolitic material at the southern end of Old Dale and in the Wintringham col, and on the western side of Camp Dale (where the septarian nodules were recorded) presents a more intractable problem. Snow or ice-meltwater washing the pebbles from the margins of the glacier would fail to adequately account for their distribution. The scattered patches of gravel at Linton Farm and in the Wintringham col at SE927702, together with the possible marginal drainage channels at Thirkleby Farm, are not sufficiently convincing evidence to support a Devensian glacier margin in this area, and even if they were, the mechanics of ice flow whereby the ice could have moved into these areas is difficult to understand as it would require a change in forward direction of the North Sea glacier of over 100°. Such a change could only have occurred if the glacier struck an insurmountable object in the western part of the Vale, and no such object exists today or appears to have existed in the past. However thick ice moving along the northern edges of the Wolds may have sent a minor distributary tongue into the Wintringham embayment and filled the latter (as appears to have been the case from the evidence of the erratics and possible channels on Thorpe Bassett Brow), but it seems unlikely that the lobe of ice could have continued to have advanced far into Wintringham col and left so little evidence of its former presence. Further it is difficult to explain why a relatively non-resistant rock should have survived the rigours of weathering and time while more resistant material (which would almost certainly have been carried by the glacier at the same time) is so much less common. These latter objections do not apply to the erratics east of Camp Dale - these could have been derived from the margin of the glacier by meltwater without difficulty.

The small patches of Sherburn-like sands which have been recorded on Staxton Wold and in Warren Slack can be interpreted in two ways. Either they represent direct outwash sediments from the glacier which deposited the sands on the escarpment, or they were reworked during the late glacial and possible Zone III cold period by snow-meltwater having been eroded from positions much nearer the scarp. The cryoturbation surface in the sands at Warren Slack suggests that some at least of the deposit was in situ during the last cold phase (i.e. Zone III) and may have been there earlier. However in view of the gullied sides of Warren Slack it would seem that a date much earlier than the dying phase of the late-glacial is unlikely because the deposit would otherwise have been swept away or buried under a considerable amount of gravel.

The Thixendale sands are very like the Sherburn Sands found on the northern scarp insofar as location is concerned. Their age is still problematical however, but the presence of quartzite pebbles should not be given too much weight or emphasis as secondary derivation from true Older Drift on the Wolds is always possible. The sands described by Lamplugh (Appendix A) in the lower part of Thixendale were probably deposited in the same manner as the Sherburn Sands at Warren Slack described above.

The last of the Wolds dip-slope deposits are those found in the fissures of the north-western area, at Thixendale, Fimber, Huggate and Linton Whins. The sediments at Huggate and Fimber appear to have been derived at least in part from loess (Catt et. al., 1974, Bray et. al. 1981) but a blown sand component is also present, (Bray et. al., op cit). They are probably of early-mid Devensian age but could equally well represent deposits derived from an earlier periglacial or glacial period, (Bray et. al.,). The Linton Whins deposit is altogether different. With its organic content it may just prove possible to obtain a C_{14} date in the future, although the reliability of the date may depend upon the degree of contamination by the surrounding and enclosed chalk and the actual age of the organic material. Indirect evidence from the enclosed and overlying loessic deposits suggests that an early - or mid-Devensian age may be indicated: alternatively this may also represent the remnant of a soil horizon of a periglacial phase of an earlier glacial period which has survived simply because it was buried. Whatever its age it almost certainly represents a semi-organic soil which sludged or slipped into a fissure in the chalk under frozen-ground conditions.

The dry valley gravels appear, like their counterparts in southern England, to have formed in the late glacial and/or Zone III periods, under periglacial conditions, (Kerney et. al., 1964, Paterson 1976). Much of the gravel was probably derived as a solifluction mud which slipped or was washed by snow-meltwater into the dry valley bottoms where meltwater streams carried large quantities of this material away. During a late stage of this process the slopewash became more concentrated and gullies were formed - perhaps this led to renewed erosion of the frost-shattered bedrock and the introduction of a coarser grade of debris into the dry valleys which has survived in some areas such as Warren Slack.

The gravels found at the foot of the northern Wolds escarpment probably accumulated under broadly similar conditions, although they formed over a longer period. The gravels at Knapton represent typical solifluncted gravels (grèzes litées - Guillen 1951, Cailleux 1963, Dylik 1960), with little or no evidence of the fluvial resorting mentioned by Edwards (1978). They probably sludged from the sides of a glacier at Knapton and thus represent a locally derived chalk/flint moraine, the faulting in these gravels being caused by the final melting buried ice in the bottom of the hollow. These gravels are also very probably of Devensian age as they are indentical to all the other solifluction gravels found on the Wolds, which are ascribed to this period and there is no evidence to suggest that any of these gravels are older than this (Edwards 1978). Indeed the solifluction gravels found here and elsewhere on the Wolds are well consolidated probably because solution of the chalk has caused a partial secondary cementation which makes them seem well consolidated for their age.

v) The drift trains of the North, East and Southern margins of the Vale of Pickering

The tills and outwash deposits which block the eastern end of the Vale of Pickering on the coast between Filey and Scarborough and the gravel ridge at Wykeham can be collectively termed the "Fil ey Moraine Complex". These tills and associated deposits were almost certainly deposited by Devensian ice although there has been much re-incorporation of older material including rafts of shelly material which are known collectively as the Speeton Shell Bed (Catt and Penny 1966, Edwards, 1978, West 1969). The upper horizons of the tills can probably be correlated with the Devensian Skipsea and Withernsea tills of Holderness (Edwards 1978) and these are thought to extend inland at least as far as Star Carr footbridge (TA028811) in the central part of the Vale of Pickering and as far as Thornton-le-Dale in the north. These tills are overlain in this eastern fringe area by gravels of variable thickness which extended westwards further into the Vale until they grade laterally into sands in the area between Brompton and Snaiton Ings. The borehole data indicate that the Sherburn sands pass laterally and in places may be interbedded with the gravelly outwash - this was confirmed by a section in the bank of the River Hertford at Star Carr footbridge. This indicates that part at least of the drift of the southern margin of the Vale is of late-glacial age (the Seamer Gravels are of late glacial age, Edwards 1978). Slingsby sands which extend along the northern edge of the Howardian Hills and pass imperceptably into the Sherburn Sands must also be of late-glacial age too.

The age of the northern gravel train west of Wykeham is more difficult to determine. The aerial-photographic evidence shows that much larger streams than those represented by Brompton Beck, Welldale Beck, Allerston Beck etc., once flowed across these northern lowlands, but it is not possible to determine the exact age of these old river channels. However, very high flow regimes are indicated and the size of the gravels found in this area combine to make a peri-glacial meltwater-flood period seem the most likely source of the water. It is suggested therefore that much if not all of this material was derived during the late-glacial and possibly Zone III periods when large quantities of snow-meltwater would have swelled then present moorland streams and added new streams (which have now dried up) to the general source of a water supply.

The extent of the alluvial deposits of the Vale of Pickering are very difficult to determine accurately and where they have been observed they are indistinguishable from locally reworked outwash - which is generally all the modern alluvium consists of. The flood plain of the river Derwent has been mapped from aerial-photographs but the actual thickness of alluvial drift appears to be rather limited. The "alluvial" deposits recorded in many of the older borehole logs were found to consist of outwash deposits and associated sediments and it would seem that reworking of the late-glacial and Zone III sediments has played a large part in the post-glacial history of the area although some new material has been added as is indicated by the convex shape of the flood plain in the central parts of the Vale.

vi) The thick basal lacustrine deposits of the Central Vale of Pickering

Underlying large tracts of the central area of the Vale of Pickering are a thick sequence (up to 30 m maximum but on average 10 - 45 m) of black, grey and brown laminated silts and clays. These are underlain by thin sands and gravels. These were thought by Kendall to represent the de- posits of his glacier dammed lake (see Chapters I and III). In fact the age of these lacustrine clays must be contemporary with or post-date the deposition of the Filey Morainic Complex in the eastern Vale of Pickering because otherwise it would not have been possible for the lake to form. The lack of evidence from the critical junction area where the laminated clays abut against or interbed with the morainic drifts means that it is not possible to determine whether a glacial or morainic dam was most likely. Perhaps, as suggested below, both ice and moraine was responsible for damming the lake waters, but more evidence is needed before a definitive statement can be made.

B. A Tentative Reconstruction of the Late Pleistocene History of the Vale of Pickering and Northern Wolds

Having described the presently available information concerning the late Pleistocene history of the field study area and evidence from some of the surrounding regions, and having described and discussed the major alternative explanations of this evidence, it is now time to reconstruct the alternative explanations as working hypotheses which would be usable as a framework for future research. The first major hypothesis which can be reconstructed is a slight modification of Kendall's 1902 Lake Pickering theory which attributes the bulk of the new evidence presented earlier (e.g. the landforms and sedimentary deposits, the evidence from the Wolds dip slope, etc.), to an earlier glaciation. The second hypothesis involves a major reconstruction of Kendall's 1902 theory and attributes much of the evidence to the Devensian glaciation. Both hypotheses have common ground e.g. the age of much of the remanié drift on the Wolds dip slope and the formation of dry valleys which are not fundamentally affected by the differences in the interpretation of the evidence as outlined below.

The author favours hypothesis 2 because this best fits the facts as they are known at present. It has been made clear above that the evidence seems to point to a more recent origin (i.e. Devensian) for much of the material presented above. However, where the evidence indicates a pre-Devensian origin this is made clear in the text.

Hypothesis 1

This is based on the assumption that the deposits on the Wolds escarpment and the associated marginal drainage channels, the channels and scattered drifts at Ampleforth and in the western Vale of Pickering and the drifts at Ebberston and Thornton-le-Dale are all of pre-Devensian age. It would still be accepted that the limits of advance of the Devensian glaciers accepted by Kendall were the true limits and that a large glacier-dammed lake formed in the central and western parts of the Vale, the level of which must have risen, for a time at least, to over 33 m O. D. (fig. 3). The lake may have continued to survive into the late glacial as it was dammed by the Filey Morainic Complex and largely drained through the Kirkham Valley. The theory has already been criticised at length in the earlier part of this chapter and will not be repeated here.

Hypothesis 2

This is based on the assumption that the physical features and sediments described from the Vale of Pickering and its margins are of Devensian age. It also assumes that the limits of maximum advance of the Devensian glaciers in the north-eastern and north-western corners of the Wolds and in parts of the Howardian Hills and Northern Yorkshire Moors would have to be revised. The total sequence of events in the development of the Vale of Pickering and Northern Wolds is described in full but it should be remembered that certain stages below (1, 2, 5 and 6) are broadly applicable to hypothesis 1 above.

Stage i (fig. 85). The whole of the area under study was almost certainly covered at least once in the past by the glaciers of a pre-Devensian glaciation (Gaunt 1976a, West 1969). The evidence for this former cover is sparse and in places difficult to interpret, but includes some of the Wolds erratic pebbles (e.g. some of the quartzites, dreikanter, gritstones etc.), and may include the sandy and silty-clay subsoils. The fissure deposits of the north-western Wolds at Thixendale may also belong to this earlier stage of glaciation. Excavation of the dip-slope dry valleys took place during the peri-glacial phases of those earlier glacial periods, and further erosion may have occurred under the ice during the period of maximum glaciation. Some of the scattered pebbly deposits in the western Vale of Pickering may also belong to an earlier period of glaciation.

Stage ii (fig. 86). Nothing is known at present about the conditions during the Ipswichian inter-glacial period beyond the fact that it was warm enough for a warm temperature fauna to thrive, (Buckland 1823, Boylan 1967, 1977). At the onset of the Devensian period (circa 70,000 years B. P.), there was a marked reduction in the mean annual temperatures combined with an increase in the extremes between maximum summer and minimum winter temperatures (i.e. there was a trend towards a more continental-climatic regime). This fall in temperature was accompanied by a fall in

Fig. 85 The Devensian development of the Vale of Pickering area Stage 1: probable conditions at the beginning of the Devensian times (for details see text).


NORTH YORKSHIRE MOORS (UPLAND)
PICKERING
PROBABLY LOW HILLS AND SHALLOW VALLEYS
EXCAVATION OF EASTWARD DRAINING VALLEY
EXCAVATION OF AMPLEFORTH GAP
HOWARDIAN HILLS (UPLAND)
MALTON
LINTON WHINS
DRAINAGE SYSTEM ESTABLISHED
SCATTERED ERRATICS AND
TERTIARY REMANIÉ DEPOSITS.
MAIN LINES OF DRAINAGE
SLOPES

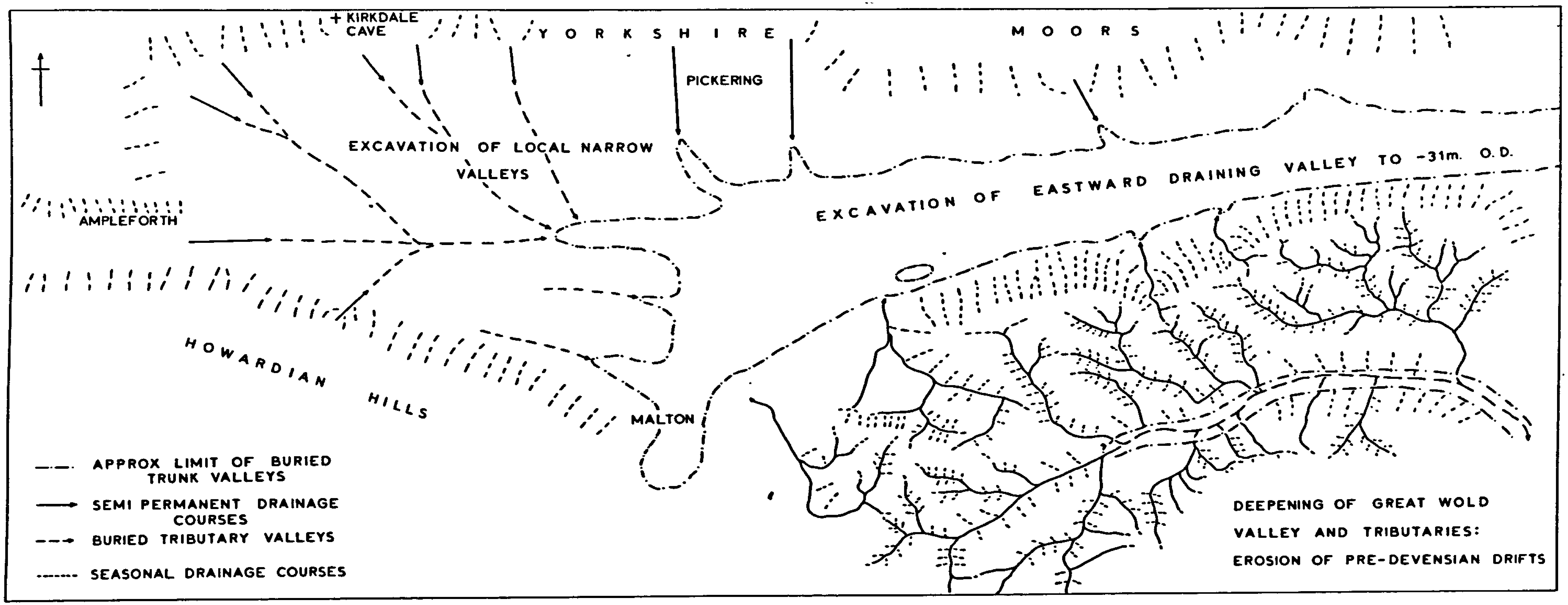
world-wide sea levels which in turn caused incision and rejuvenation of the major rivers. The latter effects were reflected in the Vale of Pickering by the excavation of a deep and relatively narrow valley to an average level of -22 m O. D. and a maximum level of -31 m O. D. at the coast at Filey. This incision phase in the Vale was paralleled by a similar phase on the Wolds where the Great Wold Valley was deepened until the rock floor at Foxholes was nearly 13 m below the modern level. This increase in erosion was probably aided by a decreased vegetation cover and possibly increased seasonal run-off during the spring snow-melting periods.

During this stage the silty sands and loesses were deposited on the Wolds (where they have been preserved in sheltered locations) and probably in the Vale of Pickering although there are now no deposits there which can be attributed to this period. It is possible that a thin organic-rich soil developed on poorly-drained areas of the Wolds at this stage and that a single remnant (at Linton Whins) has survived in a fissure. This too was covered and concealed by a thin loessic deposit.

Stage iii. During the late Devensian a two-stage ice advance has been recognised in Britain by Mitchell (1972). In southern Ireland and the Western Midlands an earlier advance (approx. 20,000 years B.P.) preceded a slightly later advance (approx. 18,000 years B.P.). In southern Scandinavia Morner (1969) estimated the age of the Pommeranian Moraine to be 14,800 years B.P., the Frankfurt moraine 17,700 years B.P., and the Brandenburg Moraine 19,500 years B.P. Morner and Dreimanis (1969) also recognised a two-stage late-glacial phase in the area around Lake Erie and Morner (1970) showed how a similar double phase is recognised on a world-wide scale.

Evidence from oxygen isotope analysis in Greenland (Dansgaard et. al., 1969), and Antarctic (Epstein et. al., 1970) and in deep

Fig. 86 The Devensian development of the Vale of Pickering area
Stage 2: mid-Devensian times (for details see text).



KIRKDALE CAVE
YORKSHIRE MOORS
PICKERING
AMPLEFORTH
EXCAVATION OF LOCAL NARROW VALLEYS
EXCAVATION OF EASTWARD DRAINING VALLEY TO -31m. O.D.
HOWARDIAN HILLS
MALTON
APPROX LIMIT OF BURIED TRUNK VALLEYS
SEMI PERMANENT DRAINAGE COURSES
BURIED TRIBUTARY VALLEYS
SEASONAL DRAINAGE COURSES
DEEPENING OF GREAT WOLD VALLEY AND TRIBUTARIES:
EROSION OF PRE-DEVENSIAN DRIFTS

ocean cores (Ericson and Wollin 1956, Emiliani 1966 and Griggs et. al., 1970), and changes in sea level (Morner 1970), all show that the late Devensian double cycle occurred on a world-wide scale.

Edwards correlated the first of the glacial advances with the Thornton-le-Dale till and the latter as a re-advance or prolonged still stand which formed the Wykeham "moraine".

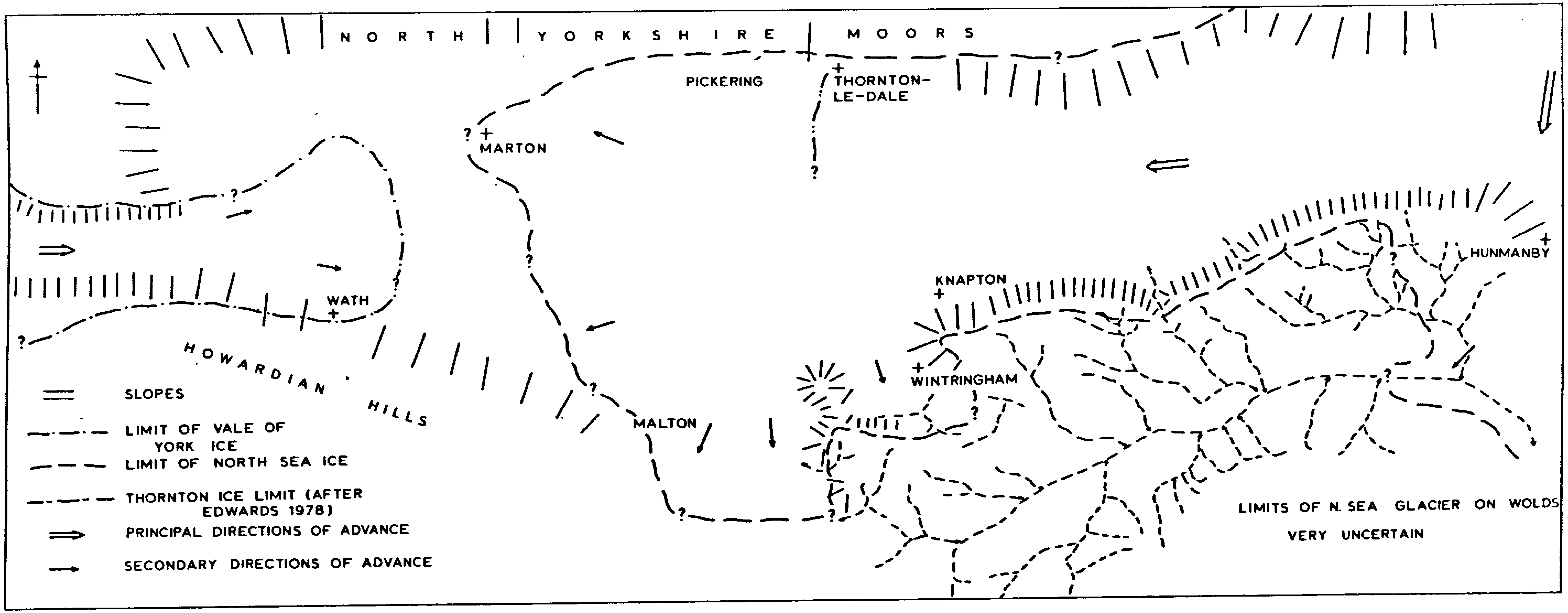
The author offers an alternative thesis - that the Vale of York Ice represents the earlier cold phase in the late Devensian and that the latter phase is represented by the North Sea ice advance - albeit a surging glacier in this case. (Boulton et. al., 1977).

After the Vale of York glacier reached its maximum extent (probably sending lobes of ice into the shallow valleys in the western Vale of Pickering), it started to melt down in situ and sent streams of melt-water flowing eastwards down the valley in the main part of the valley, possibly causing the final stages of excavation as it did so. Some of the erratic material recorded in the western Vale, may have been brought in and deposited by this ice.

The later Devensian advance would then be represented by the advance of the North Sea Ice to Thornton-le-Dale in the north and probably into the Malton embayment in the south. Boulton et. al., (1977) have suggested that the North Sea Glacier may well have been surging at this time and may have advanced rapidly down the North Sea coast. The age of the Dimlington silts (18,250 years B.P. approx. Catt and Penny 1966) shows that this could be the later Devensian advance described by authors from elsewhere, rather than the earlier one attributed to it by Edwards (1978).

The evidence for these late Devensian glacial phasesis both limited and widely distributed. On the Wolds escarpment it consists of marginal drainage channels and sediments; at Settrington (south of Malton) it consists of physical features combined with calculations based on the

Fig. 87 The Devensian development of the Vale of Pickering area Stage 3a: limit of glacial advance in the area (for details see text).


NORTH YORKSHIRE MOORS
PICKERING
THORNTON-LE-DALE
MARTON
WATH
HOWARDIAN HILLS
MALTON
KNAPTON
WINTRINGHAM
HUNMANBY
LIMITS OF N. SEA GLACIER ON WOLDS VERY UNCERTAIN
SLOPES
LIMIT OF VALE OF YORK ICE
LIMIT OF NORTH SEA ICE
THORNTON ICE LIMIT (AFTER EDWARDS 1978)
PRINCIPAL DIRECTIONS OF ADVANCE
SECONDARY DIRECTIONS OF ADVANCE

thickness of the ice further east and the gradients which ice can support without flowing; at Ampleforth it again consists of channels and sediments; on the northern side of the Vale tills are present as far west as Thornton. However, there is a lack of constructive depositional features normally associated with melting glaciers and a lack of glacial deposits in the Vale of Pickering which are difficult to account for. These deposits may be lacking however because they did not have the necessary environmental conditions which would have allowed them to develop (this will be expanded in section iv below). It is possible that the glaciers which invaded the Vale of Pickering and advanced over the margins of the area were so con- stricted at the entrances to the Vale that they lost much of the material which they were carrying in or near to these areas. It is perhaps significant that the tills in the Filey Morainic Complex are quite thick (up to 57.4 m - circa 180 ft) yet tills are almost absent further west. The presence of shear-clays at Reighton (Edwards 1978) shows that the ice was congested and constrained in this area and this, combined with the major direction of movement of the ice occurring obliquely across the entrance of the Vale (Stather 1897, Edwards 1978) probably added to the congestion of the basal ice layers in Filey Bay. The nature of the ice may also have contributed to this congestion - Boulton stated that in glaciers which are active transporting agents, the bulk of the material is carried in the basal ice and that the upper layers are relatively debris- free (Boulton 1972b). If such a layered glacier advanced into a restricted space it would be expected that the basal debris rich layers would have a high chance of becoming trapped due to their high coefficient of friction and the fact that they would probably not be able to ride over the obstacle ahead of them (fig. 88). Thus the relatively clean upper ice-layers would shear over the lower trapped layers and continue to advance into the Vale of Pickering and over its surrounding margins. This ice would incorporate some far travelled material from the trapped basal layers, but the bulk of the debris would be derived from local rocks. Where the ice overrode the Wolds escarpment these same processes of trapping and overriding would again be important and could account for the relatively minor amounts of drift found west of Hunmanby and south of the north- and west-facing escarpments. Similar circumstances probably pre- vailed in the Ampleforth area and account in part for the lack of glacial deposits there.

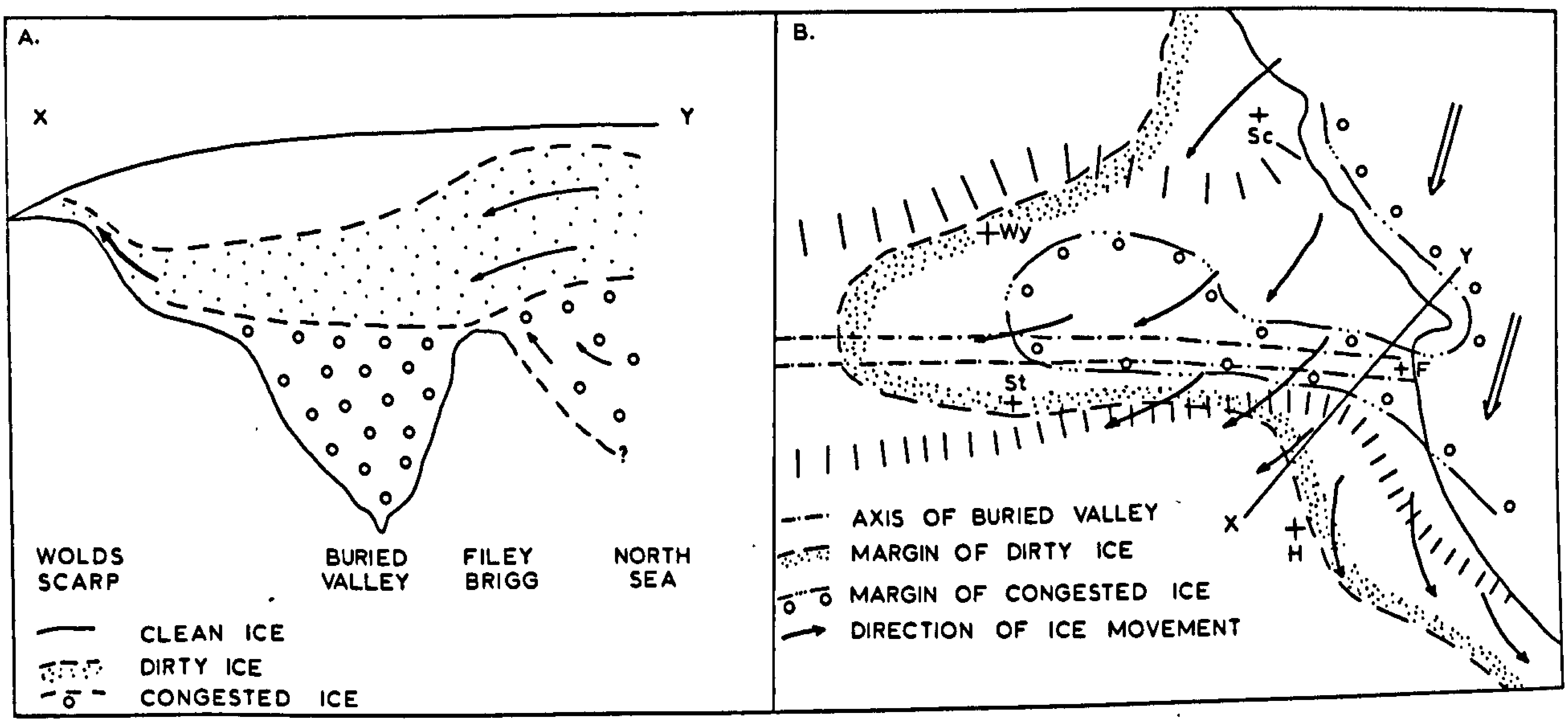
This lack of substantial evidence makes the accurate delineation of the former ice margins on the Wolds dip slope impossible. However, from the evidence provided from the scattered erratics, drift deposits and drainage channels a tentative reconstruction is offered here.

The ice seems to have advanced westwards across the Wolds dip slope from the Hunmanby area at least as far as Camp Dale, but the southward extension of this lobe is not known with any degree of certainty. In the north the presence of erratics provides some support for this hypothesis - south of the area mapped by the author evidence is lacking which may be used to help draw possible lines for the limit of advance of the ice.

Further west along the southern edge of the Vale of Pickering the ice probably swept across the Wolds escarpment and may locally have started to flow down the dip slope. Lobes of ice may have extended into the heads of the dry valleys, leaving scattered pockets of outwash sands in some of them (e.g. Warren Slack) and on parts of the dip slope itself (e.g. Staxton Wold). These outwash sands are similar to both the Sherburn sands in the Vale of Pickering and on the Wolds scarp, and have been derived from the same source.

In the Wintringham area a tongue of ice may have turned south and advanced as far as the area north of West Lutton as shown by the presence of scattered oolitic drifts. Further west on Settrington Wold the

Fig. 88 The Devensian development of the Vale of Pickering area Stage 3b: section and plan of possible ice movements and shearing of ice in the mouth of the Pickering buried valley (for details see text).


A.
X
Y
WOLDS SCARP
BURIED VALLEY
FILEY BRIGG
NORTH SEA
CLEAN ICE
DIRTY ICE
CONGESTED ICE
B.
Sc
Wy
Y
F
St
X
H
AXIS OF BURIED VALLEY
MARGIN OF DIRTY ICE
MARGIN OF CONGESTED ICE
DIRECTION OF ICE MOVEMENT

presence of possible drainage channels indicates that ice may have extended across this area too, but again the southward limit of advance cannot be drawn with certainty.

In the Leavening area the half-tube shaped feature leading from one of the Raisthorpe Depressions indicates a possible former sub-glacial feature, as does the long shallow depression in Birdsall Brow (a possible lateral drainage channel).

Stage iv. During this stage the glaciers which had invaded the Vale of Pickering and its margins began to retreat. It is not known exactly when the final stages of deglaciation were completed - in Eskdale, Jones (1977) has shown that the glaciers had largely if not entirely melted away by 16,250 years B. P., but in Holderness the oldest dated organic remains are circa 13,500 years B. P. (Penny 1974). The oldest dated organic remains in the Vale of Pickering are at Star Carr which gave a C_{14} age of 11,500 years B. P. (Clark et. al., 1954) but it can probably be safely assumed that deglaciation was complete before this time. The deglaciation of the western and central parts of the Vale of Pickering may have been accelerated by the formation of lateral and frontal ice-dammed lake systems which gradually coalesced into a single large lake which may have lasted for a time after deglaciation was complete and was moraine-dammed during the later stages. These lakes probably started to form around the margins of the glacier where snow-meltwater streams from the surrounding hills (especially the North Yorkshire Moors and Howardian Hills) were dammed by the ice in the Vale of Pickering, (Edwards 1978). On the site of Pickering Village a small delta was built up as a marginal lake developed. The height of the lake in the Pickering area must have been at least 33 m O. D. and may have been higher. It is probable that these lakes drained into and/or under the ice and may well have been subjected to marked fluctuations in their water levels, especially as the ice in the

Vale became more broken and decayed. It is also possible that the combined meltwater from the snow-fields of the surrounding hills and the melting ice caused the build-up of sub-glacial meltwater so that eventually a lake began to form beneath the ice in the Vale. The lighter debris - poor central and western parts of the glacier may well have begun to float upon this water after this had accumulated beyond a certain depth, while the debris-rich ice at the eastern mouth of the Vale remained firmly anchored in place to the bedrock. (N. B. Gaunt 1976a and b has proposed a similar model of deglaciation in the Vale of York and sub-glacial lakes have been recorded by Gjessing, 1960). If this ice was actually floating in the central parts of the vale two further comments need to be made. The first of these is that the marginal drainage channels on the northern Wolds escarpment had probably formed by this time or the margins of the ice must have remained firmly anchored to the scarp while the channels formed and only at a late stage did the ice finally break away and become freely floating, (fig. 89). Secondly in the north-eastern area where the Ayton terrace - Wykeham ridge complex was being deposited the glacier was also almost certainly not floating. This is because the Wykeham ridge was formed either as an esker or as a crevasse fill, - if it was the latter environment in which the gravels were laid down the crevasse may have formed in response to differential movements between the floating ice to the west and the anchored ice in the east.

The source of the material which became the laminated clays in the Vale of Pickering and the outlet for the water from this lake are problems which are exceedingly difficult to solve. It is possible that the source of much of the laminated clay was glacial i.e. that reworked glacial debris was the major source of supply. However the contribution by snow-meltwater streams draining from the surrounding hills should not be ignored and it is possible that much material was derived in this fashion. The outlet of the water from Lake Pickering was probably under or into the melting and decaying North Sea Glacier, at least in the early stages. It is possible that the Kirkham Valley was also used at an early stage provided that it was clear of both ice and moraine debris at its southern end. So far no other possible outlets have been found, but a thorough search in the area south of Malton may reveal possible overflows - it is conceivable for example that locally dammed lakes may have formed at the margins of the glacier and overflowed via low cols in the Birdsall embayment which are no longer easily recognisable. As the ice in the east melted away and was increasingly replaced by impermeable morainic deposits the major outlet (or outlets) must have moved to the west. Kirkham was almost certainly the last major outlet during the final stages of Lake Pickering, (Kendall 1902, Edwards 1978).

The lack of glacial depositional features such as eskers, tills etc., could also be accounted for if in the central parts of the Vale the glacier was afloat. Gaunt (1976a, b) found in the Vale of York that deposits of this type were also absent beneath his "25 ft. drifts" (a lacustrine deposit), except gravels of variable thickness. It has already been shown (Chapter III) that gravels of variable thickness occur on the floor of the Vale beneath the thick laminated clays and it is believed that these could represent glacial debris which was too coarse to be swept away by sub-glacial lake currents. Resorting and mixing of other debris may also have occurred so that the material which would otherwise be found as till etc., is now present in the form of laminated lacustrine silts and clays. During the deglacial phase reworking by meltwater streams of marginal deposits almost certainly occurred, and on the relatively steep northern Wolds and Ampleforth escarpment, land-slipping and solifluction would have contributed to the destruction of any sediments there. The

Fig. 89 The Devensian development of the Vale of Pickering area Stage 4: early melting phase and sub-glacial lake in the Pickering valley (for details see text).

SPRING
SNOW MELTWATER
LOCAL SMALL LAKES & ISLANDS: DEPOSITION OF FLUVIAL DEPOSITS IN VALLEYS.
PICKERING
THORNTON-LE-DALE
WYKEHAM
STABLE ICE
SUB-GLACIAL DRAINAGE OF LAKE INTO NORTH SEA BASIN.
DEPOSITION OF THICK SEQUENCE OF TILLS & OUTWASH.
FLOATING ICE
PRO- & SUB-GLACIAL LAKE.
DEPOSITION OF THICK LACUSTRINE CLAYS.
HOWARDIAN HILLS
MALTON
DRAINAGE VIA KIRKHAM AT LATE STAGE
MARGINAL ICE MELTWATER IN EARLY STAGES OF DEGLACIATION.
SNOW MELTWATER LATER.
T TILL
GRAVEL
ICE MARGIN
APPROX LAKE MARGIN
MAIN LINES OF DRAINAGE
GLACIAL DRAINAGE CHANNELS
SLOPES

lack of coarse debris which had been rafted in by icebergs could also be taken as evidence for the subglacial origin of these clays - such rafted blocks have been recorded from other ice-dammed lakes in Britain (Smith and Francis 1968).

Lenses of laminated clays are found in the outwash sands in the central Vale of Pickering and were supposed by Edwards (1978) to contain finer outwash sediments from the melting glaciers. He also stated that generally the sediments in the Vale of Pickering become finer westwards. In fact the picture is more complex than this (fig. 33) showing rather abrupt changes from coarse gravels east of Brompton Beck to sands and interbedded lenses of clays to the west, both sequences overlying laminated clays at depth. In the Knapton and Sherburn areas, thick lenses of gravel were also recorded in borehole logs (Chapter III Section F, fig. 33). This indicates considerable movement of coarse material, probably from the Wolds scarp brought in by either sub-glacial or lateral glacial streams, or by snow meltwater streams. Further east, a more likely interpretation is that as the ice melted away, so the meltwater rivers flowing from the eastern end of the north Yorkshire Moors and Forge Valley were able to spread the coarse fraction of their loads across Seamer Ings, Seamer Carr and Star Carr, etc., no longer being banked up along the Hutton Buscel terrace as had earlier been the case. (Edwards 1978). Clearly some form of large hollow existed here as the base of the gravels is transgressive across mixed sands and laminated clays eastwards, and rises in height as it passes to the west. Probably this can be best interpreted as the last influx of coarse material from the melting North Sea Glacier on the eastern side of the North Yorkshire Moors, the sands to the west in the central Vale of Pickering representing a sandur deposit derived by reworking of marginal sediments from the scarp and foot of the Wolds (where they had originally been deposited marginally to the glacier), and from the finer materials swept from the Forge Valley area and eastern Vale of Pickering.

On the northern Wolds dip slope during the glacial maximum and deglacial phases peri-glacial processes were probably very active. It is not known if large snowfields built up during the glacial maximum but if they did these would have contributed to the enormous amounts of meltwater both from snowfields and the margins of the glaciers which helped to excavate the dry valleys and probably caused severe erosion of the soil on the interfluve areas. The magnitude of this erosion can be estimated to some degree by the quantities of chalk gravels now found in the dry valleys of the Wolds (especially the lower Great Wold Valley and Garton Slack) and the large fan of chalk gravel which extends over the tills in the Driffield area (N. B. some of this gravel is probably Zone III age too). In the Vale of Pickering the presence of large quantities of chalk gravel can probably be partly attributed to erosion during the deglacial phase.

Stage V: Following deglaciation the climate still remained relatively cold so that snowfields probably accumulated in sheltered locations on the Wolds, especially in the marginal drainage channels on the northern escarpment (as snow still does today during the winter). Melting of this snow, especially during Zone III times when there is evidence of permafrost and frozen ground, probably caused the excavation of the gully-systems which can now be seen cutting valley sides and large segments of the northern escarpment, (fig. 90).

During or even before this phase the loess cover which is presumed to have existed on the northern Wolds was almost certainly stripped away except for isolated hollows, pockets and outliers where it has been preserved. Much of this cover may have been removed by ice meltwater draining from the southern margins of the glacier in the Vale of Pickering across the Wolds dip slope, and from melting firn or snow in same area. Katabatic winds blowing from the decaying ice from the North Sea area may also have been effective in removing much of this material and depositing it elsewhere, and possibly bringing in some blown sand and leaving a thin cover on the N. Wolds with thicker deposits trapped in hollows and depressions on the dip slope.

It is not known how long Lake Pickering survived after deglaciation - it is possible that once the Kirkham Valley was opened that it drained quite rapidly. However it seems likely that it had drained away to a relatively low level (if it had not disappeared altogether) by Zone III times when large quantities of meltwater drained from the Wolds scarp and Howardian Hills and reworked the sands on the southern margins of the Vale - indeed some of these sands may have been derived from ice-marginal deposits on the escarpment. This reworking of the material is evident from the sedimentary structures within the Sherburn and Slingsby sands, but the exact relationship of the Sherburn and Slingsby sands to Lake Pickering is still unclear. (i.e. these sands may have originally formed part of a beach deposit in the same way as the "Littoral Sands" in the Vale of York are believed to have done). However during and after Zone III times a large shallow lake continued to exist in the eastern Vale on the site of what are now Wykeham, Seamer, Flixton, Muston and Killerby carrs. This lake complex finally disappeared when the organic debris which accumulated there filled the old lake hollow. During this filling phase and probably after it had ceased the River Derwent brought down large quantities of sediment from the North Yorkshire Moors and deposited it as a complex of levées in the old lake and later in the peaty deposits which filled it. During this late glacial phase there may have been a second period of blown-sand deposition which was responsible for some of the parent material of the northern Wolds soils.

ig. 90 The Devensian development of the Vale of Pickering area Stage 5: Zone III conditions of high run-off and snow-melt and active excavation of the Wolds drainage system (for details see text).


NORTH YORKSHIRE MOORS
PICKERING
DEPOSITION OF ALLUVIUM & REWORKING OF GLACIAL & FLUVIO-GLACIAL DRIFTS
DEPOSITION OF CARR PEATS
HOWARDIAN HILLS
MALTON
FILLING OF VALLEY FLOORS WITH CHALK FLINT GRAVELS. EXCAVATION OF GULLIES BY SNOW MELTWATER.
MAJOR LINES OF DRAINAGE
SEASONAL DRAINAGE COURSES
FORMER POST-GLACIAL LAKE

At Luttons Lane on the northern wolds escarpment, at Linton Farm and Fimber Farm and in the Vale of Pickering at Knapton gravel pit, evidence has been found for the movement and deposition of blown sands, probably at this time. A late glacial age for all of this material seems most likely as it fills frost-wedges and other depressions which formed in the frozen ground, and it seems unlikely that much sand would have survived the strong erosion by snow-meltwater that was occurring on the Wolds at this time.

Stage vi: The post-glacial stage has seen the gradual silting of the central parts of the Vale until now the floor of the Vale can be seen to bulge upwards in the central areas. Continued flooding and interference by man with the natural outlet at Kirkham, combined with sudden floods derived from the Northern Yorkshire Moors has in the past led to severe flooding in the low-lying parts of the Vale. On the Northern Wolds stripping of the natural vegetation cover to clear the land for agriculture has led to soil erosion and general soil loss, a process which seems to be accelerating again today as a result of modern agricultural practices.

C. Conclusion

A survey of the literature and evidence of the late Glacial history of the Vale of Pickering and Northern Yorkshire Wolds has been carried out. This study has, it is hoped, helped to clarify some points and highlighted areas where more information is needed. It would appear to the author that an adequate case has been made for the acceptance of the need to revise the limits of maximum advance of the Devensian glaciers in this part of Yorkshire, and a revised history of the deglaciation of the area has been offered. It is hoped that this work will stimulate new research in the area into problems which have been highlighted in this thesis, and that some of the present problems can be more clearly and accurately resolved.

APPENDIX A

Fell House Hotel,

Burnsall,

nr. Shipton.

14 June, 1923

Dear Sheppard,

Many thanks for letting me see the "Rome" letters which I return herewith. They are quite interesting particularly the one which describes the drift at Thixendale Grange and other places on the High Wolds. I fancy this information was incorporated in one of the "Wood and Rome" papers, and will look it up when I get home. There used to be some dirty sand visible in the same valley a little below Burndale, but low down on the flanks. It is now hidden by talus. We know that ice was over thick in the Vale of York and it is possible there may have been a wash of thaw-water from it into the head of Thixendale Valley, though I could never find any certain evidence of it. I know that Mortimer always held that erratics had been found in some of the clayey stuff of the inner wolds, but he based his idea on very early recollections when there is just a doubt whether he knew an erratic at sight. I don't think you will find any examples in his collection - but you might have a look sometime. That weird map of Robert Mortimer's shows how crude were some of the early notions as to "superficials" on the Wolds.

I expect to get home again the end of next week.

Yours sincerely,

G.W. Lamplugh

Thanks also for the "Harpoon" pamphlet.

Edward Mitty to W (?) Rome.

Cottingham 23rd June, 1866

Dear Sir,

I have got further information from Ogar. He says at the spot where I pointed out he made a Bore upon my property the strata laid thus

Soil	2 ft
Sand and gravel	16
Marl or Red Clay	8 or 9
Quick sand	15 or 20
Yellow clay	2 or 3
	43 Total

Cottingham Village

He finds the Bed of Red or Marly clay everywhere varying in thickness from 11 to 21 feet beneath the surface of soil sand and gravel of 10 feet or so beneath the Red clay about 6 or 8 feet sep. (arated) from dale gravel, then the Yellow clay near the chalk.

At De La Pole Grange about 1 mile S.W. of Cottingham he found the Bed of Red clay 50 feet in thickness.

Tranby	6 feet	Red Clay
Loest (?) Ella	12	"
Swanland	6	"
Welton	4 or 5	"
Spring Head	28	"

He says at a House recently erected by W. Sykes, Thwaite Street, Cottingham he found 40 feet of sand and gravel quite to the Rock and no clay.

I have gone over the Wold Hills to Elloughton and Brantingham and I find the Red clay to a very considerable altitude, but varying greatly in different places, it appeared to me to run not in a continuous line parallel with the Wold Hills, but in tongues as it were varying greatly in altitude in different situations.

I found a little above Brantingham a pit dug in the chalk where some person had dug a hole through the chalk and some 6 feet into a fine Blue clay and it seems to me this is just the line of intersection between the chalk and sand stone formation.

I am Dear Sir

Your Old Servant

Edward Mitty

The Rev.d W. Rome

The horizon - Marsupitus ornatus is on the ridge west of Dane's Dyke along the line of contorted chalk C. Sewerby Buckton.

The Bridlington Clay

1st going downwards an olive green sand at the bottom of it full of fossils - 5 feet - onto more than

2nd brown clay average thickness c. 2 - 3 feet. The whole (is) full of shells

3rd the purple clay not fossiliferous except in the upper 2 or 3 inches - the Pholas! these most numerous from the above 3 beds (upwards)

Brown clay c. 9 feet (?) occupies the greater part (of the) cliff up (to) Sewerby. There the highly contorted sand and gravels.

? the White Marl

The cliff commences c. 200 - 300 yards N. of the Harbour.

Section

"C" is your Purple clay - this is very like the appearance of the scarp where intersection by the cliff. The actual form of the scarp with its covering of clay as seen when looking at it from the top of the cliff (and looking inland towards Reighton) is 0 as ?

Phillips represented it - J.L.R.

Letter by S.V. Wood Jnr., to J.L. Rome c. late 1867/early 1868. The first 4 pages of this letter have been mislaid. The letter starts (p. 5):

... the evening on Phillips paper. I had received intimation (?) of this and fully intended to be present. Having several things accumulating (?) to transact in London - when I do go I generally go early to do them whenever any papers at the Societies' meetings' induces my attendance there. The map of Steely (?) I want to hang up in case I have to bring forward the Hessle clay at Ashby in reply to Phillips and the sections I want to submit to Jenkins to lay before the Council for their consent. The proof of the Cithis you can keep as I have another.

With respect to the age of the gravels at Malton along the northern wold foot I feel fully the force of what you say. I have since Dr. Paps (?) letter entertained some doubts myself. I think it very probable that they are post Hessle like the Barnetby (?) Brigg North Cave and that it may have been the narrowness of the Malton Gorge that induced their accumulation or rather prevented their destruction by denudation after their accumulation such has taken place where these waters had free sweep along the Wold foot as was the case of the West foot. It may be also that they are of fluviatile origin as it is probable may be the case with the other post Hessle gravels and that all these except those at Hornsea have no fossils to show their nature. Our paper should certainly be in this respect and you must bear it in mind on the proof should I forget it. Maybe a memorandum on all the points on which you think the paper should be corrected or noticed by note. I am very glad that your attention has been attracted by the points, but it will be best to put the thing suggestively rather than positively - thus say that not having been able to detect the Hessle clay in the Vale of Pickering it might be inferred that waters had never penetrated here but that the height to which the clay rises along the eastern slope of Wold and its position at

Swanland etc., seems to involve such a depression as would needs have admitted the Hessle waters through the Malton Gorge or opening. That is such a view it would seem to follow that the gravels along the northern Wold foot were deposited subsequent to the sweeping (?) out there of the Hessle clay and be therefore of similar age to the beds of the coast and to the gravels of Barnetby, Brigg, Malton etc., but that probably gravels of more than 1 post glacial age co-exist along the Northern Wold foot.

If you post your letters and book post-parcel before 5 on Tuesday afternoon and address it to me at the Geol. Society I shall get it all right on Wednesday there. I take it that Mr. Simpsons letter may be regarded as sufficient to show that there are no sands on the Wold top but I think therefore that it is the more needful that you should visit those at the point of extreme elevation at Thixendale as well as the Purple clay outliers at Huggate and if possible see the sands at Fimber and Towthorpe too. I have put a cross against any brickfields or other places mentioned in the map that struck me but these you will most probably will not be able to visit.

I am very sorry to hear that you are a sufferer by the Railway mismanagement etc., I have been and still am considerably so.

If you under these circumstances would prefer not incurring the expense of the proposed Leicestershire journey do not I beg of you hesitate to say so; only let me know in good time; as any other arrangements might be affected by it. I am quite willing to take the journey by myself only the arrangements would be different.

Thanks for the photograph it is a <u>very good one indeed</u>.

Yours ?

Searles V. Wood Jr.

Your survival or ? to the <u>absence</u> of the purple clay along the western wold in consequence or absence of any clay sediments, these gravels may possibly (?) be the equivalent here of the Hossle clay.

Note in the margin p. 5 says "P.S. please return this J.L. Rome to G. Marteman (?) esq., Malton. This letter probably pre-dates by a short time that of Rome, Feb, 13th 1868.

(To S.V. Wood Jnr.)

Hull, Febry 13th 1868

My dear Sir,

Through the favour of a kind Providence yesterday was a glorious day for the Wolds, and when I got out of the train at Diffield, and saw the pale moon dissolving over the Wolds in the light of a glorious sunrise, I felt so thankful to the giver of all good. It was exhilarating in a high degree to feel the bracing morning air warmed up by the sun, and to feel also, as Tennyson had said "ancient founts of inspiration well within my spirit yet". The 9 o'clock train took me on from Driffield to Burdale, where Mr. Mortimer met me in an old spring cart ... of the wold work in the archaeological line - thence up the deep Thixendale trough, (and down to the Kimmeridge clay), past Thixendale village, up to the very head of the dale at Thixendale Grange, a farm house marked in your map, but not named. Here it is that the Drift sands occur - the precise spot I have marked in ink - as also a small outlier 2 fields off, which I have also marked thus (O), being rather higher than the point of the road marked 759', the former and main outlier being perhaps the odd 59' lower, being just at the point where the Wold brow begins to cut down to one of the branch troughs of Thixendale. The farmer told us he had himself cut 12 feet into the sand without getting to the bottom. It is a fine red quartzose sand, from which on using the spade we dug fine kidney-shaped quartzite pebbles, sandstone cobbles, and pieces of coal. It is unquestionably a drift denudation bed, the colour of the sand indicating its derivation from the Purple clay.

Thence to Huggate, past the site of the old Wilton Beacon, the very highest part of the Wolds, viz. a few feet over 800 (and not 900, as you indicated in the enclosed notes). I forgot just now to say that the sand bed at Thixendale Grange thins out up to the level of the Wold brow at the part of the road marked 759, so that tho the mass of it may be 50 feet lower, the lip of it will not be more than 10 feet lower - so that this bed is within 60 feet of the highest part of the Wolds. I should mention also that the farmer said that when digging for sand they found shells in it but he could only say they were "like cockles" - the probability is that they were Gryphaea incurva as Mr. Mortimer found several of these in this very bed some years ago. This fact is quite as certain as if I had seen it myself, and you must not hesitate to accept it. If we had had a man with us to dig a deep hole, and could have spent half a day over it we sould have found them yesterday. But being thoroughly satisfied as to their being Drift beds there was no reason for delay, especially as I had Huggate to go to. The clay here is unquestionably a Purple clay being really Purple in colour, and contains stones, for it had to be cleaned of these before use, but of what kind I could not make out, the pits having been closed for some time, and being now filled with water to the depth of 20 ft. I saw however more than one mountain limestone or trap boulder (umbrella geology cannot settle such points) in the side of the road in the village, and have got the name and present residence of the man who worked the pits and will ascertain from him about these stones. Mr. Mortimer agrees with me in thinking that we should be perfectly safe in describing this clay bed as an outlier of the Purple clay of Holderness, as also the similar clay bed at Fimber, out of which Mr. Mortimer once saw foreign stones thrown some 30 years ago, which excited curiosity at the time. The Huggate outlier is about half a mile long, and only about 100 yards in breadth and is overlain at its eastern end by an enormous accumulation of small chalk gravel, which has been extensively worked in past ages but is now grassed over its deep wide gash of excavation, pools of water standing in the bottom showing the presence of the clay beneath. You have correctly marked the site of the denudation beds on the hill-top west of Fimber, which have been worked for building sand and like those on the wold top contain boulders even granite one (says Mr. Mortimer). This bed will be 500 ft., and the one at Huggate nearly 600 ft., above the sea ... I had not time to visit but after the verifications of yesterday, we need have no scruples in mentioning it among the rest.

I intend, God-willing, on Monday week to go to Speeton and walk to Filey to see if, after these high tides, the "forest-bed" is exposed - as I have not yet had leisure to keep it a few days longer. I have found the Hessle-clay in great force at Swanland (at least 200 ft., above the sea) a tongue of it running direct west from Kirk-Ella up to that place at a point direct North of section 2 in your map, its outlook there to the west of the Humber-gorge being bold and direct. Here also it is underlaid by sand up to its Western limit. Is it correct to speak of this as overlap ? The sand, tho sporadically, seems to accompany it everywhere.

In haste, yours etc.

J.L. Rome

5 Norfolk Park Villas,
Maidenhead.
16th Dec. 1869

My dear Sir,

I thought it would interest you to hear what a great success Mr. Wood's paper was on Wednesday last week. Prestwich of course expressed his scepticism about your Norfolk glacial sequences but 2 years ago he did the same about our Yorkshire results tho now he is disposed to admit them not because he had visited Yorkshire again in order to test them but (I suppose) because Sir C. Lyell has, and is satisfied. This reverence for Big-wigs is something wonderful, and hence I felt it of the greatest importance to get Sir C. down to Yorkshire which I contrived to do through a mutual friend. The result was most satisfactory, and the impression this has produced has prepared his mind for further admissions as to the relation of our Yorkshire results with your Norfolk discoveries. Mr. Wood dispaired of being able to secure such concessions, and up to within 2 months ago wrote to me in the most downhearted way. As I do not feel this but felt about it as I feel about Christian Truth, that because it is Truth, it must prevail, I wrote to him chiding him for his discouragement and exhorting him to brace himself for another effort. The result has justified my impression. An oblique correspondence with Sir C. (through Mr. High Pres (?)) and the paper just read, in which the fossil evidence of the Middle Drift is marshalled and contrasted with the Bridlington fauna, seem to have impressed Sir C. with new possibilities of sequence and correlation and I have no doubt whatever that if Sir C. could spend 3 or 4 days in Norfolk under your guidance, that the next and probably the last non-posthumous (and therefore most important) edition of his "Elements" (on which I suspect he is at present engaged) would contain our joint results with due acknowledgement frankly as to our Yorkshire work; and I hope to hear similar acknowledgements from the same source of your work and if made in his "Elements" the general recognition of our results would be secured, for the mass of geologists are like sheep, they follow a recognised leader. Mr. Wood sometimes professes indifference as to whether such recognition comes in his life-time or not, but that is either nonsense or unconscious affectation. Gwyn Jeffreys made a great fool of himself denying the arctic character of the Bridlington fauna for which Mr. Wood made great fun of him in reply asserting that all his deductions about the character of the Bridlington fauna had been taken from Jeffreys' own Book at which the fellows grinned and laughed again. Then again Jeffreys asserted the arctic character of the Kelsea Hill fauna whereas according to his own determination as quoted in Prestwich's paper on Kelsea Hill, the whole of the Kelsea things belong to the recent British seas. I have seen the secretary since (Dallas) and he tells me that in conversing with Jeffreys afterwards he said that the only object of his remarks was to give Prestwich the credit of having settled the glacial beds of Yorkshire!! Meaning of course that we did not deserve any credit but only the great authority Prestwich who had settled all those matters of course, years before ever we entered the field just, I suppose, as Trimmer, Gunn and others settled the Norfolk Drift years before either Wood or you had left school!!

I am

Yours truly

J.L. Rome

APPENDIX B

A NOTE ON POSSIBLE AVALANCHE TRACKS ON THE NORTHERN YORKSHIRE WOLDS

After this thesis was completed the author was shown a series of avalanche chutes in central Iceland. These consist of a series of regularly spaced, parallel to sub-parallel almost straight channels which cut across local valley sides at angles near to 90° to the local slope. These were most common on short steep slopes and less common on gentle slopes - in rare cases they occurred on gentle slopes which were fairly long. Depending upon location the channels were between 30 m and 100 m apart. They are cut by two major processes:

a) in early spring they are the sites of avalanches of snow and rock. Snow which has accumulated at the top of slopes during the winter months starts to melt in the spring, becomes unstable and avalanches down the slope, sweeping loose weathered debris along as it does so;

b) in late spring and early summer, meltwater streams flow down these channels - the water being derived from snow patches which remained on the upper slopes. Again loose debris is swept down the chutes.

Cones of angular debris are commonly found at the base of the chutes - in those cases where they are absent it seems that local streams in the valley floor have swept the material away during the annual spring floods and redistributed it as fluvial sand and gravel on the valley floor. It seems possible that many of the gullies found on the Northern Yorkshire Wolds valley sides and scarp which were described and discussed in Chapter V (p. 201 et. seq.), may in part have been cut by snow avalanches. The presence of cones at the base of some chutes (e.g. Old Dale and Camp Dale - see p. 220), may represent combined avalanche cones and fans deposited by meltwater streams which were not swept away by meltwater streams in the trunk dry valleys at the end of Zone III times.

From the evidence discussed in Chapter V it would seem that if avalanching was in part responsible for the erosion of these gullies, these would have occurred in Zone I and III times. Snow banks, which would have accumulated on the interfluves and at the top of the scarp during the winter months, would have started to melt in the spring. Due to the temporarily frozen nature of the soil, or its local impermeability caused by the silty sand subsoils and saturation of them, or a combination of these factors, meltwater would tend to flow across the interfluves to the valley sides. Thus the snow banks would tend to become saturated and unstable and thus avalanche down the steep local slopes. These avalanches could cut channels fairly rapidly in the weathered chalk and solifluction gravels and deposit the eroded material at the base of the slopes - the snow would then melt and help swell the meltwater streams in the valley floors and thus redistribute the debris as fluviatile gravels on the valley floors or in the Vale of Pickering. Once these channels had started to form they would become the site for further avalanching and for meltwater streams in the late spring and early summer.

The above hypothesis would help to explain the following characteristics of the gullies which make up an important part of the secondary "drainage" system:-

a) the close spacing of the gullies along some valley sides (e.g. High Mowthorpe Dale, Weaverthorpe Slack, Old Dale);

b) the low "order" of the drainage channels;

c) the presence of large numbers of closely spaced channels on slopes >10° but the wider spacing of channels on slopes 7° - 8° , and the fact that lower angle slopes tend to be considerably longer (over 200 m) before channels appear. Avalanches would probably not gain sufficient momentum to achieve significant erosion on relatively short low angle slopes;

d) the very wide local variations in density of these channels on valley sides;

e) the straight courses of the longer channels on lower angle slopes.

f) the presence of cones at the base of some gullies.

The above hypothesis does not affect the overall contention given here that snow meltwater was an important contributary factor in the development of many of the gullies, or that it was responsible in part for excavating the trunk dry valleys, but it may shed more light on the overall nature and character of the environment of the northern Wolds during the late glacial and early post glacial period.

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TABLE 1

FAULTS AND DISTURBANCES IN THE CHALK OF THE NORTHERN WOLDS WEST OF HUNMANBY

Name	Trend	Course	Previously noted by:	Source	Visible (Feb. 1977)
1. Knapton Disturbances	N.W. - S.E. N.E. - S.W.	Escarpment at Knapton Brow Form V W. of Staple Howe (SE 895750)	-	Air-photos	-
2. Wintringham Disturbance	N.W. - S.E.	Escarpment (SE 8874) - Old Dale (SE 9173)	Neale (1974) proposed fault boundary for Specton here.	Air-photos	May thrown spring at SE 918728
3. High Belmanaer Disturbance	N.W - S.E.	Many Thorns Farm (SE 858712) Kirby Grindalythe (SE 905675)	Versey ? (1929)	Air-photos	-
	and				
	N.N.W. - S.S.E.	Many Thorns Farm - Duggleby Wold (SE 874685)	-	Air-photos	-
4. Stack Hills Disturbance	W. - E.	Thorpe Bassett Wold (SE 852714) - Thirkleby Leys (SE 918700)	Fox-Strangways (1880) Mortimer (1885) Versey (1929)	Air-photos mapping	Stack Hills SE 870745 SE 885710 Linton Farm SE 909698
5. Old Dale Disturbance	W. - E.	Rookdale Farm (SE 915717) - Dotterel Farm (SE 957714)	Fox-Strangways (1880)	Air-photos	SE 927718
	N.E. - S.W.	Black Plantation, Place Newton (SE 8971)	-	Air-photos	-
6. Weaverthorpe Disturbance	W. - E.	Weaverthorpe Village (SE 9670) - Syndale near Octon Manor (TA 038710) White Hill (TA 068712)	Fox-Strangways (1880) Versey (1929)	Air-photos	-

TABLE 1 (Continued)

Name	Trend	Course	Previously noted by:	Source	Visible (Feb. 1977)
7. Wad Dale Dist.	N.W. - S.E.	Wad Dale (SE 9572)	-	Air-photos	-
8. White Wold Disturbance	E. - W.	Ling Hall Farm (SE 927734) - Foster's Wold Farm (SE 978738) Joins Foxholes dist. here.	Fox-Strangways	Air-photos	-
9. Foxholes Disturbance	W. - E.	West Heslerton Wold Farm (SE 915744), Sherburn Wold (SE 9674) Warren Cottages (SE 987738), Foxholes (TA 013734) Cans Dale (TA 0674)	Fox-Strangways (1880) Versey (1929)	Air-photos	Foxholes (TA 013734)
10. Sherburn Wold Disturbance	W. - E.	Knapton Brow (SE 894747), Heslerton Wold (SE 9274), Sherburn Wold (SE 955750), Warren Slack (SE 990745), Ganton Dale (TA 0274)	Fox-Strangways (1880)	Air-photos	Ganton Dale (TA 011748)
11. Escarpment Disturbance	W. - E. W.N.W. - E.S.E.	N. Scarp from Knapton Brow (SE 894747) to Flotmanby Wold (TA 0778)	-	Air-photos	-
12. Staxton Wold Disturbance	N.W. - S.E. W. - E.	Binnington Brow - Staxton Brow (TA 00 - 0278) - Cottage Dale (TA 02 - 0476) - N.W. Field House Farm (TA 0777)	-	Air-photos mapping	Staxton Br. (TA 018786) Binnington Brow (TA 003777)
13. Flixton Wold Disturbance	N.W. - S.E.	Flixton Brow (TA 040790) - Burton Fleming (TA 0872)	Fox-Strangways (1880)	Air-photos mapping	Flixton Br. (TA 039793)
14. Flotmanby Disturbance	W. - E. N.W. - S.E.	Flotmanby Wold (TA 07 - 0878)	Fox-Strangways (1880)	Air-photos	-
15. Fordon Disturbance	N.W. - S.E. W. - E. W.S.W. - E.N.E.	North Fordon Farm (TA 0475) - Grange Farm (TA 072756) - South Dale (TA 0876)	Fox-Strangways (1880)	Air-photos	-

TABLE 1 (Continued)

Name	Trend	Course	Previously noted by:	Source	Visible (Feb. 1977)
16. Windle Beck Fault	N.W. - S.E.	N. Scarp at Windle Beck (SE 995778)	-	Mapping	Downthrow to west
17. Wood House Fault	N.W. - S.E.	Wood House Farm (SE 859685) - Duggleby Wold (SE 868672)	-	Air-photos mapping	SE 963681 ? Downthrow to east
18. Duggleby Dist.	E.S.E. - N.N.W.	Dogstoop Plantation (SE 858674) - Law Mowthorpe (SE 891672)	Dakyns (1884)	Geol. map	-
19. Wharram Dist.	W. - E.	Wharram Grange Chalk Pit (SE 84565) - Wharram-le-Street (SE 865658) - Low Mowthorpe (SE 899655)	Dakyns (1884) Versey (1929)	Geol. map	-
20. Burdale Dist.	W. - E.	Raisthorpe Wold (SE 8562) - Burdale (SE 874623)	Dakyns (1884), Mortimer (1885), Versey (1929)	Geol. map	Burdale Chalk Pit (SE 874623)

TABLE 2

HEAVY MINERAL ANALYSIS OF "OUTWASH" SAND SAMPLES FORM THE VALE OF PICKERING COMPARED WITH ANALYSIS FROM HOLDERNESS TILLS

	Sewerby Sand	Flixton Brow Sand	White Cottage Sand	Slingsby Sand	Mean of 6 Withernsea Till samples	Mean of 14 Skipsea Till samples	Mean of 7 Basement Till samples
a) Light Fraction, total %	98.4	97.7	98.6	97.9			
Quartz %	94.4	83.7	89.1	93.1			
Alkali felspar %	4.2	3.9	3.8	4.7			
Calcite (mainly Chalk) %	0.7	11.4	4.8	-			
Flint %	0.7	0.8	2.3	2.2			
Muscovite	-	0.2	-	-			
b) Non-opaque heavy fraction, total %	0.4	0.4	0.3	0.2			
Colourless Garnet %	19.5	13.8	7.6	10.3	2.9	11.4	17.7
Pink Garnet %	14.3	2.0	1.0	1.0	0.3	2.1	4.0
Zircon %	0.4	23.1	3.8	29.3	2.8	3.9	3.9
Tourmaline %	1.8	7.5	8.2	17.0	2.5	2.2	1.7
Epidote %	15.8	7.9	12.8	4.4	2.5	9.0	14.3
Zoisite %	2.3	1.0	1.0	0.5	0.5	1.4	2.2
Green Hornblende %	16.4	5.9	18.8	0.7	2.8	11.9	22.4
Tremolite/Actinolote %	0.7	0.2	1.7	-	0.7	3.3	5.9
Brown Hornblende %	4.5	0.6	1.2	-	0.2	0.7	1.3
Augite %	17.5	3.2	8.9	0.2	6.1	9.5	10.5
Pigeonite %	0.9	-	-	-	-	-	-
Hypersthene %	0.4	1.0	-	-	0.3	0.6	0.9
Olivine %	0.4	-	-	-	-	-	-
Chloride %	0.9	12.4	17.7	11.3	10.4	5.4	3.1
Biotite %	-	3.2	7.0	2.5	14.9	4.9	1.1
Yellow Rutile %	0.2	3.0	1.0	3.7	0.6	1.1	0.9
Brown Rutile %	-	4.5	0.6	4.7	0.2	0.3	0.2
Red Rutile %	-	1.2	-	0.5	-	-	-

TABLE 2 (Continued)

	Sewerby Sand	Flixton Brow Sand	White Cottage Sand	Slingsby Sand	Mean of 6 Withernsea Till samples	Mean of 14 Skipsea Till samples	Mean of 7 Basement Till samples
Antase %	-	0.2	1.0	0.7	0.4	0.4	0.3
Brookite %	-	0.2	0.2	0.2	-	-	-
Staurolite %	0.7	0.4	-	0.5	0.1	0.3	0.7
Kyanite %	0.4	-	-	0.5	0.1	0.4	0.5
Andalusite %	0.4	-	-	-	-	-	-
Apatite %	0.7	5.9	6.6	8.2	5.3	4.1	4.4
Collophane %	1.8	2.8	-	3.2	0.8	0.8	0.3
c) Opaque heavy fraction, total %	1.2	2.0	1.2	1.9	-	-	-
Limonite/Haematite %	82.0	82.0	86.6	87.9			
Magnetite/Ilmonite %	14.4	15.2	10.6	8.3			
Leucoxene %	3.6	2.8	2.8	3.8			

(N.B. Fine sand fraction (63 - 250 microns) is divided into three parts, the relative proportions being given by the percentages in the lines called "total %"; the percentages of individual minerals within each of these three parts total 100 %)

TABLE 3

HEAVY MINERAL ANALYSIS OF NON-OPAQUE HEAVY FRACTION OF FINE SAND (60 - 250 µm) FROM THIXENDALE GRANGE

Colourless Garnet	19.8%
Pink Garnet	3.8%
Yellow Garnet	0.8%
Zircon	8.2%
Tourmaline	2.3%
Epidote	7.5%
Zoisite	4.6%
Green Hornblede	18.0%
Tremolite/actinolite	0.2%
Brown Hornblende	1.5%
Augite	1.5%
Pigeonite	0.2%
Hypersthene	0.2%
Olivine	-
Chlorite	9.9%
Biotite	5.2%
Yellow Rutile	0.6%
Brown Rutile	1.7%
Red Rutile	-
Anatase	0.2%
Brookite	-
Staurolite	10.0%
Kyanite	0.8%
Andalusite	-
Apatite	3.6%
Collophane	7.8%
Sphene	0.6%

TABLE 4

MINERAL COMPOSITION OF SANDS OF YORKSHIRE WOLDS (AFTER VERSEY 1937)

	Garnet	Zircon	Rutile	Tourmaline	Actinolite	Augite	Hypersthene	Enstatite	Kyanite	Staurolite	Andalusite	Sillimanite	Epidote	Chlorite	Anatase	Monazite	Barytes
Thixendale (Pipes)	x	x	x	x	-	x	x	-	x	-	x	-	-	-	-	x	-
Fridaythorpe	x	x	x	x	x	-	x	?	x	-	-	-	x	x	x	-	-
Knapton	x	x	x	x	-	x	x	-	x	-	x	-	-	-	-	-	-
West Heslerton	x	x	x	x	x	-	-	-	x	-	-	x	-	x	-	-	x
Thixendale Grange	x	x	x	x	x	x	-	?	-	-	-	-	-	-	-	-	-
Fairystones	x	x	x	x	x	x	-	-	x	?	-	-	x	x	-	-	-

TABLE 5

PARTICLE-SIZE DATA OF OUTWASH IN THE VALE OF PICKERING (SLINGSBY AND SHERBURN SANDS)

	-2ϕ (%)	-1ϕ (%)	0ϕ (%)	1ϕ (%)	2ϕ (%)	3ϕ (%)	4ϕ (%)
SLINGSBY SAND							
GRAPH 1	0	0	2	9	60	10	12
" 2	28	15	13	16	18	6	6
" 3	25	2	2	3	50	17	5
" 4	11	3	5	9	45	18	8
SHERBURN SAND							
GRAPH A 1	0	0	0	12	35	58	6
2	0	0	0	7	76	16	6
3	0	0	0	4	20	71	3
4	31	4	5	12	33	10	5
5	28	4	6	19	34	8	4
GRAPH B 1	0	0	0	5	79	10	2
2	0	0	0	15	65	11	6
3	0	0	0	18	58	12	3
4	14	4	3	6	48	8	6
5	0	0	4	4	65	17	4
GRAPH C 1	23	2	2	3	21	33	12
2	0	0	0	6	14	51	24
3	0	0	0	1	6	69	21
4	0	1	3	2	1	19	42
5	0	14	2	2	4	63	13
GRAPH D 1	0	0	1	43	41	12	2
2	0	0	0	10	57	12	6
3	0	0	19	5	9	55	20
4	0	0	6	13	26	36	18
5	0	0	0	2	17	56	18
GRAPH E 1	0	0	0	4	23	63	9
2	0	0	0	2	26	53	18
3	0	0	0	1	25	69	14
4	0	0	0	0	6	63	29
5	0	0	0	7	55	17	16
GRAPH F 1	0	0	2	18	57	8	3
2	0	0	0	11	44	30	20

TABLE 6

PARTICLE SIZE ANALYSIS OF POSSIBLE OUTWASH SANDS (SHERBURN SANDS) ON THE N. WOLDS ESCARPMENT AND DIP SLOPE

Locality	-2ϕ(%)	-1ϕ(%)	0ϕ(%)	1ϕ(%)	2ϕ(%)	3ϕ(%)	4ϕ(%)	<4ϕ(%)	Graph Ref (see Fig. 31)
Flixton Brow (TA 04137796)	21.5	5	3.2	2.9	21.6	35.1	8.7	2.1	C1
Flixton Brow (04137896)	-	-	5	10	27.9	37.6	18.9	-	D4
Staxton Brow (TA 010784)	-	-	-	2.3	12.9	41	36.6	7.1	D5
Binnington Brow (TA 003775)	-	-	-	2.2	43.5	37.2	12.0	5.1	D1
Binnington Brow (TA 003777)	-	-	-	9.8	50.2	29.4	6.7	3.9	D2
Potter Brompton Brow (SE 96907573)	-	-	1.8	16.3	45.8	30	5.9	-	E1
Luttons Lane, West Heslerton Brow (SE 910750)	-	-	-	5.7	12.5	56.9	20.7	4	C2
"	-	-	-	1.1	12.4	63.4	19.5	3.5	C3
"	-	1.7	1	0	1	28	33.9	34	C4
"	-	11.8	2.7	0	9.4	58	17.6	7.4	C5

TABLE 6 (Continued)

Locality	-2ϕ(%)	-1ϕ(%)	0ϕ(%)	1ϕ(%)	2ϕ(%)	3ϕ(%)	4ϕ(%)	$<4\phi$(%)	Graph Ref (see Fig. 31)
Chalk Pit, Staxton Wold Farm (TA 01807674)	-	-	7	9.6	12.5	33.4	26.4	11	
Chalk Pit, Staxton Wold Farm (TA 01807674)	-	9.3	9.1	5.8	9.7	34.1	23	8.8	D3
Cotton Dale (TA 025768)	-	-	-	1.6	16	47.4	23.7	11.6	
Warren Slack Soil Pit 1, Depth c. o.7 m	-	-	-	1.5	22.1	47.8	17.6	10.9	
Warren Slack Soil Pit 1, Depth 1.15 m	-	-	-	0.8	24.7	51.3	17.8	5.4	
Warren Slack Soil Pit 2, Depth 0.7 m	-	-	-	1.1	7.8	40.9	36.6	13.5	
Warren Slack Soil Pit 2, Depth 1.4 m	-	-	-	1.4	29.6	46.6	13	9	
Warren Slack Soil Pit 2, Depth 1.75 m	-	-	-	5.2	12.2	49.3	20.4	6.8	
Warren Slack Soil Pit 2, Depth 2.1 m	-	-	-	-	6.8	46.9	32.8	13.5	

TABLE 7

RESULTS OF ANALYSIS OF "OUTWASH" SANDS FROM THE VALE OF PICKERING, WOLDS SCARP AND WOLDS DIP SLOPE, USING STUDENTS T TEST

SOURCE OF MATERIAL	SIGNIFICANCE	DEGREES OF FREEDOM
Sherburn Sands (Vale of Pickering) vs. sands on Wolds scarp	2.234 significant at 5% level	27
Sherburn Sands (Vale of Pickering) vs. sands on Wolds dip slope	0.318 not significant at 10% level	16
Sands on Wolds dip slope vs sands on Wolds scarp	3.644 significant at 5% level	19

TABLE 8

ANALYSIS OF VARIANCE BETWEEN MEANS, STANDARD DEVIATIONS, AND MEANS + STANDARD DEVIATIONS FOR SHERBURN SANDS ON THE WOLDS ESCARPMENT AND OUTWASH (SHERBURN ?) SANDS ON THE WOLDS DIP SLOPE

SAMPLE	F RATIO FOR VARIABLES	APPROX. PROBABILITY	F RATIO FOR ROWS	APPROX. PROBABILITY
Mean vs. mean for Sherburn Sand and dip slope sand	18.701	0.014	1.044	0.484
Mean vs. mean for Sherburn Sand and escarpment sand	8.096	0.014	0.569	0.829
Mean vs. mean for escarpment sand and dip slope sand	0.714	0.55	1.652	0.318
Standard dev. vs. standard dev. for Sherburn sand and dip slope	8.854	0.041	3.061	0.152
Standard dev. vs. standard dev. for Sherburn sand and escarpment sand	4.768	0.047	1.478	0.254
Standard dev. vs. standard dev. for escarpment sand and dip slope sand	4.689	0.095	7.381	0.041
Mean vs. standard dev. for Sherburn sand and escarpmentsand	4.954	0.341	1.587	0.138
Mean vs. standard dev. for Sherburn sand and dip slope sand	13.002	1.6	3.278	3.37
Mean vs. standard dev for escarpment sand and dip slope sand	9.781	4.884	1.442	0.193
Mean vs. mean for all three deposits	9.429	8.631	0.799	0.559
Standard dev. vs. standard dev. for all three deposits	6.191	0.024	3.763	0.052
Mean vs. standard dev. for all three deposits	7.57	1.785	1.855	0.037

TABLE 9

PARTICLE SIZE ANALYSIS OF CLAYS-WITH-FLINTS, STAXTON WOLD (TA016763): MATTHEWS 1977

Horizon Depth	Sand 2 mm - 200µ (%)	200µ - 50µ (%)	Silt 50µ - 20µ (%)	20µ - 2µ (%)	Clay < 2µ (%)
0 - 15 cm	7.8	24.1	18.7	16.8	32.6
15 - 33 cm	11.1	25.5	19.1	17.3	27.0
33 - 50 cm	3.5	4.4	3.3	7.6	81.2
50 - 70 cm	8.5	2.6	1.1	7.7	80.1

TABLE 10

PARTICLE SIZE ANALYSIS OF SANDY-CLAY SUBSOILS FROM SELECTED SITES ON THE NORTHERN YORKSHIRE WOLDS (See figs. 57 & 58)

Locality	Origin	Coarse Sand <3ϕ (%) (<120μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2μ)	Clay >9ϕ (%) (> 2μ)
Many Thorns Farm (SE 85259135) (A1)	Subsoil	28.7	50.7	1.7	1.1	17
Cotton Dale (TA 026766) (A2)	Subsoil	7.0	45.3	19.2	5.8	23.8
Humble Bee Farm (TA 03937927) (A3)	Subsoil	1.4	48.2	5.5	8.8	36.1
Flixton Wold Chalk Pit (TA 048778) (A4)	Fissure-Fill (0.8 m depth) z	7.1	56.2	8	2.9	22.3
Flixton Wold Chalk Pit (TA 048778) (A4)	Fissure-Fill (1.1 m depth)	5.9	57.5	3	13	19.4
Flixton Brow Chalk Pit (TA 0397793) (B1)	Fissure-Fill	-	27.4	3.8	8.5	60.3
Fleming Dale (TA 07187671) (B2)	Subsoil	67.9	9.6	9.4	7.7	6.2
Whin Moor Farm Chalk Pit (SE 929728) (B3)	Subsoil	51.4	5.4	8.0	2.0	33.2

TABLE 10 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2μ)	Clay >9ϕ (%) (> 2μ)
Binnington Ness (TA 01537511) (D4)	Subsoil	35.8	30.4	2	2.7	30.4
Cansdale Farm (TA 07287471) (B5)	Subsoil	28.6	27	12.2	3.2	29
Foxholes Chalk Pit (TA 014734) (C1)	Subsoil	15.4	53.5	7.6	8.2	15.5
Foxholes Chalk Pit (TA 014734) (C2)	Fissure-Fill (c. 1 m depth)	6.6	17.6	12.9	7.1	55
Weaverthorpe Slack (SW 97257290) (C3)	Subsoil	17	37.4	13.1	2.4	31
Willerby Wold Farm (TA 00127660) (C4)	Subsoil	43.2	17.8	8.3	5.5	23.4
Chalk Pit, North Wold Farm (TA 06317798) (C5)	Subsoil	57.1	25.1	3.9	2.5	11.5
North Wold Farm (TA 06137824) (D1)	Subsoil	39.4	19.3	2.3	4.5	34.2
Wilson's Wold Farm (SE 981727) (D2)	Subsoil	26.3	56.6	5	1	10.1
Ganton Wold (TA 00127689) (D3)	Subsoil	40.3	28.8	4.4	0.9	26.6

TABLE 10 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120μ)	Fine Sand 3ϕ-4ϕ (%) (120-64μ)	Coarse Silt 4ϕ-6ϕ (%) (64-16μ)	Fine Silt 6ϕ-9ϕ (%) (16-2μ)	Clay >9ϕ (%) (> 2μ)
Old Chalk Pit, Huggate (SE 875548) (D4)	Subsoil	5	50.8	18.4	2.7	23
Old Chalk Pit, Ganton Brow (SE 99753) (D5)	Fissure-Fill (c. 0.5 m depth)	8.1	24	9.6	4.5	53.9
The Sheepwalks, Ganton Wold (TA 0156750) (E1)	Fissure-Fill (c. 0.8 m depth)	42	17.9	2.2	2.7	35.1
Five Firs Plantation Flixton Wold (TA 05907596) (E2)	Subsoil	20.8	38.8	14.7	4.3	19.6
Knapton Plantation (SE 895750) (E3)	Fissure-Fill (c. 1.2 m depth)	-	1.2	24.9	67.4	4.8
Old Chalk Pit (SE 828701) (E4)	Fissure-Fill (c. 1 m depth)	23.4	42.6	1.4	0.8	31.1
Chalk Pit, Thorpe Bassett Wold (SE 852714) (E5)	Fissure-Fill (c. 0.6 m depth)	44.8	30.8	1.4	7.6	15.3
Chalk Pit, Crook Dale (SE 927705) (F1)	Fissure-Fill (c. 1.9 m depth)	-	2.7	26.8	65.1	5.9

TABLE 10 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2μ)	Clay >9ϕ (%) (> 2μ)
Chalk Pit, East Heslerton (SE 93287592) (F2)	Subsoil	21.4	21.0	16.0	9.2	32.0
Old Chalk Pit, Luttons Lane (SE 911749) (F3)	Subsoil	37.4	31.6	6.2	2.2	22.6

TABLE 11

PARTICLE SIZE ANALYSIS OF TOPSOILS AND SANDY FISSURE DEPOSITS ON THE NORTHERN WOLDS (SEE FIG. 58)

Locality	Origin	Coarse Sand <3ϕ (%) (<120 μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64 μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16 μ)	Fine Silt 6ϕ-9ϕ (%) (16 -3 μ)	Clay 9ϕ (%) (>2 μ)
Belmanaer Farm (SE 840683) (A1)	Subsoil	23	33.8	1.7	1.1	17
Gravel Pit, Waterdale (SE 826613) (A2)	Solifluction	24	25.7	34	6.2	10
Staxton Wold (TA 01867713) (A3)	Topsoil	62.3	25.3	3.6	0.9	4.7
Binnington Ness (TA 01537511) (A4)	Topsoil	35.8	28.4	9.7	3.3	11.8
North Dale (TA 0140768) (A5)	Topsoil	55.6	21.8	6.3	1.7	7.6
Linton Whins Chalk Pit (SE 886699) (B1)	Topsoil	19.8	50.3	9.6	3.8	12.5
Ganton Wold (SE 99877584) (B2)	Topsoil	49.8	26.4	7.1	1.8	8
Humble Bee Farm (TA 04107800) (B3)	Topsoil	65.5	19.8	3	0.9	6.1
Old Chalk Pit (SE 879701) (B4)	Subsoil/fissure fill	7.6	47.9	13.8	20.7	0.8

TABLE 11 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120 μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64 μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16 μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2 μ)	Clay 9ϕ (%) (>2 μ)
Old Chalk Pit, Moor Farm (SE 94847307) (B5)	Subsoil/fissure fill	27.4	37.5	13.2	2.5	19
Warren House Farm (SE 992753) (C1)	Subsoil	35.1	26.2	17.8	7.8	12
N. Scarp Wolds, E. Heslerton Brow (SE 92007525) (C2)	Solifluction Gravel Matrix	43.7	47.2	3.7	0.9	2.8
Scarp, Settrington Brow (SE 948709) (C3)	Solifluction	41.7	18.2	9.8	10	19.6
Chalk Pit, Wold Road (SE 917698) (C4)	Fissure-Fill	18	42.3	19.5	3.9	15.5
Sunning Dale (95507365) (C5)	Topsoil	20.3	54.2	12.1	2.9	8.5
South Dale (TA 07787550) (D1)	Subsoil	50.8	25.2	8.4	1.7	8.4
Ganton Brow (TA 00097487) (D2)	Topsoil	49.4	35.3	7.3	1.5	6.7
New Barn Site, Linton Farm (SE 908708) (D3)	Subsoil	8.5	35	31.2	14	11.3
SE (840567) (D4)	Topsoil	19.2	22.2	7.4	5.6	26

TABLE 11 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120 μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64 μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16 μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2 μ)	Clay 9ϕ (%) (>2 μ)
Lawson's Wold Barn (SE 94507525) (D5)	Topsoil	34.1	47.6	7.8	0.6	9.6
Fridaythorpe (SE 914603) (E1)	Subsoil	31.8	42.1	17	9.7	0.5
Old Chalk Pit Fridaythorpe (SE 915603) (E2)	Subsoil	19.8	46	22.3	11.8	2.1
Fridaythorpe (SE 868653) (E3)	Subsoil	2.6	48	9.7	11.4	8.4
West Heslerton Wold (SE 9266717) (E4)	Subsoil	1.9	49.8	20.4	4.6	23.3
High Mowthorpe Wold Old Chalk Pit (SE 891699) (E5)	Subsoil	13.1	44	30.6	11.5	2.7
The Peak, Settringham (SE 8665681) (F1)	Subsoil	17.1	44.5	13.6	10	13.8
Chalk Pit, Belle Vue Farm (SE 952674) (F2)	Subsoil	4.1	72.9	15.8	5.5	1.9
Chalk Pit, High Cowlam (SE 964657) (F3)	Subsoil	6.7	69	3.4	10.4	10

TABLE 11 (Continued)

Locality	Origin	Coarse Sand <3ϕ (%) (<120μ)	Fine Sand 3ϕ-4ϕ (%) (120 -64μ)	Coarse Silt 4ϕ-6ϕ (%) (64 -16μ)	Fine Silt 6ϕ-9ϕ (%) (16 -2μ)	Clay 9ϕ (%) (>2μ)
Roadside Bank (B1257) (SE 908613) (F4)	Sand Lens in Solifluction Gravels	17.6	52.9	15.7	0.9	12.9
West Heslerton Brow E. Side Lutton´s Lane (SE 910750) (F5)	Fill in Periglacial Depression	78.9	6.3	5.6	0.7	8.5
Chalk Pit, Duggleby (SE 874680) (G1)	Subsoil	29.3	42.8	6.3	11.5	10
E. Heslerton Wold (SE 742918) (G2)	Topsoil	40.1	38.1	8.5	10.3	3
Settrington Wold (SE 868694) (G3)	Subsoil	20.6	53.5	10.9	3.3	11.7
West Heslerton Wold, Chalk Pit (SE 924718) (G4)	Subsoil	24.7	42.8	12.6	3.8	16.1
Wardale (SE 94457438) (G5)	Subsil	29.3	35.8	8.4	5.1	21.1
Brick Pit, Huggate (SE 875584)	Upper Silts	-	8.5	9.6	49.3	32.6
Brick Pit, Huggate	Middle Silts	-	17.1	23.5	39.3	20.1
Brick Pit, Huggate	Lower Clays	-	-	5.7	53.8	40.5

TABLE 12

PARTICLE SIZE ANALYSIS OF COLLUVIAL DEPOSITS IN SELECTED DRY VALLEYS ON THE NORTH YORKSHIRE WOLDS

Locality	0 ϕ (%) (1000 μ)	1 ϕ (%) (500 μ)	2 ϕ (%) (250 μ)	3 ϕ (%) (120 μ)	4 ϕ (%) (64 μ)	<4 ϕ (%) (<63 μ)
Camp Site Soil Pit 1 0.5 m	-	3.2	6.8	30	35.1	25
Camp Dale Soil Pit 1 1.0 m	-	2.9	6.4	24.1	32.8	33.7
Camp Dale Soil Pit 1 1.5 m	-	5.3	9.7	24.7	22.8	37.6
Camp Dale Soil Pit 1 1.8 m	1.8	4.2	12	29.5	21.9	30.6
Camp Dale Soil Pit 2 0.7 m	-	2.7	13.1	38.7	23.3	22.1
Camp Dale Soil Pit 2 1.6 m	-	-	5	38.2	33.3	23.6

TABLE 12 (Continued)

Locality	0 ϕ (%) (1000μ)	1 ϕ (%) (500μ)	2 ϕ (%) (250μ)	3 ϕ (%) (120μ)	4 ϕ (%) (64μ)	<4 ϕ (%) (<63μ)
Ganton Dale (TA 015747) 1.0 m	-	1	3.5	19.5	26.9	49
War Dale (SE 949744) 1.6 m	1	2.6	26.5	39.5	29.7	0.7
Cooper´s Bottom (SE 975741)	-	0.4	4.8	41.4	24.7	28.8
Merry Dale (TA 041780) 1.6 m	2.2	10	17.6	34.3	30.8	15.1
Merry Dale (TA 044775) 1.2 m	-	1.4	25.7	35.5	26.3	11.2

TABLE 13

PARTICLE-SIZE ANALYSIS OF THE THIXENDALE SANDS AND GRAVELS

-2ϕ(%)	-1ϕ(%)	0ϕ(%)	1ϕ(%)	2ϕ(%)	3ϕ(%)	4ϕ(%)	Graph ref. (see fig. 68)
6	25	37	6	3	15	7	5
10	34	21	3	3	18	10	4
-	3	6	22	42	12	12	1
-	1	4	6	58	23	13	2

TABLE 14

DRAINAGE DENSITIES OF THE DRY VALLEYS OF THE NORTHERN YORKSHIRE WOLDS

Basin	Area (km^2)	Length of channel (km) (after Lewin 1969)	Length of gullies (km)	Density (after Lewin 1969)	Revised density	Order
1. Wintringham Beck	22.5	48.6	98.8	2.16	6.35	5
2. Settrington Beck	11.0	11.6	41.6	1.05	4.84	3
3. Old Dale/Haverdale	10.5	14	39.2	1.33	5.07	4
4. Wad Dale	3.0	4	6.4	1.3	3.47	3
5. Helperthorpe Slack/ Weaverthorpe Slack	12.5	16	57.6	1.28	5.89	5
6. Cooper's Bottom	4.5	5.2	18.6	1.16	5.29	4
7. Warren Slack	5.25	8.0	14.0	1.52	4.19	3
8. 'Foxholes Dale'	2.25	2.4	2.4	1.07	2.14	2
9. Ganton Dale/West Dale	10.13	20.0	36.0	1.98	5.53	3
10. Cotton Dale/Well Slack	5.75	6.8	23.8	1.18	5.32	5
11. Lang Dale/Merry Dale	3.5	7.8	13.0	2.23	5.94	4
12. 'Fordon Dale'	1.5	2	1.2	0.8	2.13	2
13. Escarpment	21.4	5.7	109.8	0.27	5.4	-
14. Camp Dale/Flemming Dale	9.25	10.8	24.4	1.17	3.18	4

TABLE 14 (continued)

	Basin	Area (km^2)	Length of channel (km) (after Lewin 1969)	Length of gullies (km)	Density (after Lewin 1969)	Revised density	Order
15.	South Dale	3.5	2	2.4	0.57	1.26	3
16.	Thirkleby Dale	2.25	2.2	4.0	0.97	2.76	3
17.	Old Dale (Kirby Grindalythe)	4.12	5.8	12.2	1.41	4.36	4
18.	Kirkby Grindalythe Dale	1.25	1	3.2	0.8	3.36	2
19.	'High Mowthorpe Dale'	5.88	3.4	2.0	0.34	0.92	3
20.	Great Wold Valley	42.5	25	78.0	0.59	2.43	
21.	Nova Slack	2.88	5.3	10	1.84	5.32	4
22.	'Low Mowthorpe Dale'	0.5	2.6	7	5.2	19.2	3
23.	'Low Mowthorpe Dale' (East Branch)	1.88	0.4	1.4	0.2	0.96	2
24.	'Kirkby Grindalythe Dale' (South Branch)	1.0	1.6	2.8	1.6	4.4	3
25.	Croom Dale	11.0	14	28.2	1.27	3.84	4
26.	'West Lutton Dale' (South Branch)	1.25	0.8	0.8	0.64	1.28	2
27.	Galloping Slack	4.7	11.2	27.4	2.4	0.26	4
28	Old Dale (Butterwick)	1.75	1.8	2.2	1.02	2.29	2

TABLE 14 (continued)

	Basin	Area (km^2)	Length of channel (km) (after Lewin 1969)	Length of gullies (km)	Density (after Lewin 1969)	Revised density	Order
29.	'Butterwick Dale'	2.4	2.4	8.8	1.01	4.72	3
30.	Old Dale (Octon)	2.5	4.2	10.2	1.68	5.72	3
31.	'Octon Dale' (East Branch)	1.88	1.6	5.0	0.85	3.52	3
32.	Sym Dale	6.0	5.0	10.6	0.83	2.6	4
33.	'Greenlands Dale'	6.0	4.8	20.0	0.8	4.13	4
34.	Tog Dale/Broach Dale	12.25	14.4	34.2	1.18	3.97	4
35.	Crake Dale/West Dale	15.25	2.0	4.2	0.13	0.41	4
36.	Phillip's Slack	2.2	17.6	38.6	8.28	26.45	3
37.	Croom Dale (Sledmere)	2.2	1.4	4.6	2.16	2.82	3

TABLE 15

ORIENTATION OF GULLIES WHICH ENTER TRUNK DRY VALLEYS FOR 3 RANDOMLY SELECTED AREAS OF THE NORTHERN YORKSHIRE WOLDS (SEE FIGS. 81 & 82)

Sunningdale/Weaverthorpe Slack Slack (fig. 81) Gullies on N. side of valley	Gullies on S. side of valley	"Butterwick Dale" (fig. 82)	"Old Dale" (Octon) (fig. 82)
Orientation in °	Orientation in °	Orientation in °	Orientation in °
74	105	87	73
70	103	72	50
69	114	78	30
90	91	104	47
70	90	99	18
55	91	93	0 *
90	100	88	131
65	90	72	121
92	108	90	109
88	120	69	109
72	103	73	104
74	92	37	62
	92	0 *	72 *
	93		
	90		
	92		
	91		

* N.B. extension of dry valley head

TABLE 16a

STREAM ORDER AND STREAM LENGTH FOR 12 DRAINAGE BASINS ON THE NORTHERN YORKSHIRE WOLDS - TRUNK VALLEYS ONLY (FIG. 81a)

BASIN NO.	STREAM ORDER		
	1	2	3
3	4.99	2.93	5.22
6	1.99	2.76	0
8	2.18	0.31	0
9	5.49	4.6	3.38
12	1.41	0.46	0
16	1.58	0.54	0
17	2.74	2.86	0
21	4.14	2.46	0
25	6.37	5.13	1.33
29	2.39	0	0
31	0.95	0.42	0
35	8.37	3.78	3.51

TABLE 16b

STREAM ORDER AND STREAM LENGTH FOR 12 DRAINAGE BASINS ON THE NORTHERN YORKSHIRE WOLDS - TRUNK AND TRIBUTARY VALLEYS (FIG. 81b)

BASIN NO.	STREAM ORDER			
	1	2	3	4
3	41.8	11.84	4.23	5.64
6	17.94	5.9	1.61	2.05
8	3.13	2.3	0	0
9	25.42	6.96	4.05	2.83
12	2.05	1.48	0	0
16	4.02	2.33	0.6	0
17	14.53	2.69	1.83	2.03
21	13.13	4.42	1.03	1.26
25	33.17	8.47	5.2	2.55
29	10.27	1.2	2.76	0
31	5.02	1.92	0.93	0
35	39.06	9.26	7.23	5.22

N.B. to identify individual basins, see table 14