# The origins of the geomorphology of the Yorkshire Wolds

Derek J. Gobbett
*Applegarth, Foxholes, Driffield, YO25 3QN*

---

SUMMARY.
After uplift and tilting towards the North Sea basinThe plateau areas of the Yorkshire Wolds evolved during the Cenozoic by the chemical weathering of the Chalk bedrock in a generally temperate climate. Most of the Chalk was removed in solution to produce a surface gently sloping to the SE. This became diversified by solution features in the form of pipes and dolines.
In the northern Wolds the distinctive Great Wold Valley was probably eroded by a pre-Pleistocene consequent river flowing from the west. During the Pleistocene there was a least one period when the Wolds were glaciated during which ice removed most of the flint-dominated regolith. Most of the cold stadial periods would have produced a periglacial climate with permafrost on the Wolds. Under these conditions the weathering and erosion of the chalk was physical rather than chemical and resulted in seasonal gravelly braided streams which rapidly cut steep convex-sided valleys into the plateau. Some of these may have originated from snow-filled dolines. These valleys would have been reactivated during the late Devensian Dimlington and perhaps also the Loch Lomond Stadials (~26-10 $C^{14}$ ka) to produce the very young fresh landforms we see today as dry valleys.
Thaw of the permafrost in the early post-glacial caused major landslips along the Wolds escarpment and on the steep sides of the then dry valleys.

---

In contrast to the relatively well-researched geomorphology of the unglaciated chalklands of southern England, with the exception of Lewin (1969), little has been published on the chalk landforms of the Yorkshire Wolds. Early discussion (Cole 1879, Mortimer 1885) concentrated on the most obvious and most puzzling of features, the dry valleys and their origin.

Reid (1887), recognised that surface melt-water above a frozen substrate was instrumental in eroding the now dry valleys, yet others dismissed stream erosion entirely. Cole (1879) denied that surface water was, in any way, responsible for valley formation. He thought that during uplift the chalk had suffered linear tectonic disturbances along which solution ~~of the Chalk~~ proceeded more rapidly than elsewhere causing surface collapse and the origin of the dry valley systems. He also thought that the present form of the dry valleys was the result of recent glacial erosion and he regarded the well-rounded chalk gravels, which reach a considerable thickness in the lower parts of the valleys, as marine beaches. In a later paper (Cole 1887) he agreed with Reid (1887) in recognising the importance of frozen ground in greatly enhancing physical weathering and erosion in the short term but regarded underground solution below the dry valleys as the most effective long term agent in the formation of these valleys.

Mortimer (1885) also dismissed the fluvial origin of the dry valleys. He found evidence for faults running parallel to the axes of some valleys and followed Cole in thinking that these valleys developed along "fractures in the crust" where internal solution of the chalk was more pronounced. He regarded the dolines on Raisthorpe Wold as incipient dry valleys. Mortimer did recognise some land slipping but failed to see that many of his lines of disturbance were due to such processes as camber, valley bulges and slope instability rather than tectonic movement.

Foster (1985,1987a,b,) briefly discussed the development of dry valleys and considered the fan-shaped gullies to be found at the head of many dry valleys to be post-Devensian features formed by snow melt. He thought the ice lobe in the Vale of Pickering rose up and in places overtopped the northern Wolds escarpment as far west as Thorpe Basset Brow and interpreted Snevver Scar [TA033788] and "channels", running parallel to the contour, as glacial drainage channels. The "channels" in question are actually formed by extensive land-slipping and lie behind rotational slides.

De Boer's studies of the Wolds dip slope suggested to him the presence of an erosion surface at about 60m and another surface at about 115m above OD. These surfaces are represented by a small number of discontinuous facets. None of the specific localities given by De Boer (De Boer *et al.* 1958, p.188) show any clearly discernable break in slope on the 1;25,000 map and as De Boer himself states, "*The chief difficulties in precisely defining the higher feature are also encountered in mapping the lower terrace: first the very smooth transition from the surface of the terrace to the only slightly more pronounced slope of the backface, with no clear break of slope, and second, the generally subdued relief away from the valleys*"
The idea of erosion surfaces was taken up by Lewin (1969) and considerable extended using a variety of analytical techniques. He concluded that erosion surfaces do exist and proceeded to map seven surfaces in the Northern Wolds and eight in the Southern Wolds which were tentatively correlated. Map data and observation in the field have led me to think that erosion surfaces do not exist on the Yorkshire Wolds ~~and thus do not feature in this atlas~~. His lower surfaces, e.g. those along the Great Wold Valley, can be shown to be terraces produced by post-glacial mass movement (Gobbett 2014). Lewin did not consider how the solution of the chalk during the Tertiary would have affected the surface of the Wolds. He also failed to recognise the importance of the impact of successive mid to late Pleistocene periglacial climates on valley development and mass movement.
Work in southern England (Bull 1940, Paterson 1977, Williams 1980) supports the theory that erosion of the chalk is greatly enhanced under permafrost conditions when intensive physical weathering produces frost shattered chalk which is rapidly eroded during the spring melt.

## 1. PRESENT LANDFORMS

The present landforms of the Yorkshire Wolds can be divided into 5 general types.

1. A gently sloping plateau which is widely but patchily preserved on the present Wolds dip slope.
2. The escarpment.
3. A major valley, the Great Wold Valley running ENE through the northern Wolds.
4. Dry valleys which form a dense array of dendritic patterns etched into the landscape and constitute at least 80% of the Wolds surface (see Lewin 1969, fig.13)
5. Ice marginal channels

## 1.1 Plateau areas

The Chalk outcrop of the Yorkshire Wolds is shaped rather like a west facing boomerang. Around the apex the plateau surface lies above 200m OD culminating at 246m OD at Garrowby [SE821569]. The wings of the boomerang run ENE (Northern Wolds) and SSE (Southern Wolds) and in both of these directions the plateau surface steadily declines to about 90m OD. Since the plateau is bounded by convex slopes its limits have to be somewhat arbitrarily defined.

The main watershed closely follows the top of the escarpment in the Northern Wolds except for two embayments, at Wintringham [SE880730] where the watershed is lowered to 114m, and at Wharram le Street [SE864662]where it lies at 124m. These may be relicts of former courses of a permanent river or rivers traversing the Wolds from the west. The only other scarp valley in this part of the Wolds is Sked Dale [SE966753] just south of Sherburn which lowers the watershed from 160m to 131m. From the apex of the boomerang at Leavening Brow the watershed continues SSE but here it is much indented by several scarp slope dry valley systems, the two largest of which, at Millington and Warter, push the main watershed far to the east.
Towards the concave side of the boomerang plateau height steadily decreases (see Versey 1939, fig.3) and would, before the last Devensian cold stage have ended in the cliff line from Bridlington to Hessle. This concave side is now covered by the edge of Devensian glacial deposits. The strike of the Chalk generally follows the shape of the boomerang. It dips in the northern Wolds towards the SSE and in the southern Wolds to the ENE at an average gradient of 1 in 50 ($1\text{-}2^0$). The surface of the dip slope along the interfluves follows these trends but with a shallower gradient of about 1 in 100 ($<1^0$).

On the plateau there are a number of small shallow depressions in the Chalk most of which are filled with clastic sediments and are not obvious in the landscape. They were probably originally formed as dolines. The most obvious of these is a series of linear unfilled or partially filled depressions which run *en echelon* in an east-west direction across Raisthorpe Wold [SE840625] (Mortimer 1885, Lewin 1969, Gobbett 2014). The pattern of these "Raisthorpe Hollows" suggests they may be related to structural features in the Chalk.

The clastic infill of dolines was formerly used as a source of clay and sand and several of these deposits have been mapped by Mortimer (1886). More recently Bray *et al.* (1981) have recorded more then 15m of sand and brickearth filling a doline at Fimber [SE885608]. Dolines also provide natural ponds around which many of the Wolds villages were sited (Hayfield and Wagner 1995, fig.2). Larger dolines may have existed in the Tertiary landscape which were modified by surface runoff during periods of cold climate in the Pleistocene. The heads of many dry valleys are bowl-shaped with small radial channels which coalesce to form a typical dry valley with a flat floor and steep sides (Fig.1). Foster (1987b, fig.12) mapped two other examples near Octon Lodge [T010700]. Such bowl-shaped depressions might have originally developed as dolines on the pre-Pleistocene surface. Figure 1 shows the widespread distribution of these depressions.

Solution pipes are probably common and widespread on the plateau but are rarely visible except in chalk pits, quarries and coastal exposures. They are usually filled with a flint-dominated breccia which may be cemented into "fairystone" seen *in situ* in Fairydale and at St Austin's Rock (Gobbett 2006). Boulders of "fairystone" are commonly found along field margins and road verges where they have been moved to avoid the damage they would do to the plough.

The plateau with its dolines and pipes and an average gradient of less than $1^0$ is likely to have extended over the whole area of the Wolds during the long progress of Chalk erosion by internal solution during the Cenozoic. Differential subsidence of the eroding Chalk could have produced broad shallow facets on the dip slope simulating poorly preserved erosion surfaces.

## 1.2 The escarpment

Along the front of the Wolds boomerang the Chalk is underlain for the most part by clays. The relatively slower erosion of the chalk results in a marked escarpment the character of which varies along its length. It is convenient to divide it into three sections anticlockwise from northeast to south, (Fig. 2).

### *1.2.1 Flotmanby to Knapton*

Here the escarpment runs WSW almost in a straight line. The top rises from 120m at Flotmanby Brow to 160m at Knapton: the base lies constantly at about 50m. The base of the Chalk also rises from 50m at Flotmanby to 80m at Knapton,so although it is underlain by the Speeton Clay, the steep slope of the escarpment is formed entirely or largely of Chalk (Fig.2a). The Sherburn Sands (probably of Devensian age) overlap the base of the Chalk up to about the 70m contour. There are only two small gaps ~~(mentioned above in describing the watershed)~~ one at Ganton and one at Sherburn where narrow scarp (obsequent) dry valleys have cut through the escarpment top.

The inherent instability of Chalk overlying clay has caused landslips all along the escarpment. These typically break away from near the top of the escarpment along a listric fracture and move down-slope to form a buttress with its long axis parallel to the slope. In between these slips the original scarp appears as a small valley or gully. Where the Chalk has been exposed e.g. in the pit on Willerby Brow [TA012783], it shows cambering and gulls. Westwards the slipped area increases in width and in size of individual slips as the base of the Chalk rises and thus the thickness of clay in the scarp face increases. It is particularly well developed below East Heslerton Brow where there is evidence of rotational slides. One of these is well exposed in a chalk pit at SE938761 where the Lower Chalk dips $25^0$ south.

### *1.2.2. Knapton to Leavening Brow*

From Knapton the scarp turns southwest. It is here more discontinuous with detached or partly detached outliers. At Wharram le Street and near Duggleby the escarpment consists entirely of Kimmeridge Clay.
The base of the escarpment rises from 50m to 120m but as the base of the Chalk also rises from 80m to 180m it forms an increasingly thin capping (Fig.2b). As a result there are extensive landslips which are particularly well developed on Birdsall Brow. The Stack Hills [SE8771]on the south side of the Wintringham Gap are deep rotational slips in which the Chalk dips $70°$ south towards the escarpment. In the larger Chalk outliers of Wintringham, Thorpe Basset, Duggleby, Settrington and Grimston Brow the Chalk appears to be tilted probably by cambering and some

anomalously high dips are marked on the BGS map (sheet 64, 1993). Above North Grimston is a secondary escarpment formed of Corallian limestone and separated from the Chalk by a thin layer of Kimmeridge Clay.

*1.2.3. Leavening Brow to North Ferriby*
This 40km stretch runs SSE, overall in a straight line, but it is broken by over 30 dry valleys which form the heads of spring line streams. These range from single coombes e.g. Cleaving Coombe [SE860465] to extensive basins like those around Millington and Warter which rival in size some of the dip slope drainage basins.
The top of this part of the escarpment falls from 200m to 90m and its base from 120m to 20m. The base of the Chalk drops from 180m to sea level (Fig.2c). The strata underlying the chalk are more variable but Lias clays predominate overlain in places by thin Middle Jurassic and Oxfordian strata.
The Chalk escarpment remains unstable and features landslips but generally on a smaller scale than those further north. At Partridge Hall Quarry [SE858470] the Chalk dips eastward into the escarpment at 15-20$^0$ and is cut by numerous normal faults striking parallel to the trend of the escarpment and dipping 70-80$^0$ west. These faults slice up the chalk to produce a series of rotational blocks caused by gravity collapse over the underlying clays. The Black Band is exposed at the base of the quarry and this also may have provided a weak layer over which the Chalk slipped (R. Myers-cough, pers~~onal~~ com~~munication~~).
Flanking the entrance to the Millington basin thin limestone bands in the Lower Lias form a low wooded secondary escarpment below the Chalk.

## 1.3 The Great Wold Valley
From its head at Wharram le Street the Great Wold Valley runs ENE to Burton Fleming beyond which it abruptly turns south to Rudston. Here the present valley turns sharply through another right angle and runs to the sea at Bridlington Quay. This part of the valley narrows and its longitudinal gradient steepens. The Great Wold Valley drainage basin is many times larger than any other basin on the Wolds.

In comparison with the largest dip slope dry valley the Great Wold Valley is broader, has a less steep longitudinal gradient and more gentle sides which, although commonly modified by landslips, tend to be concavo-convex in contrast to the convex slopes of dry valleys (Fig.3).

Along the base of the valley sides a number of small lobe-like rounded hills intrude into the valley floor. These occur mainly on the south, north-facing side of the valley and increase in size down valley. These small hills are usually cultivated and show no exposures of the Chalk. Their contours are smoother than those of the rotational slides of the Stack Hills on the south side of the Wintringham Gap. They appear to have been formed by mass movement of a regolith of brecciated chalk which has denuded the upper part of the slope and aggraded the lower part. This type of mass movement is probably responsible for a terrace commonly present on the lower part of the valley sides and seen particularly well northwest of Thwing [TA0272] and near Weaverthorpe [SE9770].

Although its tributary valleys are dry the main valley carries some surface water. At the present time springs from the base of the Chalk feed a small stream which has a permanent flow from Wharram le Street to Kirby Grindalythe. Between Kirby Grindalythe and West Lutton stream flow relies on a rise in the water table and is thus intermittent. Below West Lutton only after periods of exceptionally high rainfall does water rise through the valley floor to produce a surface flow which may continue as far as Butterwick before sinking into the ground. More commonly ground water rises between Foxholes and Wold Newton from where a broader stream floods the valley floor. At Rudston a permanent spring sources the stream to the coast at Bridlington Quay.

This typical "winterbourne" known locally as the "Gypsey Race" is clearly a misfit. "Gypsey" is pronounced with a hard "G". Its origin is obscure but it may come from the Norse "*gypa*" which means a gushing spring. Taylor (1996) notes that it's earliest mention is found in the chronicle of William of Newburgh who was born in Bridlington in 1136. He wrote "*Famosae illae aquae quos volgo Gipse vocant*" (This famous watercourse called Gipse in the vulgar tongue). Allen (1831) provides an excellent description.

*"The Gipseys are streams of water which at different periods are observed on some parts of the Yorkshire wolds; they appear towards the latter end of winter or early in the spring. They are then seen tricking through the grass where the ground is not broken, and sometimes rushing with considerable force through the surface; and the emission of water is often so copious as to constitute a very considerable stream, filling a drain twelve feet wide and three feet deep, called by the country-people the gipsey-race, ... ... ... .. it is undoubtedly accelerated and augmented by a continuance of heavy rains; and indeed the gipseys never make their appearance except in a very wet season, when they sometimes flow during two or three months, and then totally cease, leaving scarcely a mark to distinguish the place from which the water issued"*

## 1.4 The Dry Valleys

The Wolds plateau is dissected by numerous valleys which have all the characteristics of a fluvial origin but are presently dry. The valley sides are smooth, rounded, convex slopes which are mantled, as are the remains of the original plateau and the valley floors, by a regolith of brecciated chalk with a matrix of loess (Catt *et al.* 1974, Neal 2011).

The valleys display a dendritic pattern (Fig.1) in which the tributaries often join the main valley at high angles approaching $90^0$. This led Lewin (1969) to consider that they might be joint controlled but little is known about joint patterns in the Wolds Chalk. High confluence angles can be explained by the fact that where they occur valley sides are steep, >$20^0$. On the dip slope the dry valleys are organised into a number of small drainage basins which are elongated parallel to the plateau slopes and have narrow exits. On the scarp slope Lewin (1969 fig.13) maps 38 basins but 28 of these are small simple valleys with very small catchments.

Typically the head of a dry valley is a gentle depression traversed by several shallow gullies which converge. Down valley the gradient steepens markedly and becomes entrenched into the plateau. Unless they have been modified by landslips, the valley sides usually slope at $22^0$. This angle is remarkably constant all over the Wolds and is only occasionally exceeded up to an angle of $30^0$. The slopes are convex; the flat valley floor has a steep longitudinal gradient and in places shows traces of small channels separated by low ridges. Small tributary valleys running at right angles to the main valley commonly show signs of a small alluvial fan at their mouths.

The majority of the dry valleys have no marked asymmetry in cross section but some 30 valleys do clearly show an asymmetry. In these valleys most of the steeper slopes face between WNW and NNW ~~as shown in~~ (Fig~~ure~~ 4). Cole (1879) also noted that the steeper sides of the Wold valleys "as a rule" face north and west. Ollier and Thomasson (1957) who studied asymmetrical dry valleys in the Chilterns found "that in most cases where a valley is asymmetrical it is the west facing slopes and to a lesser extent the south facing slopes that are the steeper". It is difficult to explain the dominance of the NW-facing steeper slopes, as in a cold climate the west and south facing slopes may be regarded as thawing more and thus suffering more rapid erosion. In plan the valleys are quite variable. Regular interlocking spurs are common but many valleys are quite straight or have straight sections. ~~The sides may be symmetrical or asymmetrical and the orientation of the asymmetry is not constant.~~ Down valley the longitudinal gradient decreases, the sides become less steep and the flat floor widens progressively to 200m or more. The floor is now underlain by subrounded to rounded chalk gravel with angular flints best exposed by Station Cottages just north of Wetwang [SE935595] and in Garton Slack [SE959596] where it has been extensively quarried in the past.

The steep sides of dry valleys commonly show signs of landslips. These are similar to but smaller in scale than the slips of the escarpment. Another common feature is a marked terrace along the base of the valley side raised a couple of metres above the valley floor, e.g. at Hog walk [SE916658] and Lang Dale [TA046774]

A narrow gully running straight down the steep side of a dry valley is not uncommon. This erosive feature which ~~may show~~ the remains of a small debris fan at its base I have termed a *Torrent Scar*. Torrent scars have been observed to be eroded almost instantaneously during periods of very heavy rainfall when ground water bursts out of the hillside and cuts a narrow gully sometimes two to three metres deep through the brecciated chalk regolith leaving a deposit of angular chalk debris over the valley floor (Hood 1892, Marley 1991). Subsequent collapse of the gully sides and re-growth of vegetation leave a scar down the valley side. Snevver Scar which Foster (1987c) regarded as a glacial meltwater channel, may be an example of a large torrent scar.

### Ice marginal channels

On the lower part of the dip slope adjacent to the edge of the glacial drift some interfluves have been cut across by sinuous channels with flat floors and concave sides, bowl-shaped in cross section. These channels were described by De Boer (1945) who interpreted them as overflow channels draining a series of proglacial lakes which flooded the ends of the Wolds dip slope valleys during the summers of the late Devensian Dimlington Stadial (Fig. 5).

I previously accepted De Boer's proposal of proglacial lakes in the Wolds but Dr E.R. Connell (pers. com) has pointed out that extensive lacustrine sediments would be expected to be supplied from the sediment load within and/or below the melting ice front. No evidence of any lacustrine deposits has been found in those areas supposedly occupied by proglacial lakes.

Instead of regarding the ice front as a waterproof barrier it is perhaps more likely that melt water from the Wolds was able to drain beneath the ice in marginal or submarginal channels ( Benn and Evans 2010). Under hydraulic pressure melt water would be able to cut channels across interfluves finally escaping via Goodmanham Dale to the Vale of York and Lake Humber without any great volume of water being held in lakes.

## 2. EVOLUTION OF LANDFORMS

Unlike on the chalklands of southern England no Tertiary sediments have been reliably recorded from the Yorkshire Wolds and the history of uplift since the end of the Cretaceous is obscure. Monoclinal folding and faulting of the Chalk, produced by fault movements in the underlying Jurassic basement are probably of early to mid Tertiary in age (Starmer 2008). These structures trend east-west but show little direct relationship to any of the main geomorphological features.

The Great Wold Valley is a major element of the landscape and was probably formed by a relatively large pre-Quaternary river rising far to the west and traversing the Wolds possibly through the Winteringham Gap. It may have been comparable with the rivers that currently cut through the North and South Downs of southern England.

The processes of weathering and denudation of the Chalk are climate dependent. In the temperate climate which prevailed during much of the Cenozoic slow chemical weathering would have predominated and internal solution of the Chalk would have lowered the surface leaving a regolith of clay-with-flints. Internal solution of the Chalk would have taken place most probably beneath a forest cover and would not have been uniform. The subsiding surface would have been diversified by enclosed hollows (dolines) and possibly by steps across the main dipslope simulating superficial "erosion surfaces". To get some idea of erosion rates, if it took 60 million (6x$10^{7)}$ years to remove 600m (6x$10^{8}$ $\mu$m)of chalk the average rate of solution would be 10$\mu$m $yr^{-1}$. This may be compared to Cole's 1879 estimate of one foot in 5779 years (c. 50$\mu$m $yr^{-1)}$. Kerney *et al.* (1963, p.188) refer to Atkinson (1957) "*who presents excellent evidence from archaeological excavations on the Chalk to show that a lowering of between 15 and 20 in. on level ground during the last 4000 years* is *by no means uncommon*". This equates to 9.5 to 12.5 $\mu$m $yr^{-1}$.

The marked changes in climate during the Pleistocene introduced a number of cold periglacial periods with intervals of permafrost. Under these conditions the erosion of the Chalk would have been greatly accelerated. Physical weathering by summer freeze and thaw and erosion by mass movement and melt water could have eroded the Chalk surface perhaps an average of 1mm to 1cm per year which is $10^{3}$ to $10^{4}$ $\mu$m $yr^{-1}$. Thus recent periglacial denudation could have proceeded from one hundred to one thousand times faster than the temperate denudation by chemical solution and thus left a far more obvious footprint on the present landscape. Kerney *et al.* (1963) show that coombes on the escarpment of the North Downs in Kent were almost entirely eroded by solifluction and melt water in about 500 years during the Loch Lomond Stadial (11-10$C^{14}$ ka), when the ground remained frozen in winter.

The widespread occurrence of erratics over the surface of the Yorkshire Wolds beyond the limits of the Devensian ice (Gobbett 2014) show that the Wolds have been overridden by an older ice sheet at least once during the Pleistocene and it is reasonable to assume that the ice removed the clay-with-flints regolith although some small patches remain (Matthews 1977). The present aspect of the landforms is largely due to the weathering and erosion that occurred during the mid to late Pleistocene when the whole area must have been subjected to permafrost. The now dry valleys appear as fresh young features little modified during the Holocene. The slope angle of the valley sides (around $22^{0}$) is consistent with the angle of rest of chalk scree. The steep longitudinal gradient and flat floor typical of the valleys suggests that they were occupied by intermittent flashy braided streams carrying a gravel bed load in the Devensian summer.

During early post-glacial time gradual thaw of the permafrost would have encouraged mass movement to produce the extensive landslips and rotational slides which now diversify the Chalk escarpment, the sides of the Great Wold Valley, and to a lesser extent the dry valleys.

*Acknowledgements.* I am indebted to Prof. P. Rawson for reading an earlier version of this paper and encouraging me to publish it. Also to Dr E. R.Connell for suggesting a number of improvements and in particular for convincing me to rethink my earlier acceptance of proglacial lakes in the Yorkshire Wolds.

## REFERENCES

Allen, T. 1831. *New and complete history of the county of York*, vol.4.

Atkinson, R.J.C. 1957. Worms and weathering. *Antiquity*, **33**, 219-233.

Benn, D.I. and Evans, D.J.A. 2010. *Glaciers and glaciation.* 2nd Edition. Hodder Education, London.

Bray, D.A., 1981. Quaternary sediments at Westfield Farm, Fimber. *Proceedings of the Yorkshire Geological Society*, **43**, 377-393.

Bull, A.J. 1940. Cold conditions and landforms in the South Downs. *Proceedings of the Geological Association,* **51**, 63-71.

Catt, J. A., Weir, A.H. and Madgett, P.A. The loess of eastern Yorkshire and Lincolnshire. *Proceedings of the Yorkshire Geological Society*, **40**, 23.29 ???

Cole, E.M. 1879. On the origin and formation of the Wold dales. *Proceedings of the Yorkshire Geological Society*, **7**, 128-140.

De Boer, G. 1945. A system of glacier lakes in the Yorkshire Wolds. *Proceedings of the Yorkshire Geological Society,* **25**, 223-33.

De Boer, G., Neal, J.W. and Penny, L.F. 1958. A guide to the geology of the area between Market Weighton and the Humber. *Proceedings of the Yorkshire. Geological Society,* **31**, 157- 209.

Ellis, S. (ed) 1987 *East Yorkshire field Guide.* Quaternary Research Association. London.

Foster, S.W. 1985. *The late glacial and early postglacial history of the Vale of Pickering and northern Yorkshire Wolds.* PhD thesis: Univ. of Hull.

Foster, S.W. 1987a. The Sherburn Sands of the southern Vale of Pickering. *In* Ellis, S. 1987, pp,31-35.

Foster, S.W. 1987b. The dry drainage system on the Yorkshire Wolds. *In* Ellis, S. 1987, pp,36-38.

Foster, S.W. 1987c. Features of glacial drainage on the northern Wolds escarpment. *In* Ellis 1987, pp.39-41.

Gobbett, D.J. 2006. St Austin and the Fairy: a tale of two RIGS. *Humberside Geologist* **14**, 33-38.

Gobbett, D. J. 2014. A summary Cenozoic history of the Yorkshire Wolds, *Humberside Geologist*, **15**, 48-68.

Hayfield, C. and Wagner, P. 1995. From dolines to dew ponds: a study in water supplies on the Yorkshire Wolds. *Landscape History*, **17**, 49-65.

Hood, J .D. 1892. *Waterspouts on the Yorkshire Wolds: cataclysm at Langtoft and Driffield.* Driffield: Frank Fawcett.

Kerney, M.P., Brown E.H. and Chandler, T.J. 1963. The late glacial and postglacial history of the Chalk escarpment near Brook, Kent. *Philosophical Transactions of the Royal Society* (B), **248**, 135-204.

Lewin, J. 1969 .The Yorkshire Wolds, a study in geomorphology. *University of Hull Occasional Papers in Geography,* **11**, 89p

Marley, D.S. 1991. *Souvenir of the great flood at Driffield, Friday 20th May 1910.* Reprinted from the "Driffield Observer".

Matthews, BG. 1977. Clay-with-flints on the Yorkshire and Lincolnshire Wolds. *Proceedings of the Yorkshire Geological Society,* **41**, 231-9.

Mortimer, J.R. 1885. On the origin of the Chalk Dales of Yorkshire. *Proceedings of the Yorkshire Geological Soc*iety, **9**, 29-42.

Mortimer, J.R. 1886. *The surface geology and modern enclosure of Fimber on the Yorkshire Wolds.* Unpublished maps. Museum of transport and Hydrology, Hull.

Neal, C. 2011. *People and the environment: a geoarchaeological approach to the Yorkshire Wolds landscape.* PhD thesis: Univ. of York

Ollier, C.D. and Thomasson, A.J. 1957, Asymmetrical valleys of the Chiltern Hills. *Geographical Journal*, **123**, 71-80

Paterson, K. 1977. Scarp face dry valleys near Wantage, Oxfordshire. *Transactions of the Institute of British Geographers,* n.s. **2**, 192-204

Reid, C, 1887. On the origin of dry chalk valleys and of coombe rock. *Quarterly Journal of the Geological Society of Londo*n, **43**, 364-373

Starmer, I.C. 2008. The concentration of folding and faulting in the Chalk at Staple Newk (Scale Nab) near Flamborough, East Yorkshire. *Proceedings of the Yorkshire Geological Society,* **57**. 95-106

Taylor, J.F. 1996. *A history of Butterwick and Boythorpe.* Foxholes

Versey, HC. 1939. The Tertiary history of East Yorkshire. *Proceedings of the Yorkshire Geological Soc*iety, **23**, 302-214.

Williams, R.B.G. 1981. The weathering and erosion of chalk under periglacial conditions. *In* Jones, D.C.K. 1981. *The geomorphology of the British Isles. Southeast and southern England*, pp.225-248.

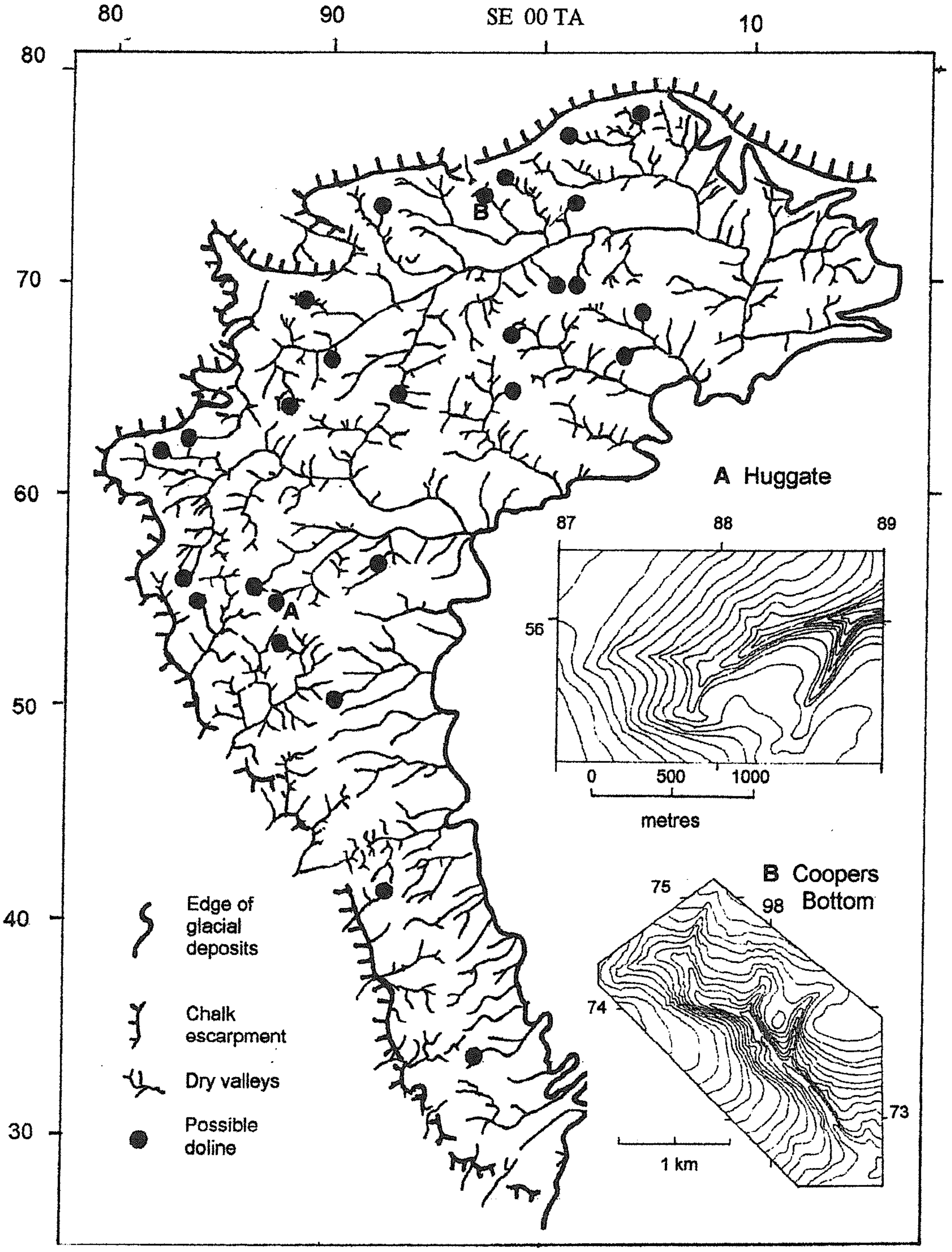
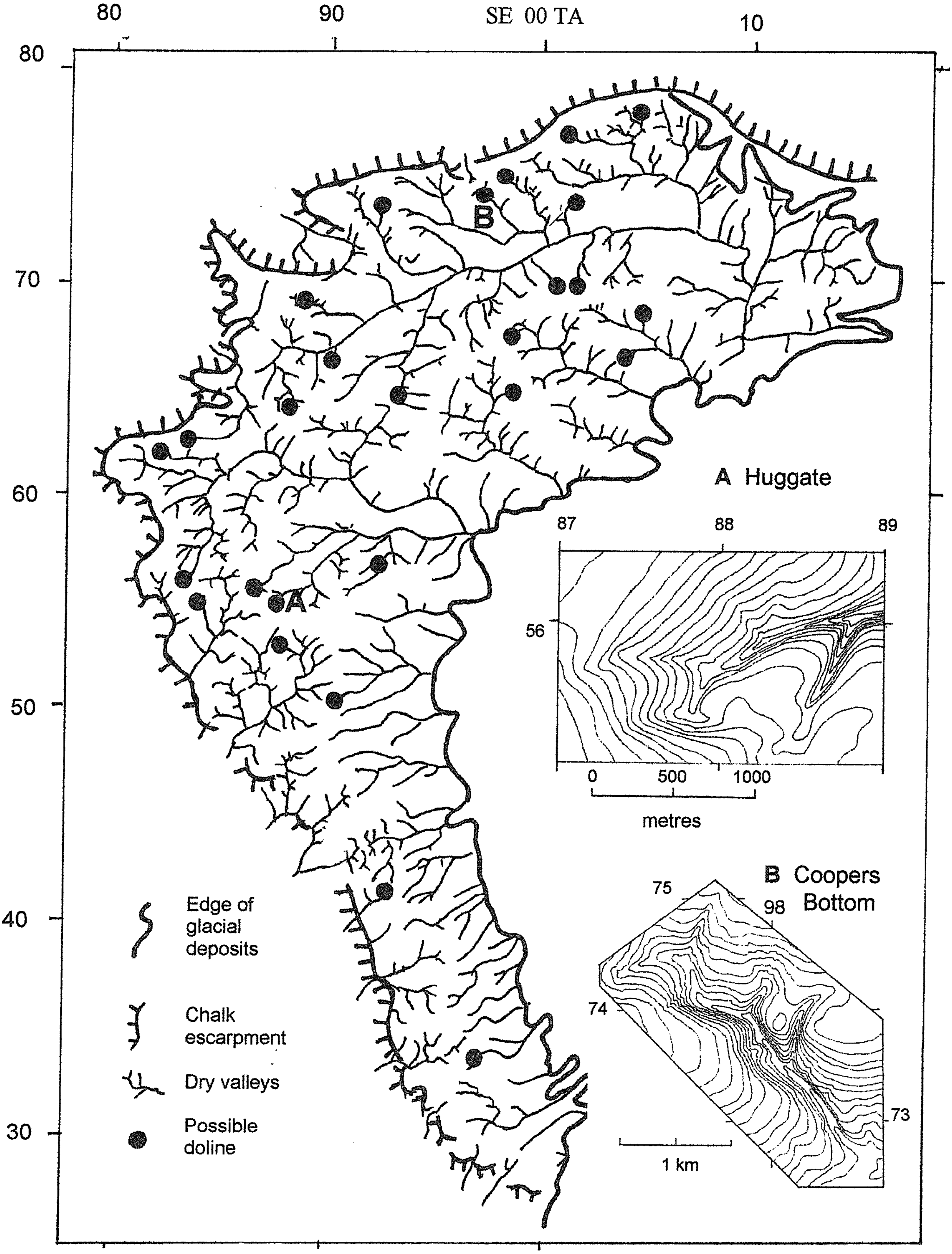
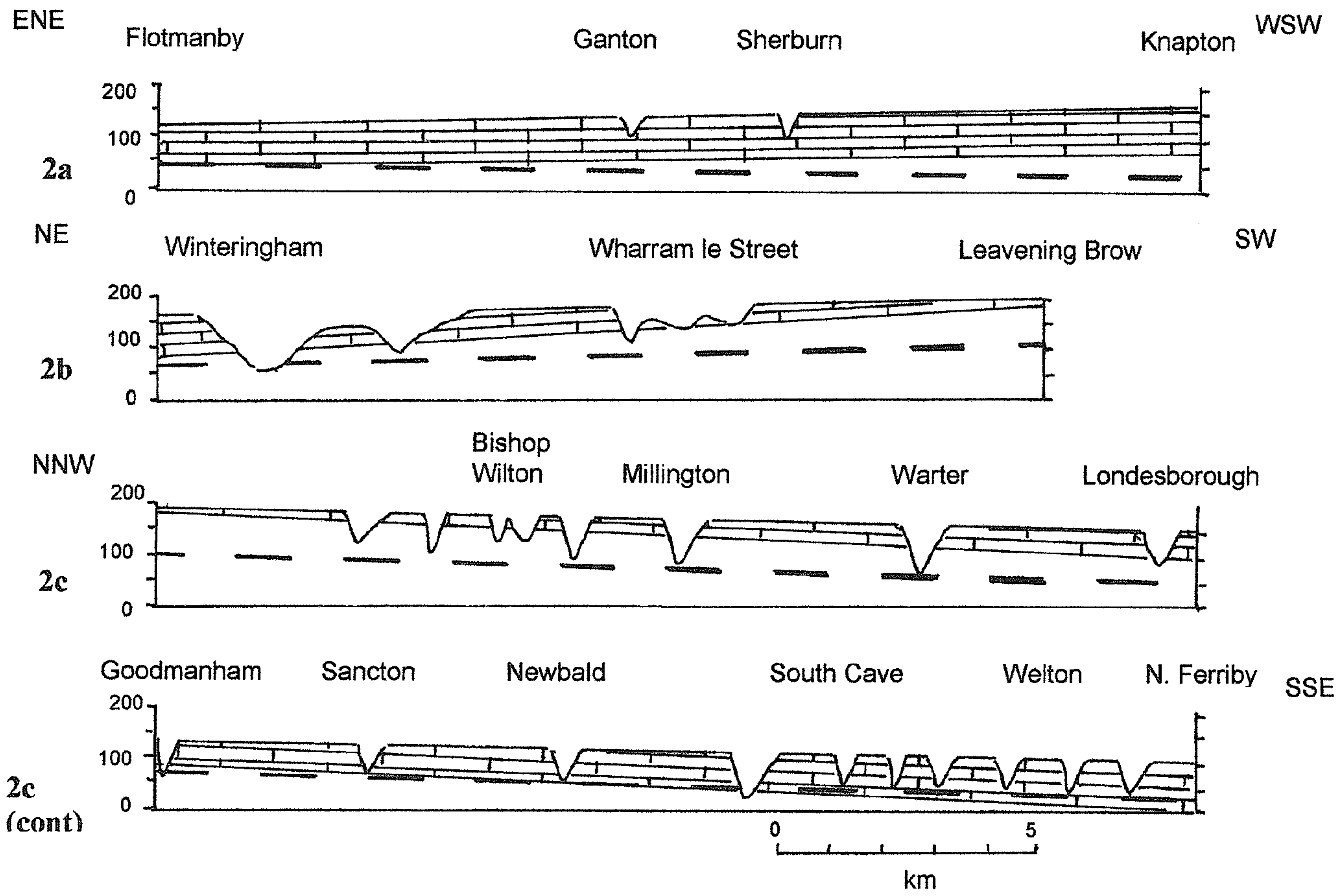



Fig. 1. Map to show the dry valley network (based on Lewin 1969, fig. 13) and the distribution of doline-like features at or near dry valley heads. Marginal numbers refer to the National Grid. Inset: details of two of these features showing contours at 5m intervals. Numbers refer to National Grid 100km squares.

old figure.



80
90
SE 00 TA
10
80
70
60
50
40
30
B
A
A Huggate
87
88
89
56
0
500
1000
metres
B Coopers Bottom
75
98
74
73
1 km
Edge of glacial deposits
Chalk escarpment
Dry valleys
Possible doline


ENE
Flotmanby
Ganton
Sherburn
Knapton
WSW
200
100
0
2a
NE
Winteringham
Wharram le Street
Leavening Brow
SW
200
100
0
2b
NNW
Bishop Wilton
Millington
Warter
Londesborough
200
100
0
2c
Goodmanham
Sancton
Newbald
South Cave
Welton
N. Ferriby
SSE
200
100
0
2c (cont)
0
5
km

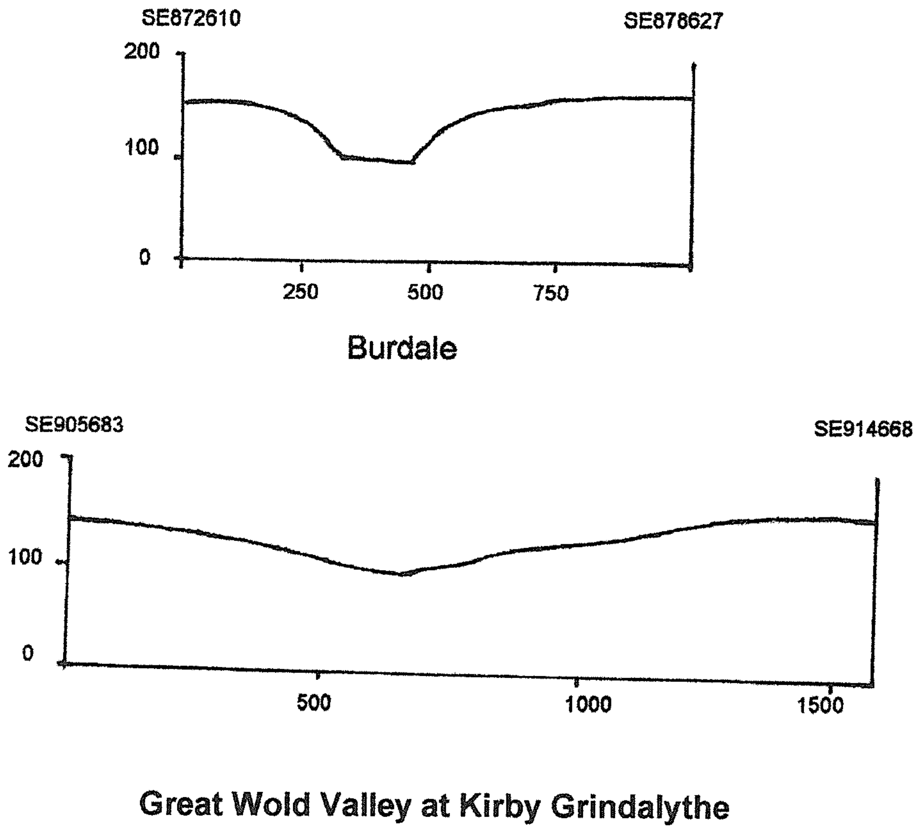



Fig.3. Comparative cross sections of Burdale, a typical dry valley, and the Great Wold Valley to show contrast in profile. Heights and distances in metres.

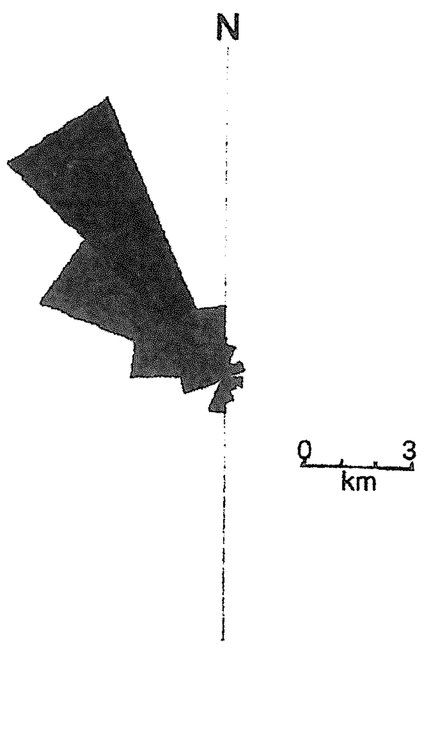
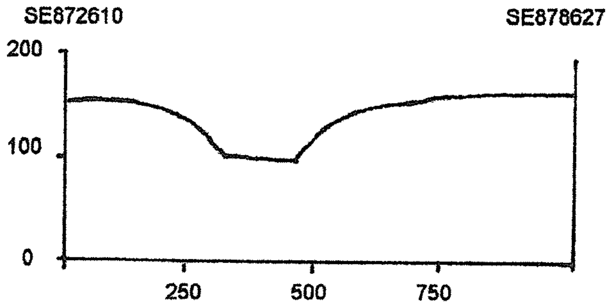
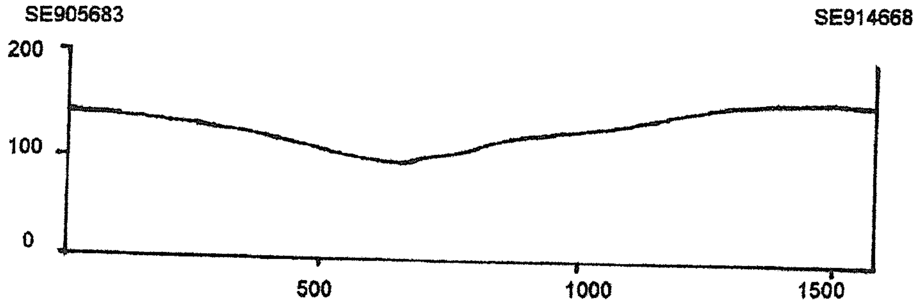



Fig.4. Rose diagram to show the facing directions of the steeper side of 30 asymmetrical dry valleys. Total length of the measured sides is 24.6 km.

Fig.2. Diagram to show features of the Wolds escarpment.
**2a**. Flotmanby to Knapton, **2b**. Knapton to Leavening Brow, **2c.** Leavening
to North Ferriby.
The scarp face is shown by vertical lines. Dashed lines indicate valleys cut int through the Chalk. Shaded areas represent the strata below the Chalk, in **2a** th Speeton Clay, in**2b** Kimmeridge Clay and Lower Lias, and in **2c** mainly Lias clays with some patches of thin Middle Jurassic and, from Newbald to North Ferriby.




**Burdale**




**Great Wold Valley at Kirby Grindalythe**

Fig.3. Comparative cross sections of Burdale, a typical dry valley, and the Great Wold Valley to show contrast in profile. Heights and distances in metres.

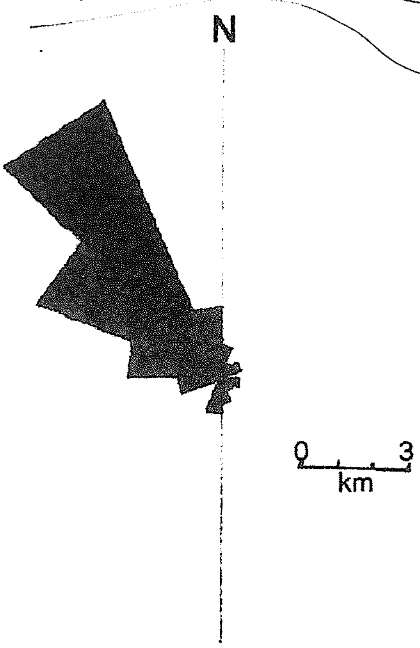



Fig.4. Rose diagram to show the facing directions of the steeper side of 30 asymmetrical

dry valleys. Total length of the measured sides is
24.6 km.

Fig.5. Map of the Yorkshire Wolds dip slope reconstructed for the Late Devensian summer. ~~Ice marginal channels after De Boer (1945) with maximum altitude above OD.~~

1. Hunmanby 70m 2. Kilham Lane 48m 3. Ruston Parva 52m

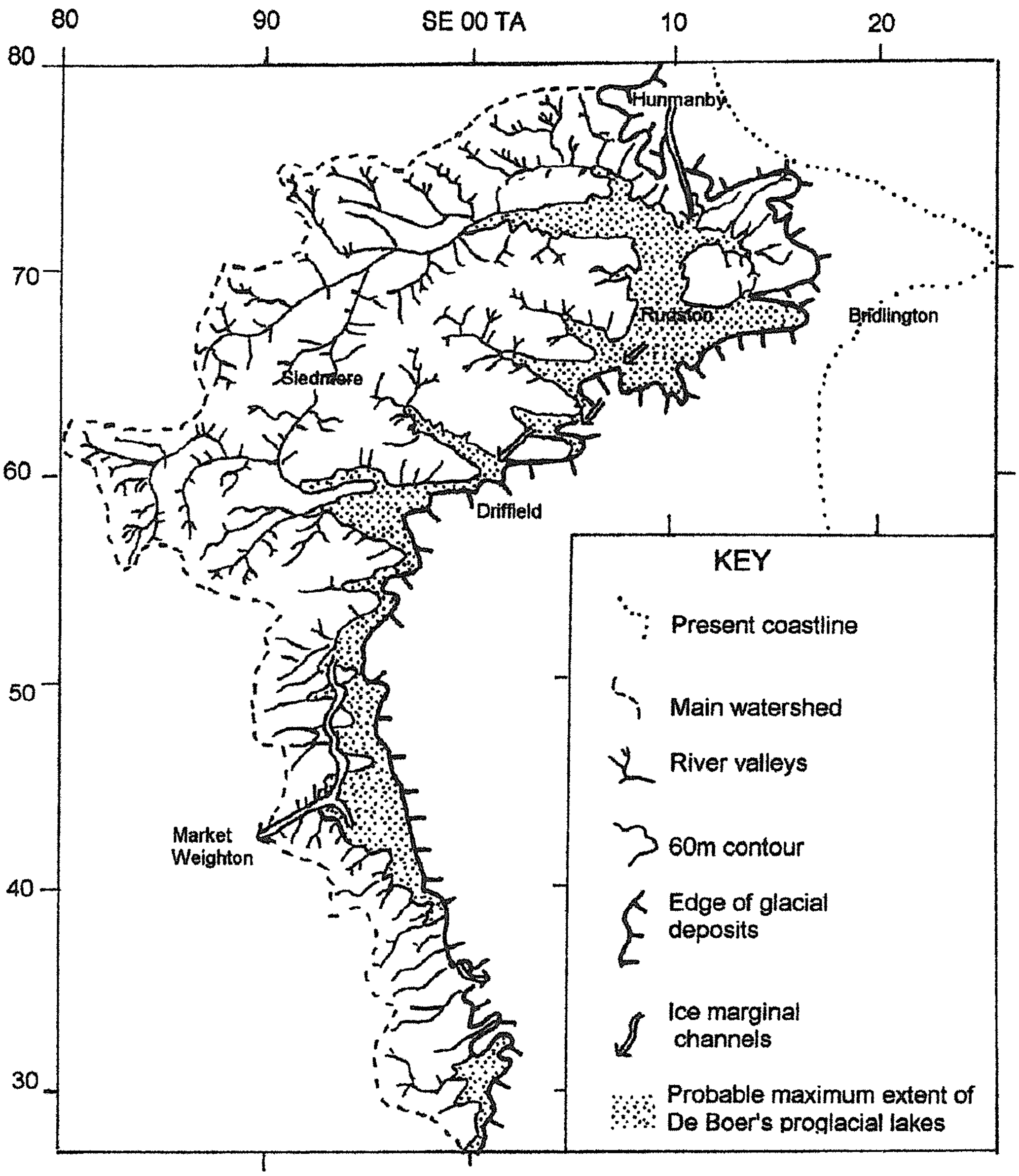
4. Danes Dale 64m 5. Middleton 63m 6. Lund Wold 57m

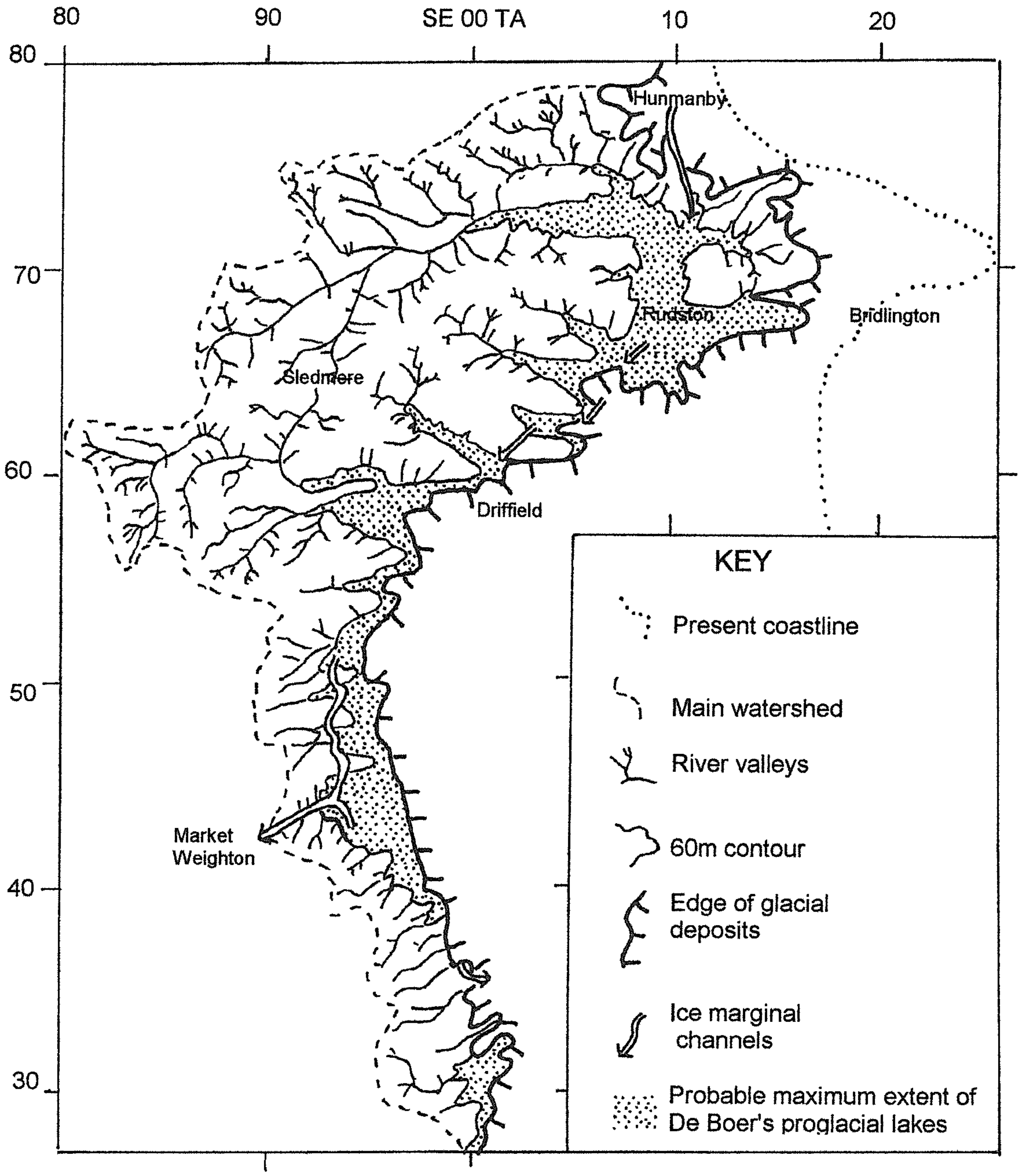
7. Holm, Short and Long Dales 52m 8. Old Dale 44m

9. Goodmanham Dale 50m 10. Risby Park 50m

Marginal numbers refer to 10km squares of the National Grid

Numbered channels interpreted by De Boer (1945) as overflow channels & have considered as ice marginal channels with maximum altitude OD as follow.


80
90
SE 00 TA
10
20
80
70
60
50
40
30
Hunmanby
Rudston
Bridlington
Sledmere
Driffield
Market
Weighton
KEY
Present coastline
Main watershed
River valleys
60m contour
Edge of glacial
deposits
Ice marginal
channels
Probable maximum extent of
De Boer's proglacial lakes


80
90
SE 00 TA
10
20
80
70
60
50
40
30
Hunmanby
Rudston
Bridlington
Sledmere
Driffield
Market
Weighton
KEY
Present coastline
Main watershed
River valleys
60m contour
Edge of glacial
deposits
Ice marginal
channels
Probable maximum extent of
De Boer's proglacial lakes