

# Geomorphology of the Kirmington interglacial deposits and the Immingham channel, north Lincolnshire

Allan Straw

**Abstract:** Interglacial deposits have been known at Kirmington since the late 19th century. In 1904 a borehole penetrated some 9m of beach and saltmarsh sediments capped by a thin till and resting on indeterminate materials based by another probable till. Studies of pollen and animal fossils have been inconclusive regarding age, but the Hoxnian was generally assumed because a sea-level of 18–25m OD was inferred. The deposits lie within a small Devensian end-moraine in the centre of Kirmington vale that was considered to be the headward part of the buried Immingham Channel. The north Wolds were glacierized during Marine Oxygen Isotope Stage (MOIS) 8; the interglacial beds post-date that event and pre-date the Devensian. Geomorphological considerations show that the beach shingle was part of a storm barrier beach associated with the buried eastern Wold cliffs at the back of the Marsh platform, close to present OD and last active in the Ipswichian Interglacial. The anomalous position in Kirmington of part of this beach and saltmarsh could be accounted for by Devensian ‘rafting’. The Immingham Channel does not extend into Kirmington vale, and the interglacial beds should not be regarded as part of its infilling. The vale, drained by a dipslope valley, existed before MOIS 8 glaciation. During deglaciation meltwaters ponded in the vale could have passed subglacially eastward along the line of this valley, modifying it into its present channel form. Aveyley and Ipswichian Interglacial transgressions subsequently cut back the dipslope and planed the Marsh platform across the channel, both to be obscured later by Devensian glacial deposits.

The existence of temperate interglacial sediments at Kirmington [TA104114] has been known a long time (Reid, 1885). Ussher (1890) referred to ‘an outlier of the shore deposits of an old sea’ and provided details of a section in the village brickyard (Fig. 1), recording 10 feet (3.1m) of well-worn beach shingle, principally flint, resting on 11 feet (3.41m) of laminated warp with a thin peat at the base, and 6 feet (1.85m) of sand. In the nearby gravel pit, the shingle was capped by 6 feet (1.85m) of reddish-brown glacial clay (Fig. 2). Because of the bearing of this site on the contemporary debates concerning glacial theory (glaciation or submergence, single or multiple glaciations) the British Association for the Advancement of Science commissioned two boreholes in 1904 (Stather, 1905). One of these penetrated 96 feet (29.6m) of superficial materials resting, at about sea-level, on bedrock Chalk (Table 1). The origin and age of the deposits have since been subject to sporadic study and much speculation.

Burchell (1931) claimed to have found Mousterian artefacts in the beach shingle. Carruthers (1948), controversially, suggested that the interglacial beds might not be *in situ* but rather were a glacially-transported ‘raft’. The meagre pollen contents of the warp (silty clay) beneath the shingle and of the thin peat (Fig. 3) were examined by Watts (1959) who proposed a Hoxnian interglacial age, a notion supported by Boylan (1966) who claimed some 16m (Beds 7-12) of the sediments as estuarine. Harland and Downie (1969) analysed dinoflagellates from the warp, confirming interglacial status with temperatures warmer than present, but could make no comment on their relative age. However, an Ipswichian age was also feasible and had been advocated by the writer in 1962 during a visit of the Yorkshire Geological Society to the

site (Worsley, 2014) and reiterated during a Quaternary Research Association (QRA) visit in 1972 (Penny et al, 1972). In the Guidebook for the INQUA Congress (Catt, 1977) details of the 1904 bore were given, the estuarine sediments were accepted as Hoxnian, and a stony clay, 1.6m thick (Bed 2) was considered likely to be Anglian till. Apart from short accounts by Gaunt et al (1992) and Berridge et al (1994), who in essence followed work by Williamson (1983), the matter rested until the late 1990s. At that time the temperate beds were generally accepted as estuarine, overlain by a Devensian till, and underlain by indeterminate clays and silts and a thin basal till. The sequence was described as the Kirmington Formation (Bowen et al, 1999) with a Hoxnian (MOIS 11) age being preferred.

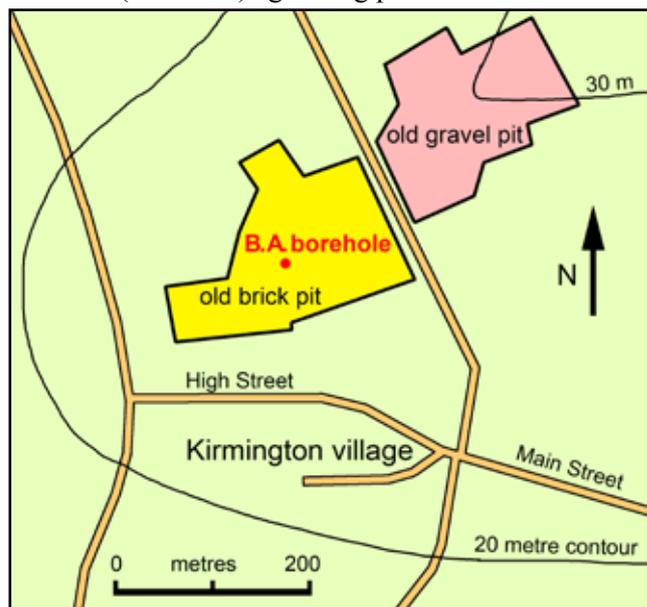


Figure 1. The two pits at Kirmington.



**Figure 2.** Kirmington gravel pit during the 1936 visit by the Sorby Geological Society. The section revealed 2.5m of flint beach shingle, overlain by 2m of reddish-brown till. View NE at TA104117. (Photo: AC Dalton.)

**Figure 3.** Kirmington brick pit. Lower part of the estuarine warp (saltmarsh silty clay, Bed 12) with thin fresh-water peat. View SSE at TA 103115 in 1972.

## The Trent Valley Palaeolithic Project

In 1999, the Kirmington site came under examination by the team on this project (TVPP) which noted that no detailed studies of the estuarine beds had been undertaken for several decades, and no attempt had been made to relate them to MOI stages (Bridgland et al, 2014). Preceding a QRA visit in 1999, a section was cleared, cores obtained for palynological study and a Field Guide prepared (Bridgland & Thomas, 1999). In 2006 the site was investigated further by TVPP, sections re-excavated and a borehole sunk to a depth of 20m. The results of the investigations have been published (Gale and Hoare, 2007) and discussed at length (Bridgland et al, 2014). Essentially the shingle and estuarine beds were confirmed as such, the latter containing bivalves and foraminifera, and the thin peat (Fig. 3) dominated by *Phragmites* near the base of Bed 1 as freshwater. However, it was concluded that the pollen allowed no determination of which temperate MOI stage the sediments belonged to, and the archaeological material was largely discounted (White, 1999). Contemporary sea-level was estimated at 18–25m OD and, although Bromehead's (1932) and Carruthers' (1948) suggestions of 'rafting' were noted, they were not assessed. As with most previous studies, there was little appraisal of the geomorphological context of the site, yet the area's landforms and superficial deposits are varied (Fig. 4), and permit construction of a sequence of events (see below). Some consideration was given to the Immingham Channel (or Kirmington 'fiord' of Shillito, 1937), within the headward part of which the interglacial deposits were deemed to lie, but the Barnetby Gap to the west (Straw, 1970) and the eastern Wold cliffs and adjacent Marsh Platform (Straw, 1961a) were hardly mentioned.

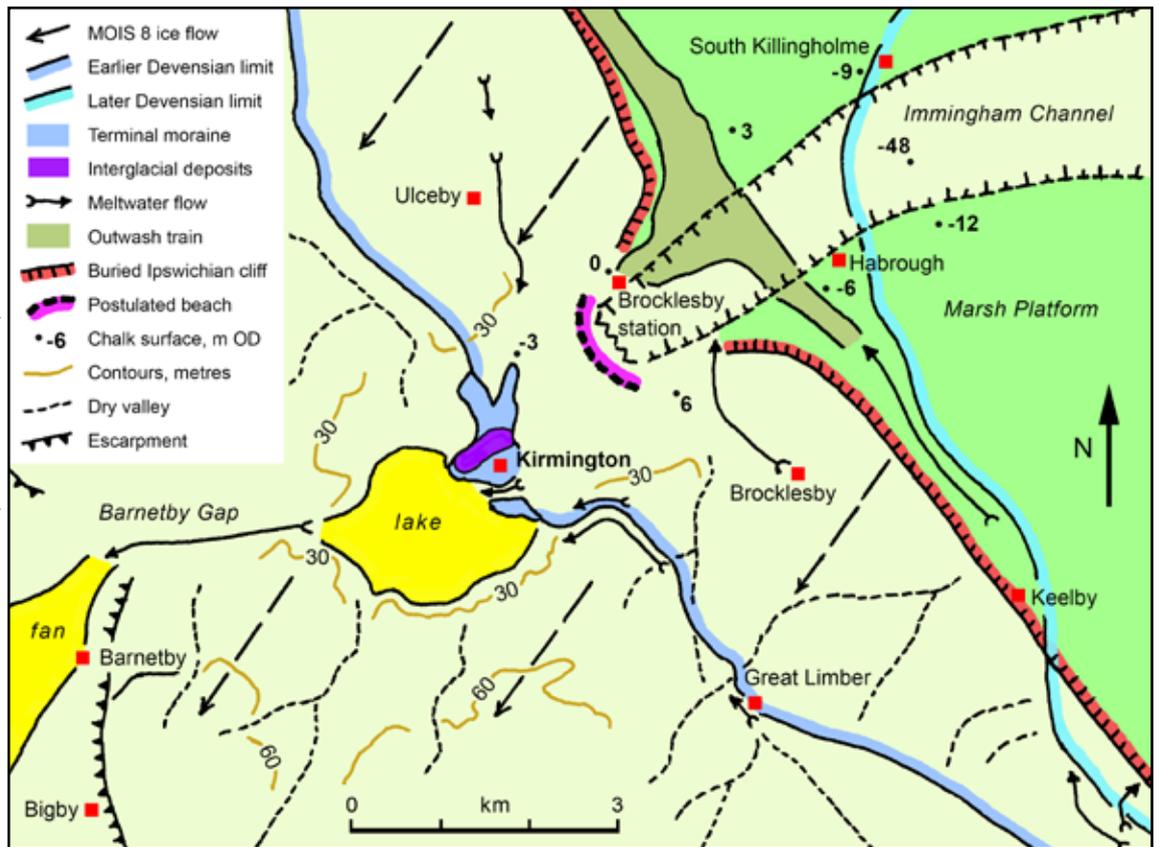
In 1972, the writer produced maps and text (Penny et al, 1972), and a map in 1962 (Worsley, 2014) showing relief, superficial deposits and geomorphological features of the wider Kirmington area. In the absence of age determinations by the biological and archaeological means noted above, it is through consideration of landforms and superficial deposits that a better understanding of the formation, survival and, significantly, the age of the Kirmington deposits can be obtained.



## Age constraints on the Kirmington deposits

Gaunt et al (1992) and Berridge et al (1994) placed the 'older drift' of Lincolnshire in the Anglian glaciation (MOIS 12), but a glaciation within MOIS 8 has been demonstrated within the last decade (White et al, 2010; Bridgland et al, 2014; White et al, 2017). To it has been ascribed the Welton and Calcethorpe Tills at Welton-le-Wold (Straw, 2005, 2015), the Calcethorpe Till of the Wolds and Horncastle areas (Straw, 1966) and the Wragby and Heath Tills of central and southwest Lincolnshire (Straw, 1969, 1983). These tills consist of materials derived mostly from outcrops of Jurassic and Cretaceous rocks south of the Humber; the north Wolds, which would then have included a much wider dipslope, were not spared this erosion. Underlain by Burnham Formation Chalk (formerly Upper Chalk), tabular flints that it contains have been carried far across the East Midlands into the Derby area (Straw, 1983; Bridgland et al, 2014). The Calcethorpe Till that survives in the central Wolds south of the Kirmington area is mostly reconstituted chalk and contains unweathered tabular flints. In places up to 16m in thickness, it was emplaced by ice that had moved down the east coast and had in part passed SSW over the north Wolds (Fig. 4) into central Lincolnshire, abrading the dipslope, influencing the alignment of larger dry valleys, and lowering the scarp crest (Straw, 1961a). The Kirmington area was inevitably impacted by some 250–300m of ice

**Figure 4.** Main features of the landscape and geomorphology in the area around Kirmington.



**Figure 5.** The brick pit at Kirmington, exposing 1.6m of Devensian till (base at pick head) above 2m of unstratified flint gravel. The gravel is the finer distal extension of the storm beach shingle exposed in the adjacent gravel pit (Fig.1). The gravel was cryoturbated before till deposition; none is incorporated in the till. View NE at TA103116 in 1963.



and it would seem impossible for any pre-existing, unconsolidated deposits not to have been eroded. At best, some might have been drumlinized, but that is not the form of the Kirmington sediments. The till (Bed 2) recorded at the base of the 1904 borehole is therefore regarded as MOIS 8 and not MOIS 12 (Anglian) as suggested by Catt (1977), Gaunt et al, (1992) and Berridge et al (1994). It is to be correlated with the Basement Till of Holderness and the Welton Till of Welton-le-Wold. Clearly the Kirmington deposits are very unlikely to belong to an interglacial prior to MOIS 8, despite all historic claims.

The beach shingle at Kirmington (Bed 13) is capped by up to 2m of reddish-brown clayey diamict (Bed 14), an oxidized and decalcified lateral equivalent of the Devensian Marsh Till of east Lincolnshire (Straw, 1969) (Figs. 2, 5). The absence of incorporated shingle, and its presence in an end-moraine, of which the interglacial sediments form part, suggests it is a flow rather than a lodgement till. The writer has long argued that the Devensian glaciation of east Lincolnshire occurred in two phases (Straw, 1957, 1958, 1961b, 1979a, 2008, 2016), the second regarded as the Last Glacial Maximum (MOIS 2) because it is associated with constructional glacial features. In northeast Lincolnshire MOIS 2 ice built the Killingholme Moraine but only rose onto the Wolds south of Keelby (Fig. 4). Meltwaters emanating from channels around Riby [TA184075] coursed along the ice margin to near Brocklesby (Fig. 4), received streams from around Kirmington and proceeded north parallel to the Killingholme Moraine to aggrade the train of sands and gravels (Straw, 1961b; Williamson, 1983)

that underlie Thornton Abbey [TA115190] and reach Humberside near Goxhill [TA102213]. The Devensian deposits around Brocklesby and Kirmington, and on the north Wolds, pre-date the Last Glacial Maximum, and are considered by the writer to belong to MOIS 4. Both advances follow formation of the Marsh Platform and backing cliffs finally eroded in the Ipswichian Interglacial, and tills owe their lithology and colour range to marine sediments that covered that platform, in contrast to the very chalky MOIS 8 deposits derived from the previously extensive dipslope. The older Devensian tills (exposed at South Ferriby cliff (Straw, 2008) and Welton-le-Wold (Straw, 2014)) have been deeply weathered, thinned to 'drift-residual' soils in places, and removed from northern Wold valley floors thereby surviving mainly on interfluves. The Kirmington interglacial deposits can therefore only be referred to either the Aveley (MOIS 7) or the Ipswichian (MOIS 5e) Interglacial.

### The interglacial sediments

The beach shingle (Bed 13), almost entirely of flint clasts, has the characteristics of a storm beach, consisting of chatter-marked, rounded cobbles and pebbles (Fig. 6), many of which subsequently have been fractured, presumably by frost. Some shattered cobbles remain entire, whereas fragments of others are dispersed but retain sharp edges. The gritty matrix has been augmented by downwash of fines from the overlying till. The deposit contains no chalk, a consequence of the latter's friability with respect to the shocks and collisions between clasts during construction of a storm beach, its long-shore transport and subsequent decalcification. Initially, the flint clasts must have been eroded from the Chalk, and then introduced to the area by longshore drift with the very small component of exotic material (Bridgland et al, 2014), coming from



**Figure 6.** Kirmington gravel pit, exposing beach shingle of rounded flint cobbles and pebbles. The whole mass has been cryoturbated, with many clasts frost-fractured, some remaining whole, others dispersed. The high ground behind is back-quarried Devensian till. The freeze-thaw activity preceded deposition of the till on the gravel. View East at TA104117 in 1957



**Figure 7.** Porlock Bay in Somerset, with a storm barrier beach encroaching on salt-marsh. The wooded slopes rise above conjoint fans of periglacial head. Both head and marsh crop out on the foreshore. View SW from SS900487 in 1989.



**Figure 8.** Prograded lobes of beach shingle (mainly cobbles of Devonian Hangman Grit) thrown forward when the beach at Porlock Bay, Somerset, was over-topped during a storm on 28-10-1996. View WSW from SS874477 in 2001.

eroded MOIS 8 till. This shingle, resting abruptly on the warp (salt-marsh clay) would have been part of a prograding beach that originally extended north and south to contact the Chalk outcrops forming the slopes of the Kirmington vale or embayment. However, no requisite erosional features at the postulated sea-level height of 18–25m (Williamson, 1983; Bridgland et al, 2014) exist along these slopes, though they are manifest in the buried cliffs that lie east of the villages of Ulceby and Brocklesby at the back of the Marsh Platform (Fig. 4). The Kirmington embayment interrupts these cliffs and could, with a rock floor at or below Ordnance Datum, have been partly flooded by the sea. Longshore drift under the cliffs would inevitably have carried flinty beach materials into it forming possibly a spit, but more likely a curving barrier beach. An excellent modern analogue is to be found at Porlock Bay, Somerset (Fig. 7), where the prograding beach is migrating over salt-marsh deposits (Fig. 8) which in turn overlie periglacial head and fluvial gravels fringing the backing slopes. However, the Lincolnshire buried cliffs and platform relate to an Ipswichian sea-level only a few metres above modern OD and can be

traced north into Holderness, where they are currently being exhumed at Sewerby (Catt, 2001). If the Kirmington barrier beach originated at this sea-level, the portion lodged within the end-moraine clearly lies in an anomalous elevated position. This circumstance supports Carruthers' (1948) notion of 'rafting', but he depicted the shingle and shelly warp as separate masses within the ice, their conjunction only occurring during deglaciation. It is plausible that Devensian ice, moving into the Kirmington embayment, overrode the deeply frozen barrier beach and estuarine warp, and glacio-tectonically translocated a slab of them forward and upward into the end moraine beneath Kirmington village.

The concept of 'rafting' permits a reinterpretation of the 1904 borehole log (Fig. 9). The postulated barrier beach and subjacent silty clays (Beds 13, 12) could have been laid down on MOIS 8 till at a level near Ordnance Datum around 2 km northeast of Kirmington. This would have been at the same time as fluvial, colluvial and perhaps aeolian materials (Beds 3–8 in the 1904 bore) were spreading over MOIS 8 till on the vale floor and beneath the site of the village. It is suggested that when Devensian ice stressed the frozen beach and silts a 'plane of detachment' developed within the upper part of the underlying till, and a rigid block was translated southwest to its present position (Fig. 10). Bed 9 in the 1904 log can therefore be considered as the equivalent of Bed 2, with valley floor deposits between, and Bed 10 might represent an oxidized upper part of Bed 9. This scenario is feasible and several corollaries can be put forward.

1. The Kirmington vale/embayment existed as the head of a dipslope valley system before the MOIS 8 glaciation. Encroaching seas and later, Devensian ice, entered a pre-existing feature.

2. The barrier beach (at whatever level) is unlikely to be of Hoxnian age, but it could be either MOIS 7 (cf. Morston: Hoare et al, 2009) or MOIS 5e (cf. Sewerby: Catt, 2001).

3. Sea-levels in the Avey and Ipswichian interglacials seem to have recovered to heights within a few metres of present OD, a little below in MOIS 7, a little above in MOIS 5e (Hoare et al, 2009).

4. The remarkably straight east cliff of the Wolds and the exceptionally wide Marsh platform (16km, east of Louth) are therefore likely to be the consequences of more than one phase of marine erosion.

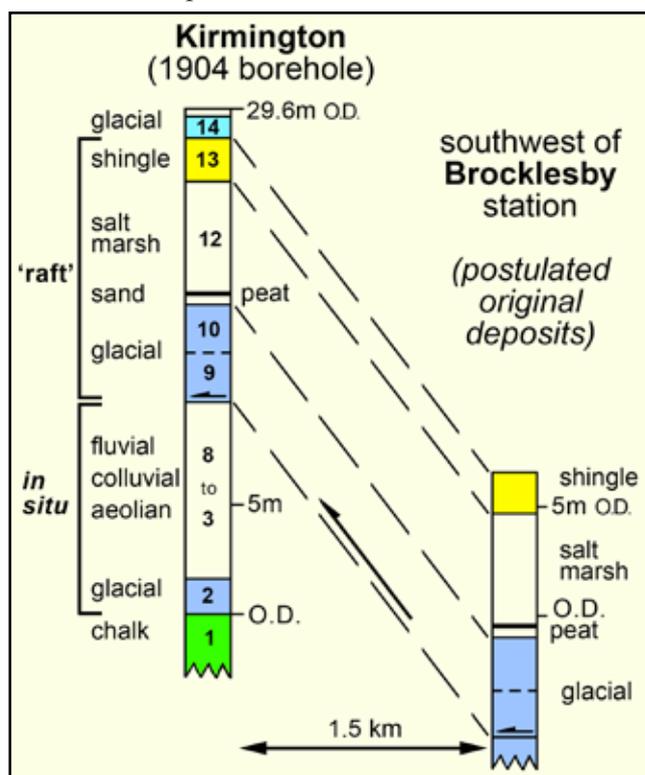


Figure 9. Schematic re-interpretation of the record from the 1904 borehole log.

Bed	Description	Thickness
15	Soil	1' (0.3m)
14	Clay with foreign stones	4' (1.23m)
13	Well-worn shingle, principally of battered flints	8' (2.5m)
12	Laminated warp with estuarine shells and, at base, a thin seam of peat associated with sandy warp containing freshwater shells	18' 6" (5.7m)
11	Clean yellow sand with pebbles of chalk and flint	4' 9" (1.5m)
10	Red clay passing downwards into tough reddish-brown clay	7' 6" (2.3m)
9	Purple clay streaked with loam and silt passing downwards into tough purple clay with small stones including some erratics	10' 6" (3.24m)
8	Stoneless purple clay	5' (1.54m)
7	Stoneless yellow clay	6' (1.85m)
6	Flinty gravel	4' 6" (1.38m)
5	Yellow clay and loam with small drift pebbles	5' (1.54m)
4	Yellow sand full of well-rounded quartz grains and specks of chalk	8' (2.5m)
3	Yellow sand and laminated clay	4' (1.23m)
2	Tough compact lead-coloured clay with a few small foreign pebbles	5' 3" (1.6m)
1	Tough yellow clay streaked with chalk	1' (0.3m)
	Solid chalk and flint	3' (0.9m)

Table 1. Log of the 1904 borehole at TA10251155, within the old brickyard in Kirmington, where its collar stood at 96 feet (29.6m) OD; beds 11-15 were exposed in the pit.

5. MOIS 6 would have been a period when the sea receded far from north Lincolnshire, and deepening of the Humber gap would allow the Ancholme river west of the Chalk scarp to remove much MOIS 8 till (Wragby Till) and Kimmeridge Clay from its valley, especially north of Brigg, prior to deposition of the Devensian Horkstow Moraine in it near the Humber. Periglacial processes are likely to have removed most if not all MOIS 8 glacial materials from north Wold slopes and modified, if not destroyed, any MOIS 7 features or sediments within Kirmington vale. On this consideration alone, the barrier beach can be deemed an Ipswichian, not Aveyly, feature.

6. An Ipswichian age for the beach shingle would, in view of the absence of hominins from Britain at that time, negate claims of the presence of artefacts.

7. The sediments in the 1904 borehole have no obligatory relevance to the origins and formation of the Immingham Channel.

### The Immingham Channel

This buried feature is a well-defined linear depression, obscured by Devensian deposits, which extends across the Chalk of the Marsh Platform (Fig.4). It has to date been taken to include Kirmington Vale. Boreholes at TA122132 near Brocklesby Railway Station reached the rock floor at -43m OD. From here the channel trends ENE for 8 km to pass beneath the modern coastline at Immingham Dock, where boreholes prove the channel floor at -74m OD (a long-profile gradient of only 1:260). North and south of the channel the Marsh Platform lies at sea-level near its backing cliff, and it lies at -15.4m OD beneath the Humber shore, a gradient of 1:400.

The channel has been known since the late 19th century, but no attempt was made to depict its shape until illustrated by the writer (Straw, 1961a, Penny et al, 1972), when its form and depth were determined from borehole logs, many of which had been collected by CFB Shillito when steward of the Yarborough estate at Brocklesby. The writer has had access to these and to others held by well-boring firms in Grimsby. Williamson (1983), Gaunt et al (1992) and Berridge et al (1994) have provided similar reconstructions. All have proved somewhat deceptive, because their small scale, close contours and smoothed sides have given the impression of a deep gorge-like channel, but they do portray clearly its existence and its relation to the Marsh Platform.



**Figure 10.** Kirmington Vale. This broad shallow valley is underlain by Chalk that forms bounding slopes (in the foreground field, and at the long wood and lime-works 3 km away). Kirmington church (with green copper-clad spire) and surrounding buildings occupy the Devensian terminal moraine, with new houses to the west on the old lake floor.

Reappraisal of the records has revealed the form of the channel in more detail. Clusters of bores into the Chalk aquifer beneath South Killingholme and Habrough permit description of a cross-section (Fig. 4). Under both villages the Marsh platform lies at -9 to -12m OD. Chalk slopes then descend at 3–5° from fairly abrupt crests to a flattish floor, about 600–700m wide, at -48m OD. The width between the bounding crests is 1600m. At Immingham the channel sides also slope at 3–5°, the width is 2000m within the Marsh Platform, and the kilometre-wide floor lies at -74m OD. The side slopes of 3–5° can be detected further west. Southeast of Brocklesby Station, boreholes reached Chalk at -43m OD, but within a kilometre to the southwest Chalk lies near present sea-level, indicating a slope of at least 3° that marks that position, and not Kirmington Vale, as the *de facto* head of the channel. Several boreholes in Kirmington village confirm the 1904 record of the Chalk surface at about sea-level, and the form of Kirmington Vale, a broad slightly-oval basin, so different from the channel, is indicated by the 30m contour (Fig. 4). Long dry-valleys extend from it SSW almost to the scarp crest. MOIS 8 ice crossed the Wolds from the NNE when the vale already existed as a fluvial feature. No doubt it was glacially eroded to some extent; till survives at the base of the 1904 bore.

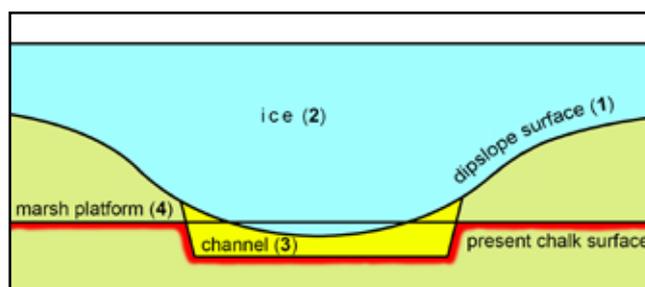
These facts bear on the origin of the channel, but there is one more geomorphological factor. MOIS 8 glaciation preceded cutting of the Marsh Platform and the subglacial surface was the Chalk dipslope, which no doubt had its share of dry valleys. Later marine erosion therefore removed Chalk and any MOIS 8 glacial materials and destroyed valley systems as cliff recession progressed. If Kirmington Vale was largely a subaerial feature then it would perforce have been drained by a substantial stream across the pre-MOIS-8 dipslope. If deep enough, its valley may not have been completely obliterated when platform cutting took place.

Several possible origins of the channel have been postulated. Ussher (1890) states that ‘the 100-foot line...sweeps into an old submerged valley’ and refers casually to the Kirmington ‘fiord’, a term utilized by Shillito (1937) although he regarded the vale as fluvial. Subsequent studies addressed only the interglacial beds, with little consideration of the channel. Following Williamson (1983), Gaunt et al (1992) concluded that the buried channel was subglacially ‘cut by a rapid flow of water...concentrated at the base of an icesheet and

driven by a substantial hydrostatic head', and Berridge et al (1994) also referred to 'catastrophic localized escape of meltwater under great hydrostatic pressure'. They all accepted that the vale was part of the channel, that Beds 1-10 (1904 bore – Appendix) were probably glacial (Anglian) and part of the channel fill, and that Beds 11-13 were Hoxnian. Bridgland et al (1999) refer only to the Kirmington deposits as filling a fossil valley, perhaps tributary to the Humber. Bridgland et al (2014) examined the Kirmington deposits closely and provided much detail obtained from analyses of pollen, plant macro-fossils, bivalves and foraminifera, confirming an interglacial status. But they did not consider the channel itself, merely referring again to 'a fossil valley cut into the Chalk in the Middle Pleistocene', although the presence of till (Bed 2) did prompt a comment that the channel might be a subglacial tunnel valley.

Contrary to all these views, it has been argued above that Kirmington Vale is genetically separate from the Immingham Channel, that the latter's head should be identified near Brocklesby Station and that the interglacial beds do not lie within it (Fig. 4). The sediments in the channel have been recorded, admittedly only in general terms, in many boreholes. Under Immingham Dock, beneath alluvium and Devensian deposits, the infilling materials are all silt or silty clay, with some sand and gravelly-chalk near the base. At South Killingholme at least 14 borehole logs record between 18 and 30m of silty clay (blue, red, grey, 'marly' or chalky) with occasional sand. At Habrough, beneath some 18m of Devensian materials, lie 40m of reddish-brown silt and clay, some noted as 'leafy', meaning laminated, some as 'marly'. The bores at Brocklesby Station proved 40–43m of white (chalky) and red (brown) silty clay beneath 18m of Devensian sediments. No coarse gravels or diamicts are recorded. Williamson (1983) figures borehole logs and sections and confirms that the dominant sediments in the channel are clays and silts, at least some being laminated, and estuarine. These predominantly fine-grained sediments are therefore unlike Beds 3–8 at Kirmington, being most probably marine/estuarine, and should not be regarded as the infill of a tunnel valley immediately after its formation. In part at least they could have accumulated in the channel during the Aveley and Ipswichian transgressions, though low sea-level during MOIS 6 may have interrupted the process and even allowed some erosion.

To return to the form of the channel, its almost flat long-profile, linear plan, and steepish head and sides could be taken to support the suggestion by Gaunt et al (1992) of a subglacial origin, possibly involving a jokulhlaup, but did suitable environmental conditions exist? Ice covered the dipslope surface and its valleys during MOIS 8. The deglacial process in Lincolnshire was one of stagnation and down-wasting (Straw, 1979a,b; Bridgland et al, 2014), and at some time it is probable that decaying ice persisted longer in the Ancholme valley west of the Wolds and on the easterly



**Figure 11.** Sequence of stages in the formation of the Immingham Channel.

parts of the dipslope, so that meltwaters could have ponded in Kirmington Vale. The present Barnetby Gap was cut by Devensian meltwaters flowing west from a small lake west of Kirmington (site of airfield) to build the Barnetby fan (Fig. 4), and was therefore unconnected with the channel. Bevels on the Chalk above this at c.40–50m OD indicate that a gap once existed at a higher level, so that MOIS 8 ponding might have been augmented by water from the west.

The relatively steep head of the channel near Brocklesby Station could mark where the ponded water began to drain under the stagnant dipslope ice. Whereas the channel's form supports such drainage, its considerable width and modestly steep sides probably militate against it being a sudden catastrophic event, but suggest a longer-term possibly seasonally-controlled flow. But why along this particular line? Before glaciation, Kirmington Vale would have been the headwater area of a dipslope valley system that could have been deepened during the preceding low sea-level phase (early MOIS 8). Although subsequently filled with ice, this valley may still have guided subglacial water toward ice-free areas further east, being modified somewhat in depth and form within the process. After disappearance of the ice, the channelled valley, then subaerial, was truncated by the Marsh Platform, which was planed during the Aveley and Ipswichian transgressions. But the valley was perhaps not completely obliterated, so its lower slopes might survive as the edges of the present buried channel (Fig. 11).

## Events at Kirmington

The North Wolds were heavily glaciated in MOIS 8 before part of its dipslope was replaced by the Marsh Platform. During deglaciation ponded water subglacially drained east along the line of a former axial valley, modifying it into channel form.

Transgressions in MOIS 7 (Aveley Interglacial) initiated, and in MOIS 5e (Ipswichian Interglacial) reactivated, cliffs that progressed inland to produce the abraded Marsh Platform. They were separated by an emergent phase during MOIS 6, and currently there is no evidence that ice reached north Lincolnshire at this time. Instead, low sea-level allowed deepening of the Humber Gap and concomitant erosion of Wragby Till and Kimmeridge Clay within the Ancholme valley.

During the Ipswichian Interglacial, the Kirmington re-entrant was part flooded by the sea, and a barrier

beach migrated over saltmarsh that accreted behind it. Field evidence indicates that ice subsequently returned to east Lincolnshire, in the writer's opinion in the early Devensian. Entering the Kirmington embayment, it dislodged and then incorporated a portion of the beach and saltmarsh in its end moraine. Later in the Devensian, the LGM advance approached but did not reach the Kirmington area. Building the Killingholme Moraine, it impinged on the Wolds only south of Keelby.

The Kirmington village interglacial deposits are therefore, contrary to all previous opinion, to be dissociated from the Immingham Channel, because the latter was produced as a deglacial event during MOIS 8, and the deposits were emplaced during MOIS 5e, both events preceding the Devensian.

## Acknowledgements

Many thanks are owing to Dr. Nigel Straw and Prof. Peter Worsley, for their helpful comments on an earlier draft.

## References

- Berridge, N.G. & Pattison, J., 1994. Geology of the country around Grimsby and Patrington. *Mem. Brit. Geol. Surv.*, Sheets 90 and 91. HMSO, London.
- Bowen, D.Q. (ed.), 1999. A revised correlation of Quaternary deposits in the British Isles. *Geol. Soc. Special Report*, 23, 174pp.
- Boylan, P.J., 1966. The Pleistocene deposits of Kirmington, Lincolnshire. *Merc. Geol.*, **1**, 339-350.
- Bridgland, D.R. & Thomas, G.N., 1999. Kirmington (TA103117). 180-184 in Bridgland, D.R., Horton, B.P. & Innes, J.B. (eds.), *The Quaternary of North-east England. Field Guide, Quat. Res. Assoc.*, 203pp.
- Bromehead, C.E.N., 1932. Kirmington. *Trans. Hull Geol. Soc.*, **7**, 117-121.
- Burchell, J.P.T., 1931. Palaeolithic implements from Kirmington, Lincolnshire, and their relation to the 100-foot raised beach of late Pleistocene times. *Antiq. Journ.*, **11**, 262-272.
- Carruthers, R.G., 1948. The secret of the glacial drifts. Part II: applications to Yorkshire. *Proc. Yorks. Geol. Soc.*, **27**, 129-172.
- Catt, J.A., 1977. Kirmington. 14-15 in Catt, J.A. (ed.), *Yorkshire and Lincolnshire. Xth INQUA Congress Excursion Guide C7*. Birmingham.
- Catt, J.A., 2001. Sewerby. 83-88 in Bateman, M.D., Buckland, P.C., Frederick, C.D., & Whitehouse, N.J. (eds.), *The Quaternary of east Yorkshire and north Lincolnshire. Field Guide, Quat. Res. Assoc.*, 218pp.
- Gale, S.J. and Hoare, P.G., 2007. The glacial stratigraphy of lowland southern and eastern Britain: temperate stage deposits at Morston and Kirmington. *Proc. Yorks. Geol. Soc.*, **56**, 245-251.
- Gaunt, G.D., Fletcher, T.P. & Wood, C.J., 1992. Geology of the country around Kingston-on-Hull and Brigg. *Mem. Brit. Geol. Surv.* Sheets 80 and 89.
- Harland, R. & Downie, C., 1969. The dinoflagellates of the interglacial deposits at Kirmington, Lincolnshire. *Proc. Yorks. Geol. Soc.*, **37**, 231-237.
- Hoare, P.G., Gale, S.J., Robinson, R.A.J., Connell, E.R. & Larkin, N.R., 2009. Marine Isotope Stage 7-6 transition age for beach sediments at Morston, north Norfolk, UK: implications for Pleistocene chronology, stratigraphy and tectonics. *J. Quat. Sci.*, **24**, 311-316.
- Madgett, P.A. & Catt, J.A., 1978. Petrography, stratigraphy and weathering of late Pleistocene tills in east Yorkshire, Lincolnshire and north Norfolk. *Proc. Yorks. Geol. Soc.*, **42**, 55-108.
- Penny, L.F., Straw, A., Catt, J.A., Flenley, J.R., Bridges, J.F.D., Madgett, P.A. and Beckett, S.C., 1972. East Yorkshire and North Lincolnshire. *Field Guide, Quat. Res. Assoc.*, 42pp.
- Reid, C., 1885. The geology of Holderness and adjoining parts of Yorkshire and Lincolnshire. *Mem. Geol. Surv.*, HMSO: London.
- Shillito, C.F.B., 1937. The Kirmington fiord. *Trans. Hull Geol. Soc.*, **7**, 125-129.
- Stather, J.W., 1905. Investigation of the fossiliferous drift deposits at Kirmington, Lincolnshire and at various localities in the East Riding of Yorkshire. *Report 74th meeting of British Association for Advancement of Science*, Cambridge, August 1904, 272-274.
- Straw, A., 1957. Some glacial features of east Lincolnshire. *East Mid. Geogr.*, **1**, 41-48.
- Straw, A., 1958. The glacial sequence in Lincolnshire. *East Mid. Geogr.*, **2**, 29-40.
- Straw, A., 1961a. Erosion surfaces of east Lincolnshire. *Proc. Yorks. Geol. Soc.*, **33**, 149-172.
- Straw, A., 1961b. Drifts, meltwater channels and ice margins in the Lincolnshire Wolds. *Trans. Inst. Brit. Geogr.*, **29**, 115-128.
- Straw, A., 1966. The development of the middle and lower Bain valley, east Lincolnshire. *Trans. Inst. Brit. Geogr.*, **40**, 145-154.
- Straw, A., 1969. Pleistocene events in Lincolnshire: a survey and revised nomenclature. *Trans. Lincs. Nat. Union*, **17**, 85-98.
- Straw, A., 1970. Wind-gaps and water-gaps in eastern England. *East Mid. Geogr.*, **5**, 97-106.
- Straw, A., 1979a. The geomorphological significance of the Wolstonian glaciation of eastern England. *Trans. Inst. Brit. Geogr.*, **4** (New Series), 540-549.
- Straw, A., 1979b. Eastern England. 1-139 in Straw, A. and Clayton, K.M., *Eastern and Central England*, Methuen: London.
- Straw, A., 1983. Pre-Devensian glaciation of Lincolnshire (eastern England) and adjacent areas. *Quat. Sci. Revs.*, **2**, 239-260.
- Straw, A., 2000. Some observations on 'Eastern England' in A Revised Correlation of Quaternary deposits in the British Isles (ed. D.Q. Bowen, 1999). *Quat.N/L*, **91**, 2-6.
- Straw, A., 2005. *Glacial and pre-glacial deposits at Welton-le-Wold, Lincolnshire*. Studio: Exeter, 39pp. (the collectionmuseum.com).
- Straw, A., 2015. The Quaternary sediments at Welton-le-Wold, Lincolnshire. *Merc. Geol.*, **18**, 227-233.
- Straw, A., 2016. Devensian glaciers and pro-glacial lakes in Lincolnshire and southern Yorkshire. *Merc. Geol.*, **19**, 39-46.
- Ussher, W.A.E., Fox-Strangways, C., Cameron, A.C.G., Reid, C. & Jukes-Browne, A.J., 1890. The geology of parts of north Lincolnshire and south Yorkshire. *Mem. Geol. Surv.*, Sheet 86, HMSO: London.
- Watts, W.A., 1959. Pollen spectra from the interglacial deposits at Kirmington, Lincolnshire. *Proc. Yorks. Geol. Soc.*, **32**, 145-152.
- White, M.J., 1999. Comment on Kirmington artefacts. 185 in Bridgland, D.R., Horton, B.P. & Innes, J.B. (eds.), *The Quaternary of North-east England. Field Guide, Quat. Res. Assoc.*, 203pp.
- White, T.S., Bridgland, D.R., Westaway, R., Howard, A.J., & White, M.J., 2010. Evidence from the Trent terrace archive, Lincolnshire UK, for lowland glaciation of Britain during the Middle and Lower Pleistocene. *Proc. Geol. Assoc.*, **121**, 141-153.
- White, T.S., Bridgland D.R., Westaway, R. & Straw, A., 2017. Evidence for late Middle Pleistocene glaciation of the British margin of the southern North Sea. *J. Quat. Sci.*, **32**, 261-275.
- Williamson, I.T., 1983. *Geological Reports for DoE. Land Use Planning. South Humberside Project*. Inst. Geol. Sci.: Leeds. 25pp.
- Worsley, P., 2014. The origin of the Quaternary Field Study Group. *Quat. N/L*, **134**, 19-27.