

The origin and geomorphological context of the Kirkby Moor Sands in Lincolnshire

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Abstract: The Kirkby Moor Sands consist of fluvial sands and gravels situated on higher ground in the angle between the Witham and Bain valleys, east of Woodhall Spa in central Lincolnshire. Older and higher than terraces associated with proto-Trent waters flowing southeast from the Lincoln gap, they rest on Wragby Till (MOIS 8). Composed of sediments derived from outcrops upstream in the Bain valley and related to the Hemingby Terrace, their possible origins as a lacustrine delta, as an aeolian sand sheet or as a sandur are discounted. It is argued that they were emplaced by a meltwater precursor of the River Bain during a deglacial stage in the later MOIS 8, and formerly extended more widely southwest onto residual ice melting back into central Lincolnshire.

The Kirkby Moor Sands comprise a dissected sheet of sediment that originally covered at least 14.2 km² of relatively high ground east of Woodhall Spa [TF196632; Fig. 1]. Designated the Kirkby Moor Member in the Geological Society's Quaternary correlation report, they were placed with other proto-Trent Members in MOIS 12 (Bowen et al, 1999). Presently disposed in three main outcrops, separated by the Bain valley in the east and a narrower valley occupied by what is here called Roughton Beck in the west, their notably level surface lies at c.27m OD (Fig. 2). They maintain a thickness of 7–14m over the whole area and are dominantly of thinly-bedded, fine to medium sands with a small component of flint gravel. The central outcrop was quarried in the later 1900s for industrial sand, particularly around Fox Hill [TF228628]. Unusual in that they occupy a watershed position yet consist throughout of shallow-water sediments they have attracted attention over many years and been subject to different interpretations.

In 1894, Carvill Lewis hypothesized that a large ice-impounded lake had once occupied the Humberhead area and the Fens. This concept was later supported by Raistrick (1934) who suggested that when ice obstructed

the Humber and Wash gaps then flooding of such a large area might well occur, with a lake-level at 100 feet (30m) OD, possibly controlled by the Lopham gap in Norfolk. Raistrick's view held sway for several decades and was still current when the writer commenced fieldwork in the early 1950's. In north Norfolk, deposits and landforms associated with a southerly advance of Devensian ice were mapped to an upper limit of c.30m OD (Straw, 1960), and it seemed entirely feasible that the Kirkby Moor Sands, with its surface at c.27m OD, was possibly a delta built into a lake at that height impounded by the Norfolk ice (Straw, 1958, 1979a, 1979b, 1991, 2008). Support for a Devensian high-level lake in the Fens has come from Clarke et al (2004) and Bateman et al (2015), but its existence has recently been discounted (Straw, 2016). By contrast Power and Wild (1982), following their BGS Mineral Assessment survey, included the Kirkby Moor Sands in a general category of Glacio-fluvial Sheet Deposits and Worsley (1991), more specifically, proposed their formation as a sandur. During an EMGS field excursion in August 2015, the possibility of an aeolian origin was discussed (Straw & Worsley, 2015), prompted by suggestions by Bridgland et al (2014) that at least some re-working by wind was possible. Several processes may therefore have contributed to formation of the Kirkby Moor Sands but before closer examination is attempted, it is deemed appropriate first to review the Quaternary features and deposits of adjacent areas.



Figure 1. Location of the Bain Valley, draining into the central vale of Lincolnshire, which previously carried the proto-Trent flowing from the Lincoln gap, was occupied by stagnant ice in MIOS 8, and now carries the River Witham.



Figure 2. Kirkby Moor Sands, south of the road at Fox Hill. Exposed are some 10m of thinly-bedded fine to medium sands, with localised flint gravels. The ground surface, at c.27 m OD, declines south at c.1:500. (View East at TF228627, in 1977)

Glacial tills

The Kirkby Moor Sands rest everywhere on Wragby Till (Straw, 1969) which extends widely over country to the northwest and consists largely of reworked Upper Jurassic clay eroded from central Lincolnshire south of the Humber. To the southeast, this passes beneath Fen margin gravels and alluvium. To the northeast, along a remarkably straight line (NNW–SSE) from Minting [TF187734] by Roughton [TF241647] to Mareham-le-Fen [TF280612], Wragby Till gives way to Calcethorpe Till (Straw, 1969) which is primarily reworked Chalk from the central and north Wolds (Fig. 1). These tills are of MOIS 8 age (Straw, 1983, 2000, 2010; Bridgland et al, 2014; White et al, 2016) and were deposited by ice streams flowing broadly southsoutheast across Lincolnshire. Both tills can be up to 15m thick, and in general in the study area they rest on a smooth, glacially-eroded surface of Kimmeridge Clay (Straw, 1958)

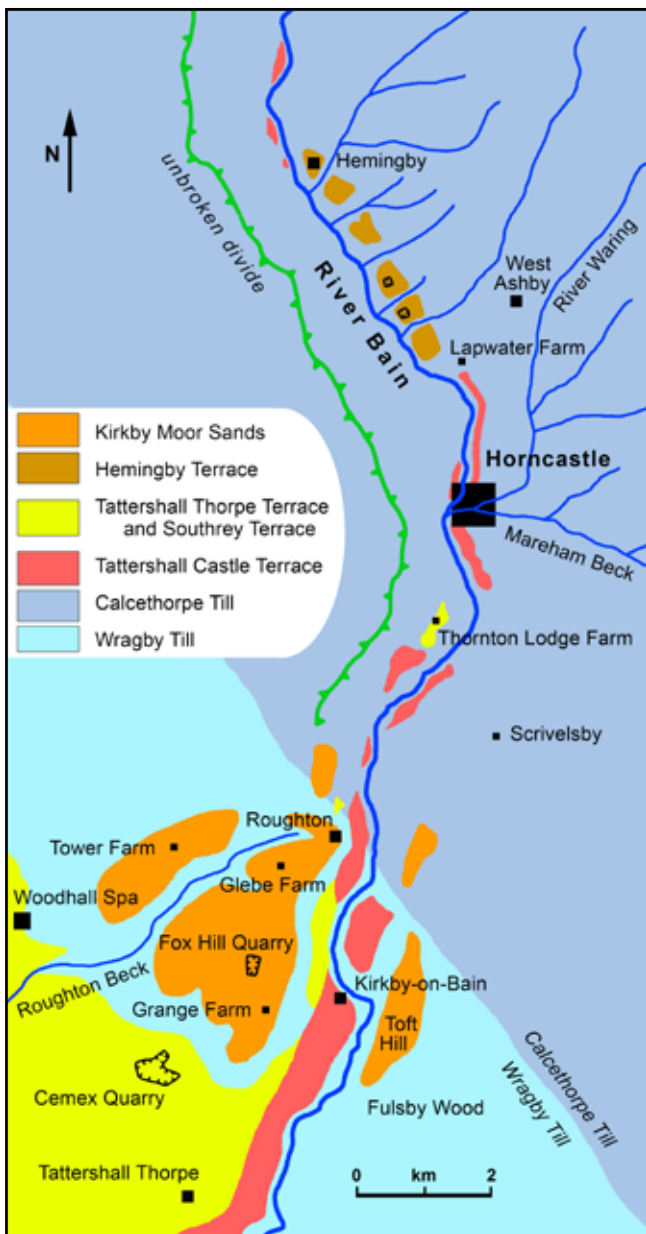


Figure 3. The Bain valley with terraces around Horncastle and the outcrops of Kirkby Moor Sands mainly on its western flank.



Figure 4. Tattershall Thorpe Terrace (MOIS 6). The lower half of the 8m section revealed chalk-rich and flint-rich gravels of Bain valley provenance. Clasts in the upper half, with the browner sands, are dominantly proto-Trent quartzites. The ice-wedge casts originated on an exposed surface at some time during aggradation of the upper gravel. (View West at TF228605, in 1977)

The Bain valley

Rising in the high Chalk area of the central Wolds the river Bain (the longest river in the Wolds at 35 km) flows southward, cutting obliquely across successive Lower Cretaceous rocks and exposing Kimmeridge Clay from Donington-on-Bain [TF236830] downstream to Hemingby [TF238745]. From this village south to Coningsby [TF223580], valley sides are formed in till and in places on terrace deposits.

A remarkable feature of the Bain system is that tributaries enter only from the northeast (Fig. 3). The largest has combined with the middle Bain to open up the wide valley between Scamblesby [TF275787] and Donington-on-Bain, now flooded by Spilsby Sandstone and Kimmeridge Clay (Straw, 1979c). Southeast of Horncastle [TF258696] three streams follow broadly parallel, curving courses across till country, each receiving tiny feeders only from the northeast (Straw, 1966) to join the Bain at Horncastle [TF255695], north of Dalderby [TF250660] and Haltham [TF246637] (Fig. 15). The country around Horncastle is mostly overspread by Calcethorpe Till and it is through this, to the Kimmeridge Clay, that the Bain and its tributaries have become incised.

The writer has argued (Straw, 1966) that prior to the emplacement of the glacial deposits, the Bain valley did not exist. It was shown that, in the middle Bain zone, three discrete valleys were occupied by southwest-flowing streams each draining a section of the Chalk scarp and outcrops of Lower Cretaceous rocks. These valleys were overwhelmed and the area substantially eroded by the Calcethorpe Till ice. The latter was deflected SSE by a contiguous ice mass in the



Figure 5. Tattershall Thorpe Terrace (MOIS 6). The 8m section comprised chalk-rich and flint-rich 'Bain' materials overlain by quartzite-rich, proto-Trent sands and gravels, all resting on blue-grey Wragby Till (MOIS 8). The terrace surface is virtually horizontal at c.10 m OD. (View NW at TF229604 toward Middleton Farm, in 1977)

central Lincolnshire vale responsible for the Wragby Till (hence the abrupt junction between Minting and Mareham-le-Fen). Assuming an essentially level upper surface to the composite ice-sheet, the vale ice would have been much thicker than the Wold ice and, after deglaciation set in, would have taken much longer to dissipate. Hence the Wolds became ice-free sooner than the vale permitting a receding ice margin to develop parallel to the escarpment, along which meltwaters could escape towards the Fens. Below Goulceby [TF255793], the lower Bain valley diverges from the scarp and is excavated only in till and Kimmeridge Clay, but it maintains a general southerly course in spite of the overall regional slope to the southwest. Incision of the Bain and its curving left-hand tributaries, which may indicate recession stages (Fig. 15), into and through the glacial materials ensured that their courses survived after complete deglaciation and that the former meltwater drainage pattern remains imprinted in the present landscape.

The Trent-Witham terraces

Southwest of the Kirkby Moor Sands, lower ground is underlain by sediments of the Southrey Terrace (Straw, 1958; Bridgland et al, 2014; Fig. 1). This terrace extends some 23 km upstream along the east side of the Witham valley above Tattershall [TF212575], its surface lying between about 6–10m OD. Bridgland et al (2014), following Pocock (1929) and Swinnerton (1937), demonstrate comprehensively that transport and deposition of quartzite-rich sediments were due to proto-Trent waters that had passed through the Lincoln gap. In the Tattershall Thorpe area [TF219595] flint-dominated Bain materials merge with the quartzite-rich ones, complicating the stratigraphical and sedimentological situations, but allowing terrace correlation (Figs. 4,5). Anomalously, flint-rich sediments underlie the former RAF Woodhall airfield north of the village and are exposed in Cemex quarry (Bridgland et al, 2014), in an upstream location where Bain sediments would not be expected (Fig. 1).

Bridgland et al (2014) review earlier research in the area in much detail. Organic materials at the base of the Southrey Terrace at Coronation Farm (Jackson, 1982) are considered to be of MOIS 7 age, and the 4–6m of terrace gravel to have accumulated largely in MOIS 6.

A higher Martin [TF120600] terrace lying, by contrast, wholly west of the present Witham, traverses the Middle Jurassic dip slope southeast from Lincoln to Billingham [TF157550], its surface declining from c.23m OD to 16m OD and averaging some 15m above alluvium. It was regarded by Bridgland et al (2014) as having been aggraded by meltwaters guided SSE by a residual MOIS 8 Wragby Till ice lobe. As shown above, meltwaters on the east were being discharged south at the same time, initiating the Bain valley. A further instance of ice-marginal drainage associated with the Wragby Till in the central vale may be noted in southwest Lincolnshire. In 1939, Kent drew attention to the parallel SSE alignments of the valleys of the Glen and Eden streams in Kesteven. These valleys, also incised across the Middle Jurassic dip slope, cut through till into Cornbrash and Oolite limestones, are believed to mark successive stages of recession of the southwest margin of the central vale ice (Straw, 1979, 2010; Straw & Worsley, 2016), and to be continued by gravels between Manthorpe [TF072160] and Uffington [TF062077] and thence southward by the Southorpe channel (Langford, 2004).

These instances of marginal meltwater drainage provide important evidence as to the nature of deglaciation in Lincolnshire of the thin, over-extended MOIS 8 ice-sheet, and have a bearing on the origin of the Kirkby Moor Sands. They strongly support the view that ice wastage was characterized by widespread stagnation, with uplands becoming ice-free while thicker ice dissipated more slowly in the central vale. Further support comes, it may be observed, from the Vale of Belvoir where meltwaters escaped eastward through the Ancaster gap and on the west initiated the unique Trent 'trench' across the Mercia Mudstones cuesta between Nottingham and Newark (Posnansky, 1960; Straw, 1963, 1979a, 1979c, 2010).

The Bain terraces

In the Tattershall Thorpe area the Southrey Terrace merges with the flinty Tattershall Thorpe Terrace, at the base of which organic materials, recorded by Holyoak and Preece (1985), are now ascribed to MOIS 7 (Bridgland et al (2014). This terrace extends up the Bain valley narrowly by Kirkby-

Figure 6. The Tattershall Castle Terrace (MOIS 5d-4-3) extending widely under the green fields around the Castle and Church. The foreground workings are in Tattershall Thorpe Terrace deposits, and the river Bain flows between the quarry and the church. The surface of this terrace lies at 5-7 m OD, but the whole suite of its materials relates to a discrete climatic cycle later than that of the Tattershall Thorpe Terrace (Bridgland et al, 2014). (View WNW from TF218575, in 1984)



on-Bain [TF242624] and a fragment may survive some 4km further north at Thornton Lodge Farm [TF679255] (Fig. 1). Its poor survival suggests it was mostly destroyed during the incision that preceded aggradation of a younger, much better-preserved terrace. The latter transects the Southrey Terrace at Tattershall (Fig. 1) and is identified as the Tattershall Castle Terrace (Fig.6). Holyoak and Preece (1985) and Bridgland et al (2014) provide thorough, in depth, discussions of all deposits and their dating in the area, and it is sufficient here to note that organic sediments at the base of the Tattershall Castle Terrace are considered to belong to MOIS 5e and the terrace gravels to the mid-Devensian (Fig. 7). For 10km upstream from Kirkby-on-Bain towards Lapwater Farm [TF259716] large stretches of the Tattershall Castle Terrace remain on both sides of the valley but curiously are absent a further 4 km north to Hemingby [TF237745]. Northward, small fragments rising no more than 2m above alluvium, occupy places where tributary streams and gullies open out into the main valley (Fig. 3).

Hemingby village occupies part of a very prominent terrace (not identified in Bowen et al, 1999) with a surface around the church at c.48m OD and some 10m or so above alluvium (Fig. 8). Higher than the Tattershall Thorpe and Tattershall Castle Terraces, it is not represented around Tattershall. The Hemingby Terrace persists on the NE side of the Bain valley for 4km between the village and Lapwater Farm, 1km southwest of West Ashby [TF266725] as six large segments separated by tributary gullies and streams (Fig. 3). Together they form a distinct bench some 400–500m wide, presenting a steep bluff to the floodplain. The constituent materials are at least 8m thick, consisting of alternating, mainly horizontal layers of stratified flint gravels and sands, resting variously on Calcethorpe Till and Kimmeridge Clay. In 1977, exposures in West Ashby quarry [TF248727] revealed epigenetic ice-wedge casts (Fig. 9).The terrace has not survived above Hemingby, except perhaps near Donington-on-Bain Mill, but the extant 4 km suffices to determine a longitudinal gradient of about 1:600. For an unknown reason, subsequent fluvial erosion



Figure 7. Tattershall Castle Terrace sediments (MOIS 5d-4-3). The cross-bedded sands and gravels include a scatter of shallow lenses containing organic materials; described by Girling (1974), they seem to be materials reworked from higher in the Bain valley. An ice-wedge cast penetrates the whole of the section; near the top, sand martins have burrowed into a podsolized soil horizon. (View East at TF231605, in 1973)



Figure 8. Hemingby Terrace (later MOIS 8). The terrace surface lies at c.48m OD around the church, some 8m higher than nearby alluvium. Calcethorpe Till or Kimmeridge Clay is poorly exposed in places beneath the terrace at the edge of the flood-plain. (View ENE from TF234743, in 1957)



Figure 9. Hemingby Terrace deposits (later MOIS 8), southwest of West Ashby. The alternating layers of sands and gravels together are c.4m thick and show an ice-wedge cast tapering almost to the section base. Flint clasts are mostly less than 5 cm in diameter. The uppermost metre is cryoturbated, with involutions, and near the base is a layer with a ferro-magnesian component. (View NW at TF248727, in 1977)

has always worked in this section along the southwest valley side, witnessed by the absence of the Tattershall Castle Terrace. In the middle Bain around Donington, sandy materials derived locally underlie thin alluvium and emerge as low flats a metre or two above it (Fig. 10). but, just upstream of Donington Mill [TF233834] quarry exposures in March 1957 revealed 2m of stratified flint gravel and sand resting on Spilsby Sandstone and capped by 2m of head (Fig. 11). This terrace fragment accords with the extrapolated gradient of the Hemingby Terrace and, if related to it, indicates derivation of much of the latter's sediments from middle Bain outcrops of Spilsby Sandstone and Biscathorpe Gravels (Straw, 1966, 1979c) and Calcethorpe Till.



Figure 11. Former quarry near Donington Mill. At least 2 m of bedded sands and gravels are exposed in the centre, resting on Spilsby Sandstone (seen on the right), and lying about 5-6 m above Bain alluvium (off to the right). Some 2 m of head, containing flints and erratics from Biscathorpe Gravels and Calcethorpe Till upslope to the West, overlie the terrace deposits. (View NW at TF233837, in 1957)



Figure 10. Low terrace at Donington-on-Bain. The eastern bluff is of Spilsby Sandstone, and the thin Bain terrace and alluvium rest on Kimmeridge Clay. (View North at TF 232827, in 1977)



Figure 12. Kirkby Moor Sands, with thin planar bedding and minimal flint, south of the road at Fox Hill. The spade handle is 1 m tall. (View East at TF228627, in 1977).

Kirkby Moor Sands

The Sands are a singular deposit. Quarried for many years till recently, sections in the central outcrop at Fox Hill [TF228628] consistently exposed between 7–10 m of thinly-bedded, well-rounded, fine to medium sands in planar units resting on Wragby Till (Fig.2). Organic materials have never been recovered. In 1976 a long section oriented east-west, lay north of and parallel to the road. Most sand units, rarely more than 40 cm thick, were shallowly cross-bedded with ‘cut and fill’ troughs, but massive horizontal units also occurred often persisting for 10m or so along the section (Fig. 12). Overall palaeoflow direction was however to the south and was characterized in the section by a high frequency of transected troughs (Fig. 13). Apart from rare far-travelled erratics derived from the Calcethorpe Till, the gravel component consisted of flint clasts disposed in occasional lenses

(channel cross-sections) or as diffuse stringers (Fig. 14). Usually less than 50 mm in diameter, the flint fragments were mostly angular and slightly patinated, but semi-rounded ones were also present.

This sand-dominated deposit has generally been regarded as characteristic of all the Sands, but it may be typical of only the central outcrop, and indeed may be even more localised, for quarrying (exploiting the industrial quality of the sand) has taken place only in the Fox Hill area. In the northwest outcrop at Tower Farm, a borehole (Power & Wild, 1982) proved 13m of gravel and, although no open sections exist, the soils of Toft Hill in the east are markedly gravelly, containing much angular and sub-angular flint, the clasts less than 5cm across. In 1957, a section [TF228631] about 300m north of the road, opened during early development of the Fox Hill quarry, revealed sands with frequent gravel lenses up to 25 cm thick, some with clasts of flint and occasional quartzose sandstones up to 20 cm in diameter.

The sedimentology therefore is such that the Kirkby Moor Sands may be construed as having been aggraded by generations of laterally-migrating, shallow, braided streams, the gravel layers comprising bed-load material. Temporarily-dry surfaces between the channels were subject to deflation and some of the flint ‘stringers’ may be regarded as lag gravels. These conditions, including a high water table, persisted throughout the period of accumulation.

The Kirkby Moor Sands demonstrably consist of fluviially transported and deposited sediments but, unlike the lower terraces, they are not confined by higher slopes. On the contrary, they occur on high ground, but with well-defined borders to east and northwest which suggest that deposition was laterally constrained (Fig. 1). The occurrence within the sands of deflated surfaces has raised the question whether the whole deposit might be of aeolian origin, and



Figure 13. Cross-bedded Kirkby Moor Sands with flint stringers, north of the road at Fox Hill. (View South at TF 227629, in 1976)



Figure 14. Kirkby Moor Sands, north of the road at Fox Hill; a small channel fill of angular and sub-angular flint lies in the cross-bedded sand. (View South at TF 227629, in 1976, after rainfall created the small notch on the right)

prompts comparison with the Cover Sands of north Lincolnshire. However, were the materials to be wind-blown it is surprising that sand (other than ‘wash and creep’) does not extend widely onto the lower adjacent slopes underlain only by till. Also, the gravel component cannot have been wind-transported.

Worsley (1991) has proposed an origin as a sandur, aggraded during melting of the ice which emplaced the Wragby Till. The sedimentology of the Sands does not conflict with this interpretation, but sandars are usually constructed by waters emanating directly from glaciers. Rather, as argued above, the materials must have been transported to the area by a precursor of the Bain. The highest part of the Sands is around Roughton, its surface declines SSW at c.1:500, and sedimentary structures confirm southward flow of water. It is also hugely significant that the Sands accord with a downstream extrapolation of the Hemingby Terrace surface gradient, and that upstream extrapolation carries to the floor of the middle Bain valley. The most obvious sources for the bulk of the sands and gravels are therefore the outcrops of Spilsby Sandstone and Biscathorpe Gravels around Scamblesby and Donington-on-Bain, and higher in the catchment. There are none in the Witham valley.

Deposition of the sands

It has been argued above that, in the later MOIS 8 glaciation, ice persisted longest in the central Lincolnshire clay vale and that the Bain valley was initiated along its eastern margin, and so ice must have been present in the area when the Kirkby Moor Sands were laid down. It is postulated that, during a late stage of deglaciation, proto-Bain waters melted the ice back and down to produce constraining walls of ice northwest of the Tower Farm ridge and east of Toft Hill and to allow sediment to be deposited against them thereby defining the present limits of the Sands (Fig. 15), and on newly-exposed Wragby Till. There is every indication, geomorphological and sedimentological, that water and

sediment then passed south and southwest on a broad front beyond the present southwest edge of the Sands, inevitably onto a decaying, stagnant ice surface.

At some point, melting and down-wasting had proceeded far enough for the fore-runners of the Bain and Roughton Beck to begin to incise into both the Sands and the upstream Hemingby Terrace. On final melting the distal supra-glacial parts of the Sands would have been completely dispersed, with

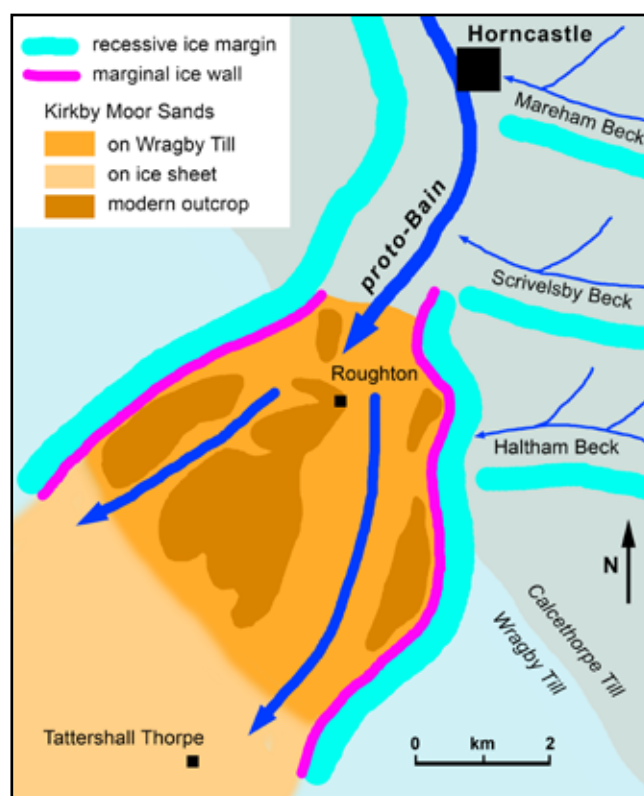


Figure 15. Original disposition of the Kirkby Moor Sands overlying Wragby Till between ice walls upstream of them spreading onto residual ice. The three streams on the east may mark stages in retreat of the ice edge. This map covers the same area as the southern half of Figure 3.

all traces of them obliterated during later formation of the Southrey Terrace except perhaps beneath RAF Woodhall airfield, where the anomalous flinty gravels could be re-worked flinty Kirkby Moor Sands, fed into the terrace by Roughton Beck.

This interpretation of the circumstances surrounding accumulation of the Kirkby Moor Sands predicates events as taking place within the later MOIS 8, and implies broad correlation with the Martin Terrace. The Sands were however never directly connected with this terrace, despite their similar heights above sea level, their being located on opposite sides of the central clay vale and its mass of residual ice. They should, as the Kirkby Member, have been correlated by Bowen et al (1999) with the Hemingby Terrace within the Bain Valley Formation (Straw, 2000).

Acknowledgements

Many thanks are due to Prof. Peter Worsley and Dr. Nigel Straw for their critical comments on an earlier draft.

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