Parallel valleys and glaciation in south-west Lincolnshire

Allan Straw

Abstract: Four valleys in south-west Lincolnshire, with north–south alignments independent of the regional easterly slope and dip, were initiated during the later stages of a glaciation in which southward-flowing ice deposited a sheet of mainly lodgement till over the area. These valleys, now incised through the till into Jurassic bedrock, ignore the courses of several pre-glacial, till-filled valleys. The three eastern valleys drain south, but the westernmost upper Witham valley drains north. This anomalous situation is explained by reconstruction of ice movements over the region in which former contiguous eastern and western ice-streams are identified. Traditionally allocated to the Anglian Glaciation (MIS 12) they are here assigned to the Wragby Glaciation (MIS 8). The Ancaster gap is reappraised and the hypothesis that the largest buried valley, between Melton Mowbray and Thurlby, had been occupied by a major Midland river (the 'Bytham River') is challenged in so far as at least the portion of this valley within the Jurassic cuesta (referred to here as the Castle Bytham valley) was modified by meltwaters as MIS 8 ice approached from both north and west.

Introduction

The south-west part of Lincolnshire, known locally as the Heath, consists of a portion of the Middle Jurassic cuesta, which slopes gently eastward from a composite escarpment of Marlstone Rock (Lias Group) and Lincolnshire Limestone (Inferior Oolite Group) to the western margin of the Fens. To the north it is bounded by the Ancaster gap, and to the south by the valley of the River Gwash (Fig. 1). A prominent geomorphological feature is the group of four valleys (of the upper Witham, Glen, Park stream, and Eden) which are aligned north–south, completely at variance with the regional slope and dip.

The area has been glaciated and formerly had an almost complete cover of glacigenic deposits beneath which, still largely concealed, are several infilled valleys mostly directed down-dip, i.e. eastward (Wyatt, 1971, plate 1). One of these is a through-valley which breaches the scarp east of Wymondham (SK 851185) and passes beneath Castle Bytham (SK 989184) to reach Thurlby (TF 103168) at the Fen margin (Rice, 1968). That part within the cuesta is referred to below as the Castle Bytham valley. It has been claimed that pre-glacially it was occupied by a large river (the 'Bytham River' – Rose, 1987, 1989a) that drained part of the Midlands around Leicester and Coventry, but today its valley is largely concealed and is transected by those of the upper Witham, Glen and Eden.

The four streams were initiated during deglaciation (Kent, 1939) and receive tributaries mostly from the west. Now incised into bedrock limestones and clays, their valley floors have been much affected by valley-bulging (Hollingworth et al, 1944; Parks, 1991) to which the streams have responded by adopting remarkably twisting courses with undercut bends below gentler upper slopes (Fig. 2) of the generally straight valleys.

The geomorphological complexity of this relatively small area goes, however, well beyond what might be inferred from the above description. For example, while the Eden, Park stream and Glen drain south, the upper Witham is directed north to cut through the scarp toward Grantham. The glacial tills thicken south of the Ancaster gap, and west of the Glen contain many 'boulders' and huge 'rafts' of Marlstone Rock, Northampton Sand and Lincolnshire Limestone formations. These circumstances, and others such as regional ice-sheet behaviour and events pertaining to the Ancaster gap and the Castle Bytham valley, are addressed below.

The valleys

The head of the **upper Witham** valley lies east of Thistleton (SK 912180) at about 118 m OD, south of the line of the Castle Bytham valley. Cut through Lincolnshire Limestone into Upper Lias clay, the valley descends due north for about 19 km deepening gently from 15 m north of Colsterworth (Fig. 3) to double that at Great Ponton, with a gradient of c.1:330 (3 m/km) to lie at 60 m OD around Grantham. Its floor is narrow, twisting and, underlain by clay, has been subject to bulging and micro-faulting.

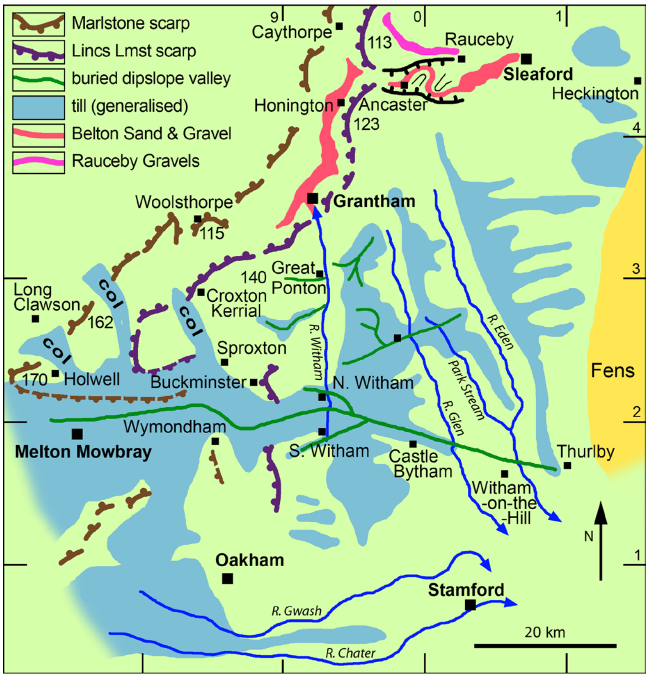

Figure 1. Valleys and glacial and fluvial sediments of the Heath and adjacent areas.

Figure 2. *Eden valley, downstream, 20 metre bluff in Blisworth Limestone, Cornbrash and Kellaways formations, with capping till under the distant trees (view ESE at TF 047260, Oct 2019)*

By contrast, the **Glen** river drains south, with its head at c.100 m OD near Old Somerby (SK 960335). For 3 km it is etched into limestone then, for the next 3 km between Boothby Pagnell (SK 970312) and Burton Coggles (SK 980259), where the valley is about 15 m deep, it is incised into till and transects a mass of Oxford Clay and Kellaways formations (Fig. 4). Thence it descends (Fig. 5), with a gradient of c.1:266 (c. 4 m/km) to c. 30m OD at Essendine (TF 047127). South of Corby Glen (SK 998250) the stream becomes sinuous and, where the valley is floored by beds of the Northampton Sand Formation, bulging and micro-faulting occur. At Little Bytham (TF 013180) it crosses the buried Castle Bytham valley.

Grimsthorpe Park lies between the Glen and Eden valleys and is largely drained by a stream that heads north-west of Corby Glen and flows south-south-east for 7 km to join the river Eden 2 km south of Edenham (TF 062218). The **Park stream** is cut into Kellaways and Cornbrash formations with a gradient of c.1:320 (c. 3 m/km) and a valley depth of never more than c.18m.

The **Eden** valley is the longest of the four, declining 25 km at about 1:367 (c. 2.7 m/km). For 8 km, from its head south-west of Kelby (SK 995405), it displays a simple form, a direct course and a depth of 5–7 m across Lincolnshire Limestone (Fig. 6), but below Hanby (TF 020320) the stream becomes increasingly sinuous and for much of its course downstream the valley sides are formed in Cornbrash and Blisworth Clay, beneath Oxford Clay and Kellaways formations, capped by glacial till. Around the confluence with the Park stream, faulting brings up the Lincolnshire Limestone and Grantham formations. From 3 km above Edenham, where the valley is about 30 m deep the stream becomes markedly sinuous with curves of 500 to 800 m amplitude and, below the confluence, these bends have more the appearance of true meanders, now incised into ground lying at 30–35 m OD. South of Manthorpe (TF 072160) where the Glen and Eden combine to flow north-east toward the Fens, level expanses of sand and gravel form ground at similar heights.

It is readily apparent that all the valleys are strikingly discordant with the underlying bedrock geology, having been superimposed from the overlying till sheet; they have broadly similar gradients of a few

Figure 3. *Upper Witham valley, c.15m deep, at Twyford: river flows R to L, then turns sharply NE in front of distant buildings; foreground is on Lincolnshire Limestone; till capping beyond the river (view NNE at SK 926232, Oct 2019)*

Figure 4. *Upper Glen valley, draining S, E of Burton Coggles: the ploughed fields and woods are on till which here conceals the buried Burton Coggles valley (view NE at SK 987253, Oct 2019)*

***Figure 5**. Glen valley, c.22m deep, above Little Bytham, draining S: foreground on Cornbrash; woods and gentle slopes beyond the river are on till (view NE at TF 015185, Oct 2019)*

***Figure 6**. Upper Eden valley, a linear incision c.7m deep into Lincolnshire Limestone, draining S (view E at TF 000371, Oct 2019)*

metres per kilometre and display comparable degrees of incision. The Glen, Park stream and Eden form a genetically-related group most probably initiated along successive margins of an episodically-receding ice mass (Kent, 1939; Wyatt, 1971). The upper Witham is fundamentally different in its northerly course, and the reason for this is better considered within a discussion of the area's glaciation.

Glaciation

The area has been inundated by glacier ice at least once, as shown by its blanket of glacigenic sediments, mostly Chalky Boulder Clay lodgement till (Wyatt, 1971; Wyatt et al, 1971). Advance from the north is proven by the composition of the tills (Morris, 1853; Jukes-Browne, 1885; Harmer, 1909, 1928; Straw, 1969, 1979a, b, 1983; Wyatt, 1971; Harrod, 1972; Lewis, 1989). Matrices of the tills are derived from the Jurassic clays underlying the Vale of Belvoir and central Lincolnshire and those, particularly the Oxford Clay, that pre-glacially covered much of the Lincolnshire Limestone of the dip slope. Perrin et al (1979) claimed that ice reached the region from the east but this cannot be maintained because the tills contain no erratics from the Wash area such as Red Chalk (Hunstanton Formation), Spilsby Sandstone and Kimmeridge Clay. Far-travelled erratics in the tills include Millstone Grit, Carboniferous Limestone, dolerite, quartzite pebbles, clasts of Mercia Mudstone and Frodingham Ironstone, and chalk and flint sourced in north-east Lincolnshire and Holderness. Straw (1983) criticized Perrin et al's sampling procedures and interpretations of results, and strongly denied that ice had dispersed west and north-west from the Wash. Instead, he depicted the north-south travel of several distinctive erratics across Lincolnshire and demonstrated that east-west facies changes in the Lincolnshire tills were closely related to the general north-south outcrops of the county's Jurassic and Cretaceous rocks (Straw, 1969, 1979a, b, 1983). Southerly flow has also been supported by studies of chalk microfossils (Fish & Whiteman, 2001) and soil chemistry (Scheib et al, 2011).

The tills survive today mainly on the interfluves between the four valleys and in the Wreake valley toward Melton Mowbray (Fig. 1). Borehole logs reveal thicknesses varying from a few metres to over 70 m, with the greater thicknesses located over the buried valleys. More generally, till thicknesses between 10 and 30 m have been recorded (Wyatt, 1971). Such volumes of material reflect the facility with which the ice could entrain and transport the soft Jurassic clays, especially, over the dip slope, the Oxford Clay; but also the fact that the ice was flowing across the valleys and not along them, a circumstance that seems to encourage deposition and which has also been held to account for the singular till deposition at Welton-le-Wold in the Lincolnshire Wolds (Straw, 2005; 2015). Where ice flowed over more resistant beds such as the Lincolnshire Limestone, glacial erosion was relatively light and deposits thin.

Regarding the tills on the Heath, all workers, including Perrin et al (1979) have considered them to comprise a single suite of glacigenic deposits (Jukes-Browne, 1885; Kellaway and Taylor, 1953; Straw, 1958, 1969, 1979a, b; Harrod, 1972; Wyatt, 1971; Perrin et al, 1979; Rose, 1989b; Bridgland et al, 2014). Wyatt (1971) and Wyatt et al (1971) had access to thousands of exploration borehole records obtained by ironstone companies and found no reason to consider multiple glaciation. This stratigraphic continuity is supported by some aspects of the geomorphology. The tills immediately underlie the present interfluve surfaces which display no features such as morainic ridges that might indicate more than one advance into the area. The valleys described above display closely similar forms and degrees of incision (Figs. 3–6) which could derive from simultaneous initiation. Indeed, Wyatt (1971, p 52) notes that 'much of the post-Chalky Boulder Clay drainage pattern must have originated during or after deglaciation'. All these factors point to a single incursion of ice flowing across the whole area from the north.

Nevertheless, further consideration of the modern drainage alignments in south-west Lincolnshire and the constitution of the tills reveals a significant dichotomy within the area, not previously recognized. The tills between the southerly-directed valleys are largely composed of Upper Jurassic clays derived from the central Lincolnshire vale and the local dip slope, with much Oolitic material and variable amounts of chalk and flint as erratics. By contrast, those west of the Glen and adjacent to the northerly-directed upper Witham are essentially Liassic (Lower Jurassic) and are further characterized by the inclusion of huge 'rafts', some being hundreds of metres across, of Marlstone, Northampton Sand and Lincolnshire Limestone and many other lumps of bedrock up to several metres across (Morris, 1853; Jukes Browne, 1885; Hollingworth et al, 1944; Kellaway and Taylor, 1953; Wyatt, 1971; Harrod, 1972). These tills, which pass laterally south-west into the Oadby Till (Rice, 1968, 1991; Douglas, 1980) can only have been deposited by ice moving up and out of what is now the Vale of Belvoir. The area under consideration appears therefore to have been affected by two parallel but contiguous ice-streams (Fig. 7) with seemingly contrasting dynamics.

Ice advancing into Lincolnshire had to adapt to the pre-existing cuesta and vale physiography. Straw (1983, 1991) has proposed that early in the county's glaciation, North Sea ice crossed the Chalk of Holderness, the Humber gap, and the low scarp of the north Wolds north of Caistor, to spread westward over the Scunthorpe and lower Trent areas thereby carrying chalk and flint (including the distinctive tabular flint from the Burnham Chalk Formation) west of the Middle Jurassic cuesta (Lincoln Cliff) and into the path of an advancing Vale of York glacier. The latter inevitably collided with this eastern ice some of which was then shunted south into the Vale of Belvoir. Denied further expansion to the west this North Sea ice was obliged

***Figure** 7. Ice-streams over the Heath and adjacent areas.*

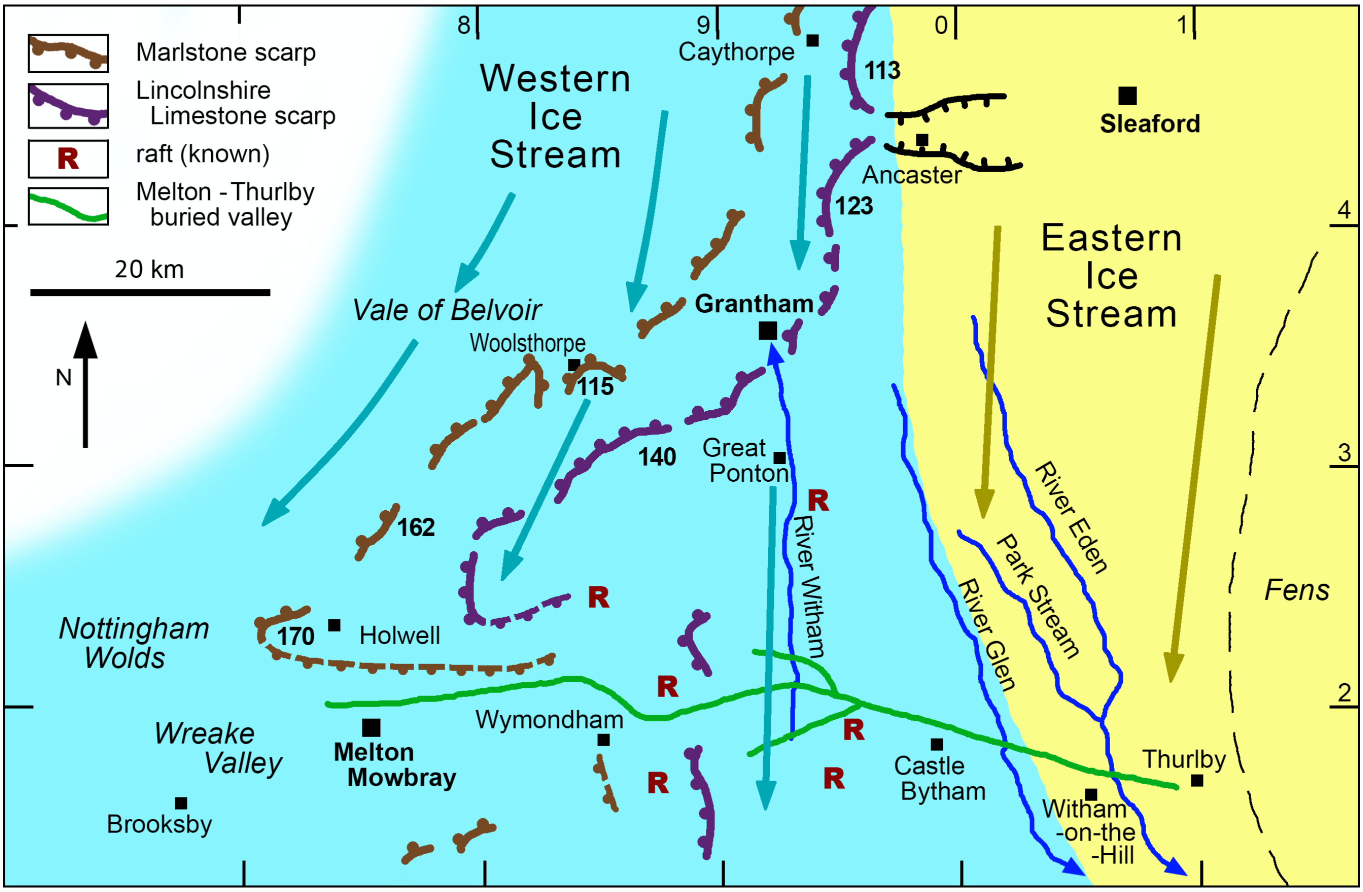

Figure 8. *Witham-on-the Hill, Heath Till (eastern ice-stream): diamicton, with matrix largely of Oxford Clay with some facies variation (view N at TF 032175, April 1989)*

also to occupy and flow down the central Lincolnshire clay vale and Lincolnshire Limestone dip slope into the Fen basin, whereas the western ice continued south along the Lower Lias outcrop. This model accounts for the existence of ice streams east and west of the Middle Jurassic cuesta linked no doubt over this limestone tract by thinner and slower-moving ice, and especially for the presence of chalk and flint in the Liassic Heath and Oadby tills

The eastern ice-stream

The North Sea ice, and any Vale of York ice which entered central Lincolnshire, were able to flow freely south over the Kimmeridge, Ampthill and Oxford Clay outcrops. Achieving considerable erosion this ice-stream was responsible for the wide, symmetrical form of the vale (Straw, 1958; Westaway, 2010; White et al, 2017) and ultimately for deposition of the Wragby Till, the Oolite-rich tills east of Sleaford and those on the cuesta south of the Ancaster gap (Straw, 1958, 1969, 1983) (Fig. 8). It may have reached as far south as the Peterborough area (Langford, 2004, 2012) and, as its energy diminished, splayed out in lobate form across the Fens.

If the three south-draining valleys are similar features and form a genetic group initiated at a receding ice margin it is rational to regard the Glen valley as marking the western limit of this central Lincolnshire ice stream (Fig. 7). This is supported by the contrasts in till composition noted above. The headward portion of the Glen valley, etched into limestone, could mark precisely the maximum ice margin, and the general south-south-east alignment of the deepening valley can be taken to approximate closely to it. The Park stream and Eden valleys may well indicate stabilizations of the receding ice edge sufficiently long to allow meltwaters draining off the ice to incise till and bedrock deeply enough to ensure that, as also with the Glen, the drainage kept to these lines with no subsequent displacement (Fig. 6). Such phased recession of the ice margin could indicate overall thinning of the ice after stagnation. As the till surface was progressively exposed, streams arose in response to the regional slope to become westerly tributaries of the main streams. Sands and gravels underlying ground at c. 30–35 m OD about the confluence of the Glen and Eden and south from Manthorpe indicate that meltwaters continued south toward Uffington (TF 063077) (Langford, 2012; Langford & Briant, 2004; Straw & Worsley, 2017). Further north, the latest identifiable drainage line is indicated by the Martin Terrace below Lincoln and gravels at Heckington (Westaway, 2010; Bridgland et al, 2014), though this line has been taken to mark the maximum western edge of the central Lincolnshire ice (White et al, 2010; Westaway, 2010; Westaway et al, 2015; Bridgland et al, 2015). It can be noted that somewhat similar circumstances prevailed along the eastern edge of the decaying MIS 8 ice, where the River Bain, receiving tributaries only from the east, also originated as a marginal meltwater stream (Straw 1966, 2018).

The western ice-stream

In the model outlined above, Vale of York ice is held to have met North Sea ice in the southern Humberhead area, with sufficient strength to deflect the latter south into the Vale of Belvoir (Straw, 1979a, b, 1983, 1991). Lincoln Cliff, with increasing height and prominence southward, would have early influenced and determined the development of eastern and western ice-streams within the overall ice-sheet. As flow continued south the eastern part of the western ice-stream would have become increasingly defined by the scarps of Lincoln Cliff and Edge which were consequently eroded and smoothed (Fig. 9). Towards Caythorpe (SK 938485) the Marlstone Rock begins to form a prominent anterior cuesta with a strike vale on upper Lias clays separating it from the Lincolnshire Limestone scarp. The south-flowing ice would have overridden the Marlstone and, in occupying the clay vale, have closed off the Ancaster gap. From Grantham the Marlstone cuesta and the Oolite scarp curve south-west in response to the Holwell synclinal flexure, forming the head of the Vale of Belvoir and gaining heights of c.140 and c.170 m OD respectively (Fig. 1). Inevitably therefore, in significant contrast to the eastern ice-stream, free-flow of the western ice was obstructed by a major physiographic feature (Fig. 10) with a relative relief approaching 100 m (Straw, 1979a, b, 1983). The glaciological response would have been for the ice to thicken in front of the scarps and thence, when its surface was sufficiently high, to surmount them and flow faster to relieve the pressure, thereby enhancing erosion of the rocks under the rising ground and deposition on the lee-side dip slope (Straw, 1979b). Such circumstances can be responsible for what Linton (1963) termed ‘intrusive’ troughs, and the writer has described (Straw, 1968) many such features along the Niagara escarpment of Ontario where it was scoured by Shield ice. It is pertinent to consider whether the upper Witham valley is a modest Lincolnshire example.

Figure 9*. Lincoln Edge, scarp of the Lincolnshire Limestone, between Navenby and Coleby, relative relief c. 50m; foreground on upper Lias clay (view N at SK 980579, Oct 2019)*

The unusually straight south-north alignment of this valley and its breach of the Lincolnshire Limestone scarp where the latter begins to turn away south-west have already been described. What merits further notice is that this alignment accords with that of the Oolite scarps of Lincoln Edge and Cliff. It can be postulated that the western ice-stream, flowing south parallel to the scarps and in part controlled by them, entered the Grantham upper Lias vale and then rose onto the Middle Jurassic cuesta taking advantage of the pre-existing gap in the Oolite scarp indicated by the buried valleys under Ponton Heath (Wyatt, 1971) (Fig. 7). This gap was then subsumed into a larger 'intrusive' feature in the form of a deep groove in the Lincolnshire Limestone surface extending some 15 km due south. This scenario gains support from the presence of the large 'rafts' discovered within the tills west of the Glen valley. These can be several hundreds of metres long and tens of metres thick, those of Marlstone and Limestone indicating erosion on a large-scale and to their transport up to 20 km to the south. Gaps in the anterior cuesta between Barrowby (SK 880364), Woolsthorpe (SK 837340) and Belvoir Castle (SK 820337) (Fig. 7) may be specific sites of Marlstone excavation (Straw, 1979b, 1983).

During deglaciation, subglacial drainage may have been concentrated along the zone between the two ice-streams following particularly the line of the groove in the limestone surface, deepening it and establishing a north-flowing stream permanently in the landscape. As melting proceeded and the ice margin receded into the Vale of Belvoir meltwaters coursed down this valley and thence north and east from the Grantham area to pass through the pre-existing Ancaster gap toward the Fens and, in the process, commence deposition of the Belton Sand and Gravel along its floor (Straw, 1963; Berridge et al, 1999; Bridgland et al, 2014) (Fig. 1). In the Heath the precision of the juncture between the two ice-streams, considered to be the line of the Glen valley, is not unique; in central Lincolnshire, the contact between Wragby Till ice and Calcethorpe Till ice is marked at the surface not by a geomorphological feature but by an abrupt change in soil type along a straight line stretching some 15 km from Minting (TF 188735) to the Fen margin at Mareham-le-Fen (TF 278612).

This discussion surrounding the development of the south-west Lincolnshire valleys and emplacement of the tills reveals differences in ice behaviour between the two ice-streams. It has been necessary to go further afield to explain why these differences occurred. The essential point is that whereas the eastern ice-stream, once across the north Wolds, was free-flowing and able to reach a natural lobate limit as its energy dissipated, the western ice, sourced from the Vale of York, had to contend with a prominent obstruction before moving on toward Melton Mowbray, Loughborough and Derby. The southern limit of the ice which crossed the study area remains ill-defined, but could well be close to the Gwash and Chater valleys (Fig. 1).

It remains to consider the timing of this glaciation. Traditionally it has been placed within the Anglian stage (MIS 12) (Perrin et al, 1979; Rose, 1987, 1989a, b; 1991; Bowen, 1999; Stephens et al, 2008; Bridgland et al, 2014) and its deposits assigned to the Lowestoft Formation. Certainly, ice in this stage must have covered south-west Lincolnshire because it extended as far south as the Thames valley, but Wyatt et al (1971) regarded the chalky boulder-clay of this area as of later Saale (Wolstonian) age. In central Lincolnshire the Wragby Till overspreads wide areas, is flanked on the east by the chalky Calcethorpe Till and passes south-west into the tills east of Sleaford which have a stronger Oolitic component. The Wragby Till is overlain by MIS 7 organic sediments at Southrey (TF 137666) and Tattershall (TF 212576) (Bridgland et al, 2014) and is correlated with MIS 8 (Westaway, 2010; White et al, 2010; Bridgland et al, 2014, 2015, 2019; White et al, 2017). Accordingly, the adjacent tills of both the Wolds and the Oolite cuesta must be coeval (Straw, 1966, 1969). The absence of diagnostic Wash area erratics in the tills of the eastern part of the cuesta and demonstration that the latter were emplaced by south-flowing, not west-flowing, ice show that there is no reason to regard the tills as part of the Lowestoft Formation and *ipso facto* of MIS 12 age as traditionally claimed (Perrin et al, 1979; Bowen, 1999). The writer has long pressed the view (Straw,1969, 1979b, 1983, 2010) that Lincolnshire has been strongly impacted by a post-Anglian/pre-Devensian glaciation, and a more realistic interpretation is that central Lincolnshire was occupied during the Wragby Glaciation by MIS 8 ice flowing mainly from the north and north-east (Fish and Whiteman, 2001) over the northern Lincolnshire Wolds and partly from the north-west from the Scunthorpe area, and that this ice extended south as far as the Glen valley and the Peterborough area, where marginal features survive (Langford, 2004).

West of the Middle Jurassic scarps, till survives east of Gainsborough on an ice-eroded surface that declines south toward lower ground along the Lias Group outcrop, which was drained toward the Lincoln gap by the post-Anglian proto-Trent and its right-bank tributaries, the rivers Smite and Devon. This till was emplaced prior to deposition of the glacifluvial Eagle Moor terrace of the Trent, designated later MIS 8 (Bridgland et al, 2014; White et al, 2017). Southward, till seems not to have survived over the Vale of Belvoir, perhaps for two main reasons. First it was an area of ice erosion where material was being picked up subsequently to be deposited further south as the Liassic Heath and Oadby tills. Second, following deglaciation, fluvial erosion and transport by the rivers Witham, Devon, Smite and Till responding to isostatic uplift (Bridgland et al, 2014, 2019) could have lowered the surface, reworking glacial materials into the several terraces (Balderton, Scarle and Fulbeck). The former presence of ice in the Vale is indicated however by the discordant pattern of these streams around Long Bennington which is suggestive of superimposition from ice over outcrops of Granby Limestone (Lower Lias) (Straw, 1963, 2002). It has been proposed that MIS 8 ice reached the Nottingham/Derby area by way of the Trent 'trench' (White et al, 2010; Bridgland et al, 2014, 2019) and this could have happened if the 'trench' was then in existence, but it is highly unlikely that ice did not occupy simultaneously the adjacent wide, and equally low, Vale of Belvoir.

South of Grantham the Liassic Heath Till lies on the Jurassic dip slope westward of the Glen valley. Its composition indicates transport from the north by ice that has traversed the Lias Group outcrop, and a case has been made above for a western ice-stream extending from the Humber-head area, parallel to and adjoining the central Lincolnshire ice, to the Wreake valley. Within the study area there is no reason to dissociate the tills east and west of the Glen valley on grounds of age when, regardless of the dichotomy, they comprise a single stratigraphic unit and occupy the same position in the landscape (Straw, 1969; Wyatt, 1971). The corollary is that both eastern and western ice-streams belong to MIS 8.

The Heath tills pass west and south-west into the Oadby Till (Rice, 1968), ice having descended into the Wreake valley. The ice responsible for the chalky component of the Oadby Till is considered to be that mass which is held to have first crossed the northern Lincolnshire Wolds and was then shunted south of the Scunthorpe area by Vale of York ice in the earlier stages of the MIS 8 glaciation, picking up Liassic and some Triassic material *en route.* It eventually came into contact with Midlands ice responsible for at least part of the Thrussington Till in the area around Melton Mowbray and Loughborough. (Rice, 1968, 1991; Carney, 2007). A summary observation is that from the Welton and Calcethorpe tills of the Lincolnshire Wolds in the east to the Oadby Till in the west, the tills are to be differentiated solely through facies changes and not by age.

These considerations of ice movement and behaviour, and particularly the argument that MIS 8 ice (Wragby Glaciation) was responsible for glacial and related features in south-west Lincolnshire, prompts more comment on two major landforms.

***Figure 10**. The Marlstone Rock scarp near Barrowby, relative relief c. 55m; foreground on thin alluvium over upper Lias clay (view ESE at SK 855370, Oct 2019)*

The Ancaster gap and Melton Mowbray –Thurlby valley

The **Ancaster gap** is about 2 km wide north-east of Honington (SK 943431), with ground rising north and south on Lincolnshire Limestone to c.115 m OD, and nearer 4 km across near Rauceby (TF 460023) in the east. An inner sinuous valley develops east of Ancaster (SK 982435) defining two spurs which are possible remnants of a mid-level gap floor at c. 60 m OD. (Fig. 1). Gap sides and those of the spurs are heavily cambered (well seen in the Ancaster railway cutting – Fig. 11). Devoid of glacial deposits, its floor is however covered in part by a complex of sediments (Belton Sands and Gravels – Wyatt, 1971; Berridge, 1999; Bridgland et al, 2007, 2014) (Figs. 1, 12) deposited by the upper Witham before it diverted itself (possibly in MIS 6 by excessive aggradation between Honington (SK 944432) and Sudbrook (SK 971447)) through a low pre-existing gap in the Marlstone ridge west into the Vale of Belvoir, leaving the main gap occupied only by the underfit stream now known as the River Slea.

Bridgland et al (2007, 2014) have described a series of high-level sands and gravels along the north side of the gap between Caythorpe Heath and Rauceby, descending east from c. 96 to 79 m OD (Fig. 1). Lacking any materials indicative of glacial input, but including many quartzite pebbles, these Rauceby gravels were considered to date from pre-Anglian times being deposits of an early proto-Trent that drained an area around Nottingham, probably including the precursors of the Erewash and Dover Beck. Subsequently this river commenced incision of the gap along the south side of the deposits. If this is the case, then these sediments have survived both MIS 12 and MIS 8 glaciations, which is hardly plausible, and at best they may be vestiges only of formerly more extensive sediments. It is noteworthy too that these sediments do not lie within a valley feature and that northward the Lincolnshire Limestone high ground declines steadily away from the gap.

A gap, shallow in MIS 12, deeper in MIS 8 would have been occupied by ice in both glaciations. Although the southerly ice flow was across it, it received little if any glacial infill probably because the ice had travelled over resistant, frozen, limestone surfaces. While the spurs and the sinuosity within the eastern part of the gap may be indications of a valley floor produced by meltwaters and later by a river that developed after the Anglian glaciation, no major river appears to have utilized it after the MIS 8 Wragby Glaciation. Instead, during deglaciation, upper Witham meltwaters, which commenced deposition of the Belton Sand and Gravel on a valley floor already in existence, could also have reworked any till present in the gap. Devensian solifluction could also have played a part in removing till from slopes.

The **Melton Mowbray–Thurlby** valley (figured variously by Rice, 1965; Wyatt, 1971; Rose, 1989; Stephens et al, 2008) provides many contrasts. As reconstructed from borehole records it is much longer (over 20 km) and, relatively narrow, leads from a funnel-like re-entrant in the Lincolnshire Limestone scarp about 2 km wide between Wymondham and Buckminster, tapering east with a floor only 0.5 km wide at and below Castle Bytham to Thurlby (Fig. 7). This lower section (referred to here as the Castle Bytham valley) contains sands and gravels considered by Rose (1987, 1989a, b, 1994, 2009) to have been deposited by a large, east-flowing, pre-Anglian river ('Bytham River') under cold climatic conditions. Draining north-east mainly from the Stratford-on-Avon area by Coventry and Leicester, this was associated with the Bagington-Lillington Sands and Gravels of the Midlands, a lithological unit defined by Shotton (1953). Rather than continuing north-east parallel to the Jurassic escarpments, the river was held by Rose (1989a) to have turned east at Melton Mowbray along the line of the present Wreake valley to cross the Middle Jurassic cuesta and excavate the Castle Bytham valley. If so, why at this point? It may have been superimposed across the cuesta from a

***Figure 11**. Ancaster railway cutting, showing cambered Lincolnshire Limestone; the slumped, vegetated sections mark parallel 'gulls' (fissures opened by 'stretching' of the limestone and filled with soliflucted and colluvial materials) transected by the cutting (view E at SK 995443, April 1968)*

Figure 12. *Limestone-rich Belton Sands and Gravels, with small intra-formational ice-wedge cast, SW of Rauceby (view SE at TF 030437, April 1962)*

higher land surface (Rose, 1989a), but it can be noted that the Wreake valley coincides with an anticlinal feature pitching slightly east that parallels the Holwell syncline to the north responsible for the curve of the scarps south-west of Grantham. Differential denudation of the anticline crest relative to that of the syncline may have produced lower ground preferred by the river, especially if high land extended west of the Holwell syncline. The presence of this is indicated by former drainage through the till-filled cols (Fig. 1) across the syncline at Croxton Kerrial (TF 835295), Eaton (TF 798290) and Holwell (TF 735237) (Wyatt et al, 1971).

The undoubted fluvial sediments of the Castle Bytham valley within the cuesta are over lain by thick glacigenic materials, largely till, which complete the infilling of the valley and render it virtually undetectable in the modern landscape (Fig. 8). The sorted sediments, some 18 to 20 m thick, have been described from Castle Bytham (Rose, 1989b) and from Witham-on-the-Hill (Lewis, 1989). Lower sands and gravels, 8–9 m thick, with clasts consisting mainly of local ironstone and limestone are overlain by a similar thickness of sands capped by 12 to 13 m of glacigenic sediments (Fig. 13). The upper layers of the sands, which have been glacially disturbed, grade upwards into glacigenic silts (Rose, 1987, 1989b). Some of the fluvial sediment has been incorporated into the lower layers of the till as ice moved south over it (Fig. 14). This till, part of the sheet that covers the cuesta, has long been regarded as the lateral equivalent to the Lowestoft Formation and assigned to the Anglian glaciation (MIS 12) but, as argued above, it is more likely to be of MIS 8 age. Therefore, if the fluvial deposits in the Castle Bytham valley are pre-Anglian, they would have had to survive two glaciations.

If the capping till is MIS 8 and the underlying sediments are pre-Anglian then it has to be assumed that any weathered horizons, Anglian glacial deposits and other sediments that may have developed in stages MIS 11–9 have been removed, and their nature and landscape development in this period are impossible to determine. Clearly such speculation is avoided if the till is MIS 12 but would also be avoided if the fluvial sediments were MIS 8. Is it possible that the formation of the Castle Bytham valley and the accumulation of the sands and gravels that survive within it were achieved at a time and under conditions totally unrelated to a former trunk river? It was noted by Gibbard et al (2013) that the Castle Bytham valley deposits are separated from possible East Anglian equivalents by the wide Fen basin. Rice (1968, 1991) observed that

Figure 13. *Witham-on-the Hill. Heath Till (eastern ice-stream) on trough-bedded, limestone-rich, sand and gravel (view N at TF 032174, April 1989)*

Figure 14. *'Thunderbolt Pit', E of Castle Bytham: Heath Till (western ice-stream); diamicton part-sheared into fluvial sands, with joints affected by gleying (view N at SK 997183, May 1963)*

the head of the Wreake valley was filled with till and further that a reverse gradient existed between the Thurmaston Sands and Gravels near Leicester and the Castle Bytham sediments (explained by Westaway (2010) by differential uplift).

The Wreake and its tributaries today occupy a wide west-draining valley, obsequent to the Marlstone/ Lincolnshire Limestone scarps (Rice, 1965, Stephens et al, 2008). On its north side the scarps are obscured by thick Oadby Till as it descends into the valley, but they re-emerge south of Melton Mowbray (Fig. 1). The axis of the valley coincides with the anticlinal feature that parallels the Holwell syncline to the north. Across the country, scarp recession has frequently overtaken the heads of dip slope valleys (there are many examples in the Cotswolds, Chilterns and South Downs) to leave cols over the scarp crests. It is possible that the Castle Bytham valley originated as a normal dip slope valley similar to the buried one at Burton Coggles (Fig. 1), its head being lost as the Wreake valley extended eastwards to leave a low col across the scarp crest.

To speculate further, as MIS 8 ice moved south along central Lincolnshire and the Vale of Belvoir, the Ancaster gap would be closed and any drainage through it suppressed. Backing up of water was inevitable as happened at some stage in the Midlands as shown by Shotton (1953) who identified a huge lake he named Lake Harrison, dammed on the west by Severn valley ice. In MIS 8 while the eastern part of the Vale of Belvoir ice-stream overrode the scarp south-west of Grantham to gain the higher ground the western part probably moved more quickly out of the Vale of Belvoir and was deflected south-west (Fig. 7) toward Loughborough and Melton Mowbray, where it met Severn valley ice responsible for the Thrussington Till (Rice, 1968; Carney, 2007) before the eastern part reached the Castle Bytham valley. A lake could have been impounded between the conjoint ice masses and the Jurassic scarps around the Wreake valley (Carney, 2007). Overspill, perhaps on many occasions, may then have utilized the scarp-crest col and coursed strongly down the beheaded dip slope valley, deepening the col, steepening the sides, and scouring the floor. Sediments deposited as ice approached from the north were soon to be sealed off by masses of lodgement till. While the bedload basal sands and gravels may bear witness to erosion of limestones in the upper part of the valley, the sands and any materials of western provenance could have been carried by either or both the obstructed Midland river and the Thrussington Till ice which had crossed Midlands Triassic and Carboniferous outcrops, with flint contributed by the Oadby Till.

A scenario can be envisaged therefore where the Castle Bytham valley is a beheaded dip slope valley modified by glacial meltwaters during the MIS 8 Wragby Glaciation, and which can explain both the form of the valley and the contained glaci-fluvial deposits.

Conclusions

Consideration of the four valleys and of the composition and disposition of the tills has led to proposals that the Heath area of south-west Lincolnshire was overspread by ice in MIS 8, and that the ice entered the area as two contiguous ice-streams, one down central Lincolnshire, the other along the Vale of Belvoir (Fig. 7). In the eastern part of the Heath the limit of the central Lincolnshire ice is marked by the Glen valley and the interfluve tills were emplaced by southward-flowing, not westward-flowing, ice. To the west, the northerly-directed upper Witham valley was eroded by the western ice-stream and formed a channel for meltwaters during deglaciation which commenced transport and deposition of the sediments known as the Belton Sand and Gravel (Berridge, 1999) along the floor of the Upper Lias vale by Grantham and the Ancaster gap.

It is evident (Rice, 1968; Carney, 2007; Rose, 2009; Bridgland et al, 2014) that deposits of two glaciations (MIS 12 and 8) are present in the area around Melton Mowbray, Loughborough and Leicester, and that in each case ice entered it from both north and west, meeting in fluctuating zones west of the Jurassic scarps. There is therefore potential for at least two Thrussington-type and two Oadby-type tills. During MIS 8 chalk and flint could have been carried first into the Scunthorpe/ Humberhead area by west-flowing coastal ice and thence into the western ice-stream to be transported south and become components of an 'upper' Oadby Till. During MIS 12, some Anglian ice would also have inevitably followed a Vale of York/Humberhead/ Vale of Belvoir trajectory and, if it had arrived in the Scunthorpe area *before* any coastal ice, then chalk and flint would not be incorporated into western ice-stream deposits. This may explain the presence of chalk-free Liassic 'lower' Oadby Till (Carney, 2007). The coastal ice would, instead, have streamed south over central Lincolnshire and the Wolds carrying chalk and flint to the Milton Keynes area. It may not be too much to claim that all chalk-bearing tills south and south-west of Grantham are of MIS 8 age.

Despite the wealth of detail regarding the hypothetical 'Bytham River' the possibility has been raised in this paper that the cuesta section of its presumed valley, referred to as the Castle Bytham valley, might have been produced during a relatively short period of pro-glacial activity. Were this the case and if, in spite of Brandon's later work (1999), Rice's view (1968, 1991) is accepted that drainage in the pre-glacial Wreake valley was to the west, then the only direction for a pre-glacial river to have followed from the Brooksby area (Stephens et al, 2008) was to the north, continuing its course along the foot of the Jurassic scarps (Shotton, 1983) to join the proto-Trent and pass through the Ancaster gap (Straw, 2002). Although this has been refuted by Bridgland et al (2014), some of its deposits might remain beneath the thick tills of the Nottingham Wolds, but from there north-east to the gap others, if they once existed, clearly have not survived the combined effects of MIS 12 and MIS 8 ice erosion.

Finally, if the Castle Bytham valley was modified by meltwaters as suggested above, then eroded materials would have been spread out beyond the Fen margin, only to be re-worked quickly by the advancing central Lincolnshire ice and perhaps thence incorporated within some of the sand and gravel features described by Langford (2004, 2012), Bridgland et al (1991) and Davey et al (1991).

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Allan Straw, 31, Tilmore Gardens, Petersfield GU32 2JE
allan.straw@btinternet.com