The intra-Anglian-Devensian glacial event(s) of Lincolnshire

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A one-day field discussion meeting was held on Sunday 23 August, 2015, to consider the evidence for identifying a glaciation between the Anglian (c 450 ka) and the Last (Devensian) Glaciations within Lincolnshire. Some 20 participants gathered at Blossom Hill [063088], northeast of Stamford to begin an excursion across the Fens and Wolds to finish at Welton-le-Wold [280882], west of Louth (all grid references are in NGR square TF). This paper is an extended report of that excursion and the discussions and conclusions that emanated from it.

Since the new millennium, support has grown favouring a glaciation with a possible c 250 ka age within a cold stage that had earlier been called 'Wolstonian' (Mitchell *et al.,* (1973). Such a glaciation of eastern England (as represented by the Wragby and Calcethorpe Tills) has long been argued (Straw, 1969, 1983), despite widespread scepticism. The new edition of the Geological Society of London's Quaternary classification (Bowen, 1999) proposed that the 'Wolstonian' embraced two separate cold stages. Clearly this is a confusing outcome, but, unlike the first report, this revision embraced the marine oxygen isotope stage (MOIS) chronology (which had been proposed in the mid-1950s by the marine geochemist Cesare Emiliani). When applied to Lincolnshire, the glaciation that emplaced the Wragby and Calcethorpe Tills was correlated with MOIS 12, i.e. the Anglian (Lewis, 1999). We believe that this correlation is unsound, and a correlation with an intra-Anglian-Devensian glaciation during MOIS 8 is more likely.

Concerning the new thinking about the timing of glaciation, within the post-Cromerian interglacial MOI Stages (Fig. 1) those between 12 and 2 were relevant to the excursion. A massive report of work carried out between 2007 and 2014 by the Trent Valley Palaeolithic Project (TVPP) unexpectedly conflated much evidence for glaciation within MOIS 8 (Bridgland et al, 2014). Yet there remains no unanimity on this correlation. Some would argue that this glaciation is best assigned to either MOIS 10 or MOIS 6, rather than MOIS 8. Alternatively all three glaciations may be represented within the stratigraphic record of eastern England, with discrimination between them yet to be resolved. Whatever is the truth, there is clearly a range of opinion on this topic and debate continues; this provided the rational for the field meeting, which was designed to facilitate free discussion on the theme, to the extent that the publicity declared that the leaders may not always be 'singing from the same hymn-sheet'. Further an attempt was made to explain to the non-specialist the nature and significance of the field evidence in the context of global climatic changes.

Six principle stops were planned for the day's excursion. In the event, time constraints led to the omission of Locality 2. However, as the evidence there is poorly known but is important to the overall objective, details of it are included in this account. Lunch was taken at the Bluebell Inn in Tattershall Thorpe [219595] after Locality 3. Localities 1 to 3 are within 10 km northeast of Stamford, and localities 4 to 6 lie roughly in a line between Sleaford and Louth.

Locality 1, Blossom Hill [063088]

This site consists of a small pit just north of Uffington village, some 3 km east of Stamford. It was first brought to the attention of the Quaternary community by Harry Langford in a Nene Valley guide produced for a Quaternary Research Association short field meeting, although curiously the site was not visited at that time (Langford, 2004). Accordingly, the Society was making the first publicly organised visit. The locality is

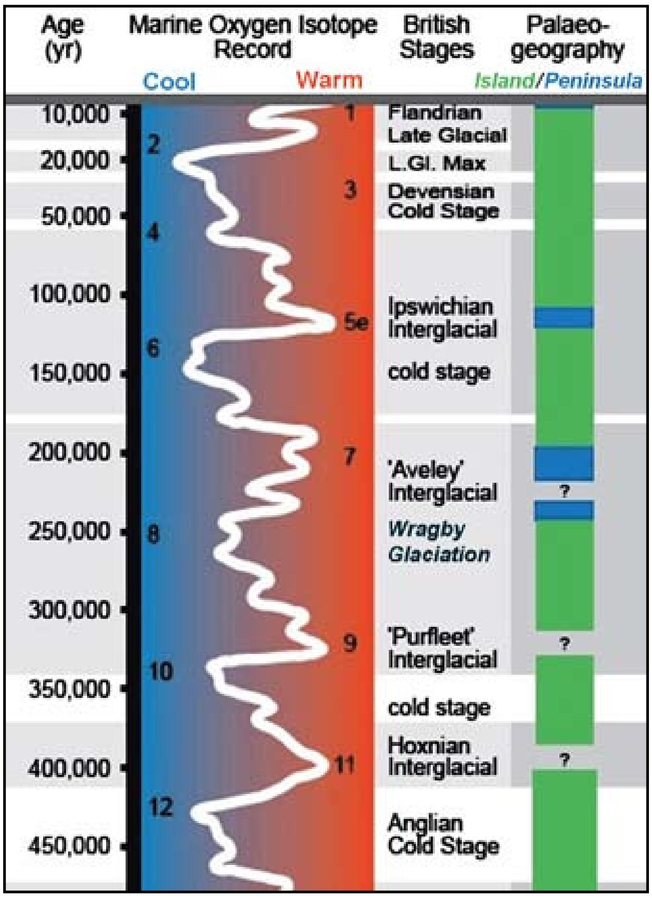

***Figure 1**. The generalised marine oxygen isotope record for the later part of the Pleistocene, with suggested stage names (MOIS) from the British terrestrial succession.*

Figure 2. *Blossom Hill east face, showing the large cross-bedded set of a Gilbert-type delta character representing a sediment flux into a water body.*

Figure 3. *The facies forming the cross bedding. Scale coin is 22 mm across, with a pale, derived Gryphaea to the right of it.*

remarkable because of the apparent disconnect between the sedimentology of the pit exposure and the landform. Blossom Hill is a low hill some 300-400 m in diameter rising 5 m above a generally featureless landscape. Earlier mapping by the British Geological Survey (for the Stamford sheet) identified a series of isolated mounds or spreads of 'glacial' sand and gravels in the vicinity, but no specific genetic morphology has been assigned to them. The most detailed geological map is in the Industrial Minerals Assessment Unit's report into the area's aggregate resources (Booth, 1981).

The sedimentology is dominated by coarse gravels forming a single large-scale set of cross-bedding some 2.0–2.5 m thick (Figs 2 and 3). The top of the set, partly corresponding to the modern land surface, appears to be erosional and hence the full thickness of the set cannot be established. The lower contact was obscured by talus, but the floor of the pit is likely to be Oxford Clay. Critically the exposure swings through more than 90° and shows that in three dimensions the sediment body is a tabular set dipping to the south. The set is interpreted as part of a classic Gilbert-type delta, whereby an abundant bedload was being fed into standing water with the sand and gravel avalanching down an advancing slope. A set of the kind seen might be developed by a large bar within a deep channel, but such an isolated feature would be totally out of keeping with the local evidence.

The cyclic nature of the grain-size variations within the cross-beds suggests a rapidly pulsating sediment delivery. Normally the presence of top sets might be expected, and their absence is presumably due to subsequent erosion. The lateral limits of the unit might be controlled by an ice-margin. Typical percentage values for clast composition are: Jurassic limestone 58; flint 26; ironstone 10; sandstone 3; 'Bunter-type' quartzite 2; others 1. A large clast of dolerite (?Whin Sill) and a small clast of *Rhaxella*-bearing chert (fossil sponge from north east Yorkshire) were identified, both suggesting a provenance in the north. The sequence appears to represent rapid sedimentation into water with a depth of at least the set thickness.

In the local context of the hill morphology truncating the cross-bedded set, and with the wide range of clast compositions, Peter Worsley thought it plausible that an ice-marginal environment dominated by flow fluctuations driven by local solar diurnal cycles was represented. In effect the hill might be regarded as a modified kame. Alternatively, Allan Straw suggested that Blossom Hill was a residual feature due to erosion, one of a group of low, gravel-capped eminences that extend north for 7 km to Manthorpe [072160], all with surfaces at 20-30 m OD, and that collectively they may be parts of a former outwash train, now transected by the River Welland and a stream at Greatford, aggraded by meltwaters flowing south. Such an interpretation does not preclude the close proximity of ice to Blossom Hill and consideration of its deposits as a modified kame, although an alternative origin as a bar in shallow, strongly-flowing waters is also possible.

Regarding the composition of the sediments, Allan Straw noted the high proportion of locally-derived materials and, considering their provenance, drew attention to the alignments of the Glen and Eden valleys north of Manthorpe. These valleys trend anomalously NNW-SSE across the Middle Jurassic dip-slope and the buried Bytham valley, and could have been initiated as ice-marginal gutters (Straw, 1979, 2011), cutting through till into Cornbrash and Oolite limestones. Bridgland *et al* (2014, Fig. 2.69a) indicated a north-trending margin from Peterborough, passing east of Bourne, but the Glen valley and Blossom Hill provide a more precise position for the ice margin.

Locality 2, Casewick Cutting [074101]

Currently there are no exposures in the cutting. During the construction of the Great Northern Railway in the early 1850s, a long excavation some 6 m deep, was excavated 1.6 km north east of Blossom Hill. A shallow Pleistocene channel was revealed just north of where a bridge was constructed in the middle of the railway cutting (Morris, 1853; Judd, 1875). The channel was 2.5 m deep and 27.5 m wide and cropped out below 2.3 m of gravel that extended to the ground surface. The gravel consisted of angular and rounded flints, rounded quartz pebbles, and minor clasts of oolite. Laterally, small sandstone boulders and a pebbly chalky paste were associated with this unit. The sequence within the channel is shown in Table 1, and the channel base was described as an oolite 'slightly disturbed and re-aggregated'.

Mollusca were collected from the channel by Morris (Table 2). Tantalisingly, these constitute a temperate assemblage, but alas are not diagnostic of a particular interglacial; the assemblage would not be incompatible with that expected in a Holocene river channel infill.

The Casewick sequence is pertinent for three reasons. First, the uppermost gravel is part of an upper bed of glacigenic material that probably extends to Blossom Hill. Second, beneath this is a freshwater bed of temperate (interglacial) character. Third, the base of the channel contains 'northern drift', i.e. till material that clearly ante-dates the interglacial channel. Hence, a classic glacial-interglacial-glacial succession is present. Taking a count from the top, it is speculated that these climatic units might represent MOIS 8, 9 and 10.

Grey sandy clay	0.6 m
Brown sandy clay and veins of gravel	0.45 m
Peaty clay with frags of plants and shells	0.45 m
Dark sandy clay, with plants and shells, pebbles of chalk and flint, and portions of northern clay drift in fragments	1.0 m

Table 1*. The sequence of clastic sediments within the Pleistocene channel exposed in the Casewick Cutting.*

Bithinia tentaculata and operculata, plentiful.
[*Bithynia tentaculata* shells and opercula]
Valvata pisinalis, plentiful.
Valvata cristata, rather rare.
Planorbis marginatus, rare. [*Planorbis planorbis*]
Planorbis carinatus,
Planorbis imbricatus, only one. [*Gyraulus crista*]
Limneus pereger, rare and immature.
[*Radix balthica* = *Lymnaea peregra* auct.]
Succinea putris, rare and immature.
[might also include *Oxyloma elegans*]
Ancylus fluviatilis, rather plentiful.
Valetia lacustris, rather plentiful. [*Acroloxus lacustris*]
Cyclas cornea, rare:fragments. [*Sphaerium corneum*]
Pisidium amnicum, rather rare.
Pisidium pulchellum, mostly immature. [this could refer to other species, rather than the true *pulchellum*, which is scarce]
Pisidium pusillum, mostly immature. [this taxon subsumes several others; it is not a valid species]
Pisidium obtusale?, immature.
Helix hispida, rare. [*Trochulus hispidus*]
Helix pulchella, only two. [*Vallonia pulchella*]
Helix aculeata, young only one. [*Acanthinula aculeata*]
Carychium minimum, only two.
[may also refer to *Carychium tridentatum*]
Cypris, small species, one valve. [ostracod]
? *Candona lucens.* young, one valve. [ostracod]
Candona reptans, three valves. [*Herpetocypris reptans*, ostracod]
Seeds and other plant remains, *Ceratophyllum, Equisetum etc.*

Table 2*. Species collected from the Casewick Cutting freshwater deposit (after Judd, 1875), with updated names in square brackets by courtesy of Richard Preece.*

Locality 3, Baston [122146]

A public road across Baston Fen afforded views into an active aggregate quarry. This pit was in the closing stages of production, with restoration of the floor in progress (Fig. 4). A small section by the gate showed the succession typical of the immediate area, consisting of some 4 m of sandy gravels over the Oxford Clay

Figure 4*. The Baston aggregate quarry, seen from the public road, during restoration of the quarry floor in 2015, by dumping stockpiled overburden onto the exposed Oxford Clay.*

Figure 5. The ice-wedge cast seen on the excursion. This is related to the lower horizon of wedges at the locality, and penetrates the Ancholme Clay at the base of the section.

Formation (Ancholme Clay Group). Sub-rounded clasts of oolitic limestone and ironstone dominate the gravels, along with rounded ‘Bunter-type’ quartzose material and flints with varying degrees of angularity. Within this pit, ice-wedge casts are not as ubiquitous as those in the pits just across the road to the east (Worsley, 2014)); but fortuitously one example was visible (Fig. 5), this being in the lower horizon of ice-wedge casts at Baston antedating the Last Glacial Maximum (Worsley, 2014). The ice-wedge stratigraphy at Baston shows two main horizons of development, one just below the current land surface and another approximately in the middle of the succession. Although the assumption is that both are Devensian, the lower horizon and the allied gravels may be pre-Ipswichian (Last) Interglacial; this age could be demonstrated just 6 km to the south, at Maxey, where lenses of undoubted Ipswichian organic material occur in the middle of a superficially similar gravel succession. However, no glacial sediments, as distinct from periglacial sediments, have been identified in the immediate region, indicating that there has been no influx of glacial outwash since gravel sedimentation commenced. It is concluded that the gravels mainly aggraded in a permafrost environment as low-angle, alluvial fans. Hence there is no evidence to support a glaciation prior to MOIS 5e (Ipswichian Interglacial), although MOIS 6 periglacial sediments are probably present.

Figure 6. The east-facing section in the Tattershall Thorpe quarry in 2016. The dark grey material on the quarry floor is the Wragby Till, which underlies the fluvial sequence.

Figure 7. Fluvial facies of mainly horizontally-bedded sandy gravels, signifying a braid-plain environment, exposed in the quarry shown in Figure 6.

Locality 4, Tattershall Thorpe [224597]

Following lunch, a short walk led to a working pit that has the only current exposure in the ‘low terrace’ of the River Bain (Fig. 6). At the base of the pit, a bluish-grey chalky till cropped out and this was assigned to the Wragby Till of central Lincolnshire. Unfortunately at this locality the overlying sequence of sandy gravels was thinner than the normal 4 m, and barely attained 2 m. The available sections were disappointing as they lacked any clear, permafrost-related, sedimentary structures, but they did reveal that the stratification was dominantly planar with minor cross-bedded sets indicating a southerly direction of palaeo-flow (Fig. 7).

A number of workers have studied the palaeotology and lithostratigraphy of this terrace. It is pertinent to note that as recently as 2007 the main terrace gravel body was being interpreted by the Trent Valley Project as an early Devensian aggradation (White *et al.,* 2007), but by the time of their report in 2014 this view had changed to an MOIS 6 age (Bridgland *et al.,* 2014). Indeed, Peter Worsley felt obliged to change his opinion of the age of the aggradation immediately prior to the field meeting, even though this necessitated rejecting five, finite, radiocarbon, age estimates (Middle Devensian) as being totally spurious. The dated samples were obtained from organic lenses at different levels within the succession, but when plotted according to depth below the modern land surface, a random order was apparent. Contamination from 'infinitely old' organics derived from the terrace base is suspected as the cause. One such shallow channel fill at the base of the terrace had been investigated (Holyoak and Preece, 1985), and an Ipswichian age inferred, although an earlier temperate stage was not ruled out. This conclusion was suggested before it had become clear that two interglacials of similar character post-dated the Wragby Till (MOIS 7 and 5e). Consequently, from current understanding the palaeontological data could be interpreted as favouring an early MOIS 7 interglacial. A correlation of this River Bain terrace with the lower Witham east bank Southrey Terrace, which lies just north of Tattershall Thorpe, appears reasonable. Since the Southrey Terrace has what appear to be MOIS 7 organic sediments at its base in the Coronation Farm borehole, a MOIS 7 age is now favoured for the basal interglacial material at Tattershall Thorpe.

Exposures of the succession below the floodplain of the Bain immediately to the east of the Tattershall Thorpe terrace are enabled by groundwater pumping, but access was not possible due to the weekend break in quarrying. These sediments probably relate to the former exposures at Tattershall Castle [208570] where the Ipswichian Interglacial (MOIS 5e) was present.

Locality 5, Kirkby Moor [228628]

Fox Hill has the sole remaining exposure of the Kirkby Moor Sands. These form a somewhat elevated position above the Bain terraces and are therefore older, but they lie ubiquitously on blue-grey Wragby Till and are therefore not older than that glaciation (MOIS 8).

Allowing for dissection, the sands now cover some 12.7 km^2, and have been exploited industrially because of their high silica content, but the party visited only a disused and partly-reclaimed quarry south of the road at Fox Hill. Although degraded, some 10 m of bedded, fine-to-medium sands with occasional trough cross-bedding could be seen. The sand is well-sorted, and the sedimentary style persisted from bottom to top of sections. Former, more extensive workings lie north of the road (Fig. 8), where the sands were disposed in near-horizontal, undisturbed, planar layers, rarely more than 40 cm thick, displaying many 'cut and fill' features with trough cross-bedding (Fig. 9). Massive beds also occur, many for 10 m or so across exposures, suggestive of sheet-flow. Overall flow direction was to the south. Flint was the only gravel component, apart from rare erratics, with clasts generally less than 6 cm across (rarely up to 10 cm). These occur in infrequent shallow lenses, probably bed-load material transported along shallow channels, and as stringers representing lag gravels and possible deflation surfaces.

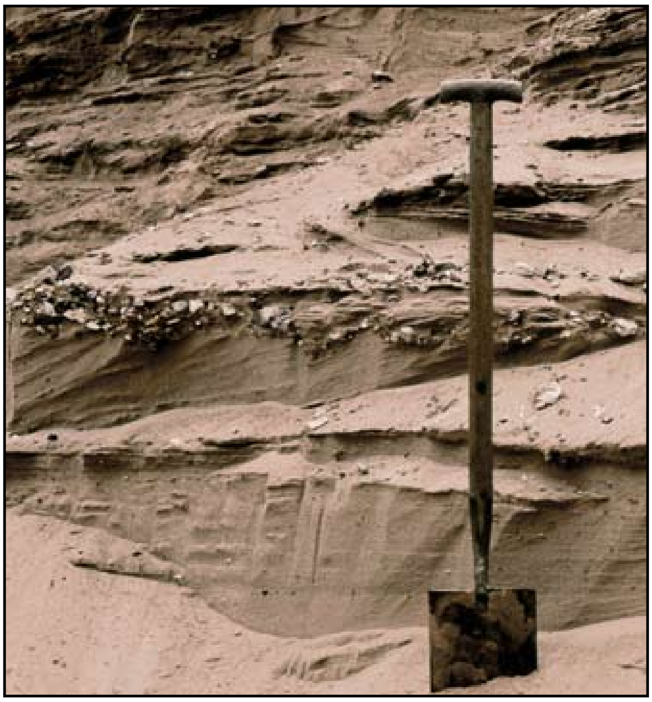

***Figure 9**. Kirkby Moor Sands with flint clasts in nearly horizontally stratified sand and shallow, trough, cross bedding, in Fox Hill north quarry. View towards the south at TF 22706290, (1976).*

Spade for scale in both photographs.

***Figure 8**. Kirkby Moor Sands exposed in the south face of Fox Hill north quarry. View to the south at TF 22706290, (1976).*

As the result of incision by the Bain valley in the east and by the smaller valley of Roughton Beck in the west, these enigmatic sands now underlie three outcrops, with the Fox Hill quarry in the central one. They are enigmatic in that they occupy an elevated position with ground falling away on all sides except narrowly in the north, yet the sedimentology indicates shallow-water deposition throughout. Overall, the sand surface declines at 1:500 to the southwest from near Roughton at 27m OD; this is more gently graded than the surfaces on the Bain terraces, and the gravel sheet may originally have extended further to the southwest, before it was curtailed during aggradation of the Southrey and Tattershall Terrace.

Discussion within the group focussed on origin and date of the sands. Several origins have been postulated in recent years: water, wind, or a combination of the two. When exposed today, the sand is readily transported by wind, and within the sands the flint clast stringers may indicate deflation episodes. But if the deposit were wholly aeolian, it is surprising that its northwestern and eastern borders are so well defined, and that sand does not extend onto the adjacent, lower surfaces that are underlain only by till. There would seem to have been only intermittent reworking by wind during fluvial deposition of the sands.

It has been argued (Straw, 1958, 1979, 2008) that the sands could be deltaic materials supplied by a proto-Bain related to a Devensian Lake Fenland, with a water level at c.30 m OD, but such a notion is now untenable. Origin as a sandur, associated with meltwater issuing from a retreating glacier, has been suggested, on the basis of the sands' sedimentology (Worsley, 1991). However, the composition of the sands strongly indicates derivation from outcrops of Biscathorpe Gravels and particularly Spilsby Sandstone in the upper Bain valley around Scamblesby and Donington-on-Bain; it is therefore difficult to envisage remnant ice to the north, over the site of the Bain valley, during deglaciation (Straw, 1966).

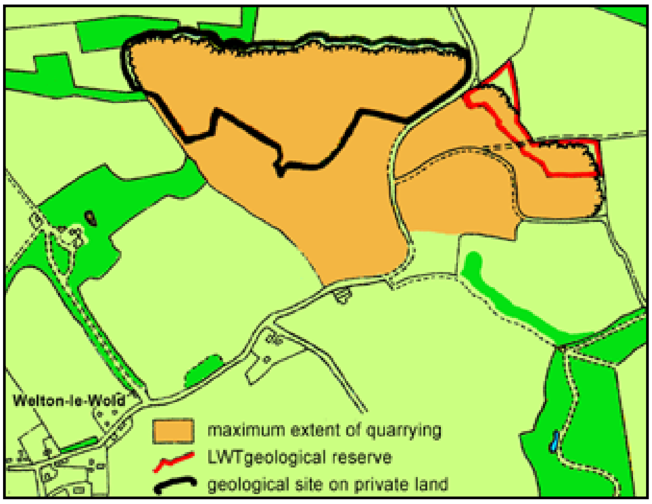

Figure 10. *Locations of the two quarries at Welton-le-Wold. The road between the quarries follows a small Devensian meltwater channel, and roughly lies at the limit of Devensian ice advance from the east. LWT = Lincolnshire Wildlife Trust.*

The age of the sands is also controversial. No organic materials have been recovered from them but, if radiocarbon age estimates of middle Devensian age (Girling, 1974) from the lowest Bain terrace at Tattershall Castle are reliable, geomorphological relationships indicate that the sands should be older. During discussion, reference was made to Optically Stimulated Luminescence (OSL) age estimates of c.178 ka for the sands (Bridgland et al., 2014), which point to an early MOIS 6 age. However if, as suggested, the OSL ages are likely to be under-estimates, and the sands aggraded during deglaciation, then a late MOIS 8 age might be nearer the mark. Clearly, the dilemmas concerning age and origin await resolution.

Locality 6, Welton-le-Wold [282884]

The quarries at Welton, now redundant and largely backfilled, are designated conservation sites on account of their suite of glacial and pre-glacial deposits that survive (Fig. 10). Sections are visible east and west of the minor road that separates the quarries; that to the west is on now private land, while the eastern one is maintained by the Lincolnshire Wildlife Trust. To reach them, the group had to walk across backfilled and reclaimed ground, where some of the woodland was planted 50 years ago. The quarries were exploited during the 1940s when aggregate was required for airfield construction, but extraction of the valuable chalk-free, flint-rich gravel continued until increasingly difficult conditions forced closure.

Some 43 annotated photographs of sections, taken by Allan Straw between 1954 and 1973, have been archived in The Collection, Lincoln. Over the years, west of the road, a sequence comprising some 13 m of Calcethorpe Till overlying Welton Till above a similar thickness of sands and gravels (Welton Gravels) was progressively exposed (Figs 11, 12 and 13). East of the road (Fig. 10), a third till, the Marsh Till, lies unconformably on weathered Welton Till and Welton

Figure 11. *Welton west quarry, with Calcethorpe Till (whitish, 3–5 m thick) overlying Welton Till (greyish, 8–10 m thick). The oxidised till base appears as a band 10–20 cm thick, and rises over a lens of chalky diamicton (head), which lies on Upper Welton Gravel. View to west at TF 27928838, (1970).*

***Figure 12**. Degraded section in Welton west quarry, about 100 m west of that seen in Figure 9 and close to that seen on the excursion. Calcethorpe Till overlies Welton Till (foreground right). The erratic block of Jurassic calcareous grit (probably of North York Moors provenance) had been recovered from Welton Till. View to WNW at TF 27918838, (2002).*

***Figure 13**. Welton east quarry as it was in the 1970s. Marsh Till (4–6 m thick) above a nearly horizontal thrust plane over the darker, oxidised top of the Welton Till (4–5 m thick). The till unconformably overlies Upper Welton Gravel (c 5 m thick, and passing through the deep shadow). A metre of stratified Lower Welton gravel is exposed lower left. View to the north at TF 28598808.*

Gravels (Straw, 2005, 2015). On the day of the visit, the partly over-grown western section displayed mostly Calcethorpe Till. This is a chalky diamicton that includes distinctive, far-travelled erratics. Large blocks of calcareous grit (North York Moors), dolerite (Whin Sill), granite (Scotland), and Carboniferous sandstone (northern England) were seen. This till overspreads the Wolds from the Horncastle area, via Calcethorpe Farm [249884] to Welton. At the base of the section a small exposure of the subjacent Welton Till could be seen. This contains erratics similar to those in the Calcethorpe Till, and was emplaced by ice moving south across the Welton valley. The Calcethorpe Till is considered to have been deposited by ice that traversed more of the chalk outcrop. The two Tills constitute a single glacial depositional unit, no break ever having been observed between them.

***Figure 14**. Welton east quarry, at almost the same site as Figure 13, as it is today with faces degraded and partly covered by plants.*

The underlying Welton Gravels could not be seen on the day of the excursion, but some 15-20 m of them had been worked over many years previously (Straw, 2005, 2015). In 1969 and 1970, three Acheulian hand-axes and a flake, and mammalian fossils including elephant and red deer (now in The Collection, Lincoln), were found in the gravels in the northeastern corner of the pit (Alabaster and Straw, 1976). These sands and gravels accumulated, under increasingly cold conditions that culminated in permafrost, within a palaeo-valley some 600 m wide, and were derived wholly within the catchment. The dominant flint clasts came from surrounding high ground, and the sands were from Lower Cretaceous outcrops in the head of the palaeo-valley, which now, as a consequence of glacial disruption, is occupied by headstreams of the River Bain.

Within the eastern quarry [285881], the group observed the Marsh Till rising and thinning towards the west above a planar unconformity. At this end of the available section, the Welton Till is brown and oxidized, and thins towards east beneath an unconformity that descends onto Welton Gravels (Fig. 12). The Marsh Till, with a rich suite of erratic rocks, was brought by North Sea ice moving west from Louth after a long period of valley erosion that had shaped the older tills and gravels into an east-pointing spur. This ice, of Devensian age, rose onto the spur as far as the position of the road, with its meltwater later cutting the meltwater channel.

Controversy has long attached to the age of the older tills and gravels, and the fossils have little value in this context. The deposits have been variously ascribed to MOIS 12 or MOIS 6, but Allan Straw has always claimed that they are younger than MOIS 12 (Anglian), and has favoured an age of MOIS 8. The recent Trent Valley Project research in central Lincolnshire, which places the Wragby Till within MOIS 8, assists ageing of the Welton deposits, because in the Bain valley, around Horncastle and Tattershall, the Wragby Till can be shown to be contemporary with the Calcethorpe Till. At this stage, it is clear that ice overwhelmed the whole of the Wolds and invaded central Lincolnshire well into the fen area. It may have reached Blossom Hill, thus providing a meaningful link between the beginning and end of the excursion.

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William Wright of Black House Farm kindly granted permission to enter his gated land at Fox Hill. Helen Gamble (Lincolnshire Wolds Countryside Service) obtained permission to enter the privately owned Welton west quarry sections and guided us to the site. The Lincolnshire Wildlife Trust granted access to their geological reserve at Welton east quarry. All the participants entered into the debate in a constructive and good humoured manner. Ian Sutton encouraged the leaders to plan the excursion.

References

Alabaster, C. & Straw, A., 1976. The Pleistocene context of faunal remains and artefacts discovered at Welton-le-Wold, Lincolnshire. *Proc. Yorks. Geol. Soc.*, **41**, 75-93.

Booth, S.J. 1981. The sand and gravel resources of the country between Stamford, Lincolnshire, and Peterborough, Cambridgeshire (sheets TF00 and TF10). *Inst. Geol. Sci. Mineral Assessment Report*, 80.

Bowen, D.Q. (ed.), 1999. A revised correlation of the Quaternary deposits of the British Isles. *Geol. Soc. Spec. Rept*, 23, 174p.

Bridgland, D. R., Howard, A.J., White, M.J. & White, T.S. (eds.), 2014. *Quaternary of the Trent*. Oxford: Oxbow Books, 434p.

Girling, M.A., 1974. Evidence from Lincolnshire of age and intensity of the mid-Devensian temperate episode. *Nature*, **250**, 270.

Holyoak, D.T. & Preece, R.C., 1985. Late Pleistocene interglacial deposits at Tattershall, Lincolnshire. *Phil. Trans. Roy. Soc.*, **B331**, 193-236.

Judd, J.W., 1875. The geology of Rutland. *Mem. Geol. Surv*., 320p.

Langford, H.E., 2004. Post-Anglian drainage reorganisation affecting the Nene and Welland. 36-43 in Langford, H.E. & Briant, R.M. (eds.), *Nene Valley field guide.* Cambridge: Quaternary Research Association.

Lewis, S.G., 1999. Eastern England. 10-27 in Bowen, *op. cit*..

Mitchell, G.F., Penny, L. F., Shotton, F.W. & West, R.G., 1973. A correlation of the Quaternary deposits in the British Isles. *Geol. Soc. Spec. Rept*, 4, 99p.

Morris, J., 1853. On some sections in the oolitic district of Lincolnshire. *Q. J. Geol. Soc.*, **9**, 317-344.

Shotton, F.W. (ed.), 1977. *British Quaternary studies recent advances*. Oxford: Clarendon, 298p.

Shotton, F.W., Banham, P.H. & Bishop, W.W., 1977. Glacial-interglacial stratigraphy of the Quaternary in midland and eastern England. 267-282 in Shotton, *op. cit*..

Straw, A., 1958. The glacial sequence in Lincolnshire. *East Midland Geogr.*, **2**, 29-40.

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. Naturalists' Union*, **17**, 85-98.

Straw. A., 1979. Eastern England. 3-139 in Straw, A. & Clayton, K.M.*, Eastern and Central England.* London: Methuen.

Straw, A., 1983. Pre-Devensian glaciation of Lincolnshire (eastern England) and adjacent areas. *Quat. Sci. Rev.,* **2**, 239-260.

Straw, A., 2005. *Glacial and pre-glacial deposits at Welton-le-Wold, Lincolnshire*. Exeter: Studio Publishing, 39p, (www.thecollectionmuseum.com).

Straw, A., 2008. *The last two glaciations of east Lincolnshire.* Louth Naturalists', Antiquarian & Literary Society & Lincolnshire Naturalists' Union: Louth, 46p, (www.thecollectionmuseum.com).

Straw. A., 2011. The Saale glaciation of eastern England. *Quat. N/L.*, **123**, 28-35.

Straw, A., 2015. The Quaternary sediments at Welton-le-Wold, Lincolnshire. *Merc. Geol.,* **18**, 227-233.

White, T.S., Bridgland, D.R., Howard, A.J. & White, M.J. (eds.), 2007. *The Quaternary of the Trent Valley and adjoining regions: Field Guide*. Quaternary Research Association: London, 163p.

Worsley, P., 1991. Possible Early Devensian glacial deposits in the British Isles, 47-51 in Ehlers, J., Gibbard, P.L., and Rose, J. (eds.), *Glacial deposits in Great Britain and Ireland.* Rotterdam: Balkema.

Worsley, P., 2014. Ice-wedge growth and casting in a Late Pleistocene, periglacial, fluvial succession at Baston, Lincolnshire. *Merc. Geol.,* **18**, 159-170.

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