The Hunstanton Park esker, northwest Norfolk

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Abstract: A well-developed, sinuous esker, almost two km long, terminates close to a glacial meltwater channel and is just inside the Devensian glacial advance limit. William Whitaker discovered it in 1882, although initially its glacigenic status was in some doubt. An off-shore bar mechanism was favoured by some until the 1920s, influenced by the presence of a marine fauna. Morphological and sedimentological evidence suggests that the esker was superimposed onto the chalk bedrock from an englacial or supraglacial position, rather than having been formed subglacially. The esker is currently assigned to the Ringstead Sand and Gravel Member, part of the east coast Holderness Formation (including the classic Hessle/Hunstanton Till) of Last Glacial Maximum age at about 20 ka BP.

Eskers are long narrow ridges of sand and gravel of glacigenic (fluvioglacial) origin with an orientation which is generally parallel with the ice flow direction (Fig. 1). They are commonly sinuous and often appear to be independent of the form of the ground upon which they lie (Fig. 2). Ridge location is determined by the former position of confining walls of glacier ice, hence their sides are described as ice-contact slopes. The word esker is derived from *Eiscir* which means a ridge or elevation in Gaelic. In contrast, kames *per se* are today identified as isolated non-linear mounds of glacigenic sand and gravel, but somewhat confusingly kame was originally a synonym in Scotland for esker. Eskers, kames and kettle holes arise from the melt-out of buried, detached ice masses during glacier retreat.

The word esker was introduced into the geological literature by the amateur geologist Rev. Maxwell Close (1867) who was described by Gordon Herries Davis (1995) as 'a most acute observer of Irish glacial phenomena'. David Hummel (1874) developed the original concept of glacial meltwater rivers transporting debris within a glacier which, upon ice retreat, were subsequently left as ridges. He envisaged them being the aggraded infills (sediment casts) of tunnels at the base of a glacier, in a subglacial position, with the meltwater derived from surface melt descending crevasses to the glacier bed. Holst (1876) elaborated the concept by suggesting that sediments transported by meltwater rivers flowing in supraglacial channels might also subsequently produce eskers. These Swedish ideas were brought to English-speaking audiences through the work of James Geikie who had regular contact with Scandinavian workers, so that in his *The Great Ice Age* (1894) he preferred to use the Scandinavian word Ås for them, rather than the Irish-derived esker. However, his successor as the doyen of British glacial geology, the Irish-born W. B. Wright of the Geological Survey of Ireland, favoured the term esker in his *Quaternary Ice Age* (1914), and this has stayed in use in the British literature. Observations of modern eskers in Iceland and Alaska (Price, 1973) demonstrate that buried ice within the esker landform exaggerates their size since after the ice melts the resultant landform is much diminished.

Mainly in the late nineteenth century there was a struggle for terrestrial glaciation concepts to become the established wisdom at the expense of the glacio-marine submergence hypothesis. Studies of contemporary glacial environments by British glacial geologists commenced in 1865 when Archibald and James Geikie together with William Whitaker mounted

Figure 1. *An esker ridge trending from right to left (across the centre of this image) in front of the retreating glacier of Renardbreen, at Bellsund, west Spitsbergen. The esker is about 4 m high, is parallel with the direction of ice movement direction, and lies on a recently deposited till plain. Isolated kame mounds occur, and the boulder-strewn ridge beyond the esker is a drumlin recently emerged from the glacier margin.*

Figure 2. *An esker alongside the eastern shore of the glacial lake of Breiðárlón in southern Iceland, with the Breiðamerkurjökull ice margin in the background; this esker is ice-cored and a more poorly defined linear ridge is likely to remain after melt-out.*

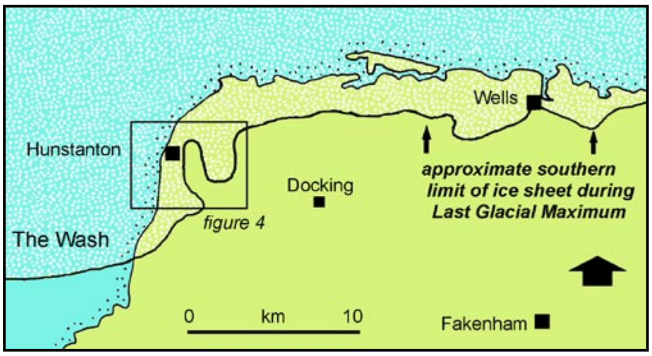

***Figure 3**. The Last Glacial Maximum ice limit in north-west Norfolk in relation to the esker, which has its southern terminus very close to the advance limit (modified after Allan Straw and British Geological Survey).*

an expedition to the Norwegian Arctic, although it took several decades for the land ice hypothesis to be fully accepted (Worsley, 2008). Even as late as the early 1920s J. W. Gregory, the Professor of Geology at Glasgow University, was still advocating a marine mechanism for esker genesis (Gregory 1921, 1922).

In England, eskers are not common, but a well-developed esker, some 2 km long, occurs in Hunstanton Park just east of The Wash in north-west Norfolk (Figs. 3, 4). Since it is located in private land, it is not particularly well known. Much of its length is covered by dense woodland that obscures its morphology, such that 'Park House', a ruined hunting lodge dating from 1623, sited on its crest, is almost invisible. The park has only 15 m of relief, and is drained by a small, north-flowing stream (Fig. 5). The esker has been only poorly documented, whereas the Blakeney esker, 30 km to the east has been investigated in detail (Sparks & West, 1964; Grey, 1998; Gale & Hoare, 2007).

Pioneer Victorian investigations

In the Geological Survey's primary mapping of East Anglia, the eastern part of Sheet 69 (published in 1886) covered western Norfolk and was the work of a team of geologists led by William Whitaker. In 1883 he organised a long weekend field meeting for the Geologists' Association to demonstrate the area's geology and this involved an examination of Hunstanton Park where

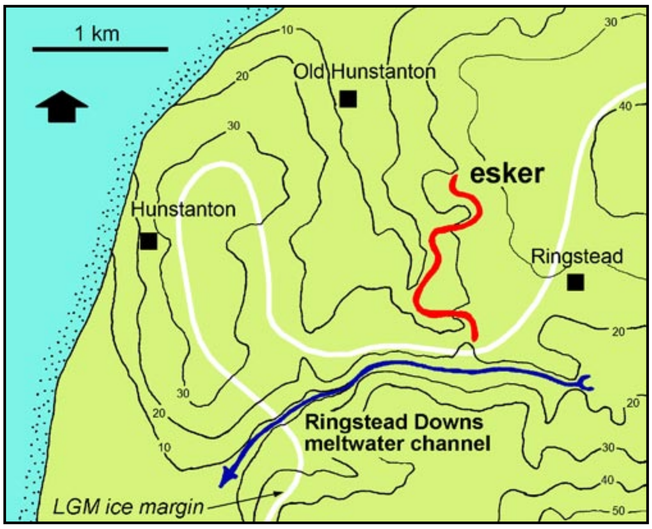

***Figure 4**. Relationship between the Hunstanton esker and the Ringsted meltwater channel; the white line traces the southern margin of the ice sheet during the Last Glacial Maximum, which is very close to the esker's southern limit.*

in the southern part 'he shewed them a peculiar long narrow winding ridge of gravel and sand, like similar ridges known as kames in Scotland, and as eskers in Ireland' (Whitaker, 1885, 1891). He appreciated that the landform was constructional in origin rather than an erosional remnant and that it was likely to be a product of glaciation. T. V. Holmes had been with the Survey in 1868-1879 and was familiar with extensive esker-type features in northern Cumberland. Accordingly, Horace Woodward, a senior member of the mapping team, had invited him to see the esker-like landforms in Norfolk, and Whitaker asked him to comment on the structure of the Hunstanton Park esker during his field meeting.

Woodward had been studying the glacial landforms in the lower River Glaven valley, 30 km east of Hunstanton. He had written (1884) '…Blakeney [Wiverton] Down, [is] a ridge that looks in places like a great railway embankment, running in a serpentine course for about 2 miles. In the same neighbourhood are many little hills of gravel, standing out in the midst of ploughed fields; and being uncultivated, and covered with gorse and broom, they form striking objects'. He added that they were 'the last relicts of the Great Ice Age

***Figure 5**. The esker in a view looking east, towards the former Cedar Pit, with the aligned hummocks that misleadingly appear as beaded or segmented.*

… and to have been formed by the floods and torrents that attended its passing away'. Two weeks previous to Whitaker's field excursion, Holmes had read a paper on eskers and kames to the Norwich Geological Society, of which Whitaker was then President (Holmes, 1883). For one of his figures he used a woodcut by Woodward showing the distribution of eskers south of Blakeney.

Despite Woodward having linked the Blakeney eskers and kames to terrestrial glaciation, Holmes took a contrary view; struck by the analogy between the eskers and marine sand banks, he chose to interpret them as products of glacio-marine submergence. He was aware of the common association of eskers and enclosed hollows (kettle holes) but attributed the latter to 'diverse currents'. Holmes (1884) appreciated the irony of promoting a marine offshore environment for esker genesis in the company of Whitaker, who was one of the chief champions of the power of rain and rivers in forming escarpments since he had won the approbation of Charles Darwin for his paper on the subaerial denudation of the North Downs escarpment despite it having been rejected by the Geological Society of London (Whitaker, 1867).

In the discussion following the reading of Holmes's paper in Norwich, Woodward commented on the divergent opinions on esker genesis and noted that James Geikie was in favour of them being a product of subglacial meltwater deposition. Whitaker added that he was struck by the discordant nature of the ridge with respect to the surrounding terrain form. Surprisingly, Whitaker appears not to have then been aware of a derived marine fauna in the esker sediments, although in the Arctic in 1865 (Worsley, 2008) he had observed a glacier pushing fossiliferous marine sediment to form a moraine ridge.

Figure 6*. A subglacial esker emerging from the margin of Fingerbreen, Svartisen, arctic Norway. The smoothly rounded esker ridge is 45 m long and up to 6.5 m high, and emerged during ice recession between 1963 and 1966. A lower linear moraine ridge crosses the foreground, and a similar dark feature lies just in front of the glacier margin on the left; these were formed by annual winter re-advances of the glacier. These sediment features are comparable with those seen by Whitaker in 1865.*

During 1885-6, the American geologist H Carvill Lewis made a detour to Hunstanton to examine the 'so-called' esker during his tour of Britain and Ireland. He found fragments of marine shell in a sand pit at the southern end, and this evidence, combined with an unexpected absence of kame knobs and kettle holes, led him to conclude that the feature was a portion of an old sea beach lying 15 m above the modern sea level (Lewis, 1894), a view in accord with that of Holmes. In the third edition of his magnum opus, James Geikie (1894) commented that 'formerly åsar [eskers] were believed to be of marine origin – heaped up by tidal currents – but that interpretation had now been abandoned'.

The Sheet 69 Memoir (Whitaker & Jukes Browne, 1899), stated '...on the north and west borders of Norfolk, and also north of Boston, there appears to be a different kind of boulder clay which is brown or reddish in colour and contains very little chalk debris, but many stones from distant sources. With this clay are also associated a varied series of loams, sands and gravels'. Clay of this character was known as 'Hessle' (Wood & Rome, 1868). The patches of sand and gravels were assigned to the Hessle Clay group, and these included the esker-like ridge in Hunstanton Park. An old pit cut into the southern end had yielded a derived marine fauna to A.C.G. Cameron, to confirm Lewis's discovery. It was recorded that the esker terminated above a dry valley falling westwards from Ringstead.

Twentieth Century research

Interest in the Hunstanton esker was renewed by Gregory (1922), who uniquely claimed it to be locally known as the Ringstead sand-hills. In the old pit at the southern end he recorded an uppermost bed or surface wash of angular flints over a till that was described as disturbed in patches or sheet-like and <0.6 m thick, overlying an irregularly denuded surface of a sand succession. The sands contained fragmentary marine shells including *Mytilus* sp.. Gregory chose to interpret the esker as a product of denudation, on the basis that the surface wash capping the ridge could only have been derived from a higher source and the slopes of a former valley had enabled the flints to move from the chalk slopes to the ridge crest. He claimed support for this concept in 'outlier' mounds of sand that were also seen as erosional remnants, and therefore regarded the esker as a 'residual kame'. An immediate challenge to his interpretation came from Percy Kendall (1922) but others simply ignored Gregory's paper.

There had been a suggestion that the Last Glaciation ice limit might lie within the conventional one at Flamborough Head (Farringdon & Mitchell, 1951), but the established view concerning the limit, based upon fresh landforms and the distribution of the Hessle till was confirmed by Suggate and West (1959), with only minor changes. The latter noted that the only known locality where the Hessle till could be seen unambiguously above a chalk-rich till was at Welton le Wold, in Lincolnshire. Their investigation of the biostratigraphy of the fill of a possible kettle hole at Aby Grange, southeast of Louth, demonstrated that the Hessle Till was directly overlain by a Late-glacial sequence. These data, along with radiocarbon age estimates (then newly available in England), suggested that the till lining the hollow was of Last Glacial age. In accord with Jukes-Browne (1887), they argued that the relief expressed by the Hessle Till indicated a little-modified, deglaciated land surface that characterised the 'Newer Drift' rather than the incised and eroded 'Older Drift'. Within this landform system they noted the presence of 'an excellent example of an esker in Hunstanton Park'.

In 1958 Allan Straw extended his seminal studies of Lincolnshire glacial geomorphology across the Wash into Norfolk (Straw, 1960, 1979). His concern was to compare the patterns of glaciation in Lincolnshire and North Norfolk and to establish the Last Glacial ice limit by determining the extent of the Hunstanton [Hessle] Till. Little was said on the Park esker, other than to record that it was 'a fine one' and 2 km long. The Hunstanton Till was not mapped in the park itself and it was postulated that, prior to the ice advance, a stream had drained north-westwards from Ringsted across Hunstanton Park. He portrayed the maximum ice extent as a lobe from the north that roughly followed the park boundary (Fig. 4). The esker drainage was thought to have discharged into a meltwater channel that is now the dry valley draining westwards from Ringstead.

The character of the uppermost tills in coastal eastern England, variously called Hessle, Hunstanton and Holkham depending on location, is now related to post-depositional weathering, mainly during the Flandrian (Madgett, 1975; Madgett & Catt, 1978). Thus, the Hessle Till is now defined as a pedostratigraphic unit, whereas the parent till is believed to be the Skipsea Till (apart from a restricted area of Withernsea Till in Holderness). Where the till is thin, as in most of northwest Norfolk, its entire thickness is weathered.

The Hunstanton Park esker was designated a SSSI in 1990, and the Ringstead meltwater channel fell into a second SSSI established primarily for its chalk grassland flora. The channel is up to 15 m deep and 60 m wide (Fig. 7). The esker and the meltwater channel were viewed as contemporary, with a knick point where the esker joins taken as indicative of development in two stages. Hywel Evans (1976) documented the morphology and sedimentology of the esker. He also led a field meeting of the Quaternary Research Association that revealed sands and gravels containing a mainly comminuted derived marine fauna in shallow excavations in its southern part (Fig. 8).

The course of the esker was accurately defined for the first time in 1979 on the new Geological Survey map (Sheet 145 with 129, at 1:50,000) and was described in the memoir as being both sinuous and beaded (Gallois, 1994). It was mapped as being flanked by an apron of head wider than the esker itself, and this rested on a thin veneer of till. The head was defined to include post-glacial slope material, which suggests that the esker has degraded in a periglacial environment, and the slope deposits of Evans (1976) probably relate to this.

A review of the glaciation event in north-west Norfolk asserted that it 'should not be assigned to any Stage of the Quaternary prior to the availability of any definite chronostratigraphic or biostratigraphic evidence' (England & Lee, 1991), despite prior work (Gale *et al.,* 1988). Ironically, the first geochronological data consisting of five amino acid D/L ratio assays on derived marine shells (collected from the esker by the writer in 1976) were published in the same year with *Macoma baltica* yielding values of 0.15, 0.16, 0.14 and *Arctica islandica* 0.19, 0.14, (Bowen, 1991; Bowen *et al.,* 2002). These values were interpreted to a Marine Oxygen Isotope Stage 5 age for the fauna (c.95-130 ka BP), which is consistent with a Last Glacial Maximum age of 20 ka BP for the ice advance to the Hunstanton Till limit.

The 2008 1:50,000 geological map for Wells-next-the-Sea (Sheet 130 from the British Geological Survey)

***Figure** 7. The Ringstead Down meltwater channel, with its asymmetric cross profile eroded into the Lower and Middle Chalk; looking east (upstream) towards Ringstead from NGR 688399 adjacent to Downs Farm.*

Figure 8. *Part of the Hunstanton Park esker in September 1977, during the visit by the Quaternary Research Association. The view is towards the west-north-west from NGR 697404 when small-scale quarrying of sand and gravel was in progress. In the foreground, the Cedars pit is similar in extent to when it was examined by Hywel Evans.*

Figure 9. *The esker in November 2012, after restoration of the gravel pits, now levelled and grassed over, seen from about the same location as that in Figure 8.*

approaches to just a few hundred meters short of the esker, and adopts a more refined lithostratigraphic classification for the glacial Quaternary, with the Hunstanton [Hessle] Till becoming the principle component of a Holderness Formation. This Formation also includes the Red Lion Till Member (restricted to a small area around the eponymous inn at Stiffkey) and the Ringstead Sand and Gravel Member, (McMillan *et al.,* 2011). Curiously the glacigenic Ringstead Sands and Gravels have no formal stratotype, rather a stratotype area embracing Heacham, Ringstead, Hunstanton and Holkham, and covering a broad range of sedimentary geometries, landforms and modes of formation in a veritable bucket of glaciofluvial sediments, including the Hunstanton esker.

The esker geomorphology

The Hunstanton Park esker is sinuous, with a total length of 1.9 km over a north–south extent of 1.25 km (Fig. 10). Parts of its crest are flat, notably around Park House where the flat width is 12 m for just over 100 m along the axis. There the esker attains its greatest height at about 16 m. Some 1300 m of the esker's length covered by dense woodland and largely impenetrable undergrowth of box trees; only two stretches of some 300 and 400 m in length are open grazing land. The esker has been quarried in the past and old pits might simulate kettle holes. Towards the proximal, northern end, and within dense woodland, a dish-shaped hollow on its western flank does have the character of a small kettle hole. West of this, the fields inside the esker bend have two more, shallow, kettle-like depressions. Both Evans and Gallois have used the descriptive term 'beaded' in connection with the esker morphology. Unfortunately this term is not appropriate in the context of its previous usage in the glacial geological literature.

A beaded esker is one with zones of widening along its length; the beads are formed where eskers deposited sub-aquatically during ice retreat are punctuated by small deltas that aggrade during the summer months when sediment supply is at a maximum (de Geer, 1897). An English example is in Aqualate Park in Staffordshire (Worsley, 1975). At Hunstanton there is no evidence for sub-aquatic deposition, and tellingly the segment described as 'beaded' (Evans, 1976; Gallois, 1994) is orientated almost normal to the ice movement direction. This part of the esker is atypical, with its short series of linear hummocks, but it is possible that these are erosional forms and not depositional.

The esker sedimentology

Within Hunstanton Park glacigenic materials are thin, and the esker rests mainly on chalk bedrock. Exposures in former pits are grassed over, so previous documentation (Evans, 1976) of the small Cedar Pit (55 by 20 m), near the southern end of the esker, are vital to understanding the genesis (Fig. 11). A maximum thickness of 5 m of

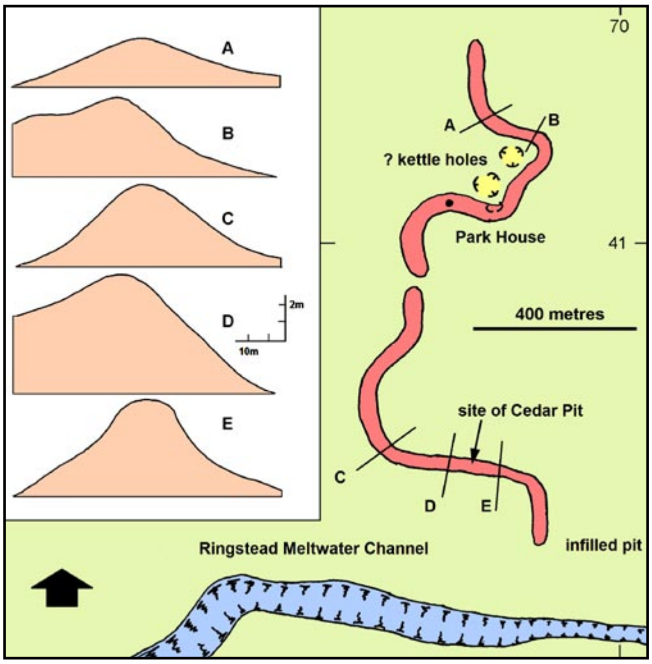

Figure 10. *Geomorphology of the Hunstanton Park esker and part of the Ringsted meltwater channel. Inset has the five levelled cross profiles of the esker drawn with a vertical exaggeration of 20; profiles B and D are asymmetric, reflecting the slope of the surface beneath the esker and suggesting that the esker was superimposed.*

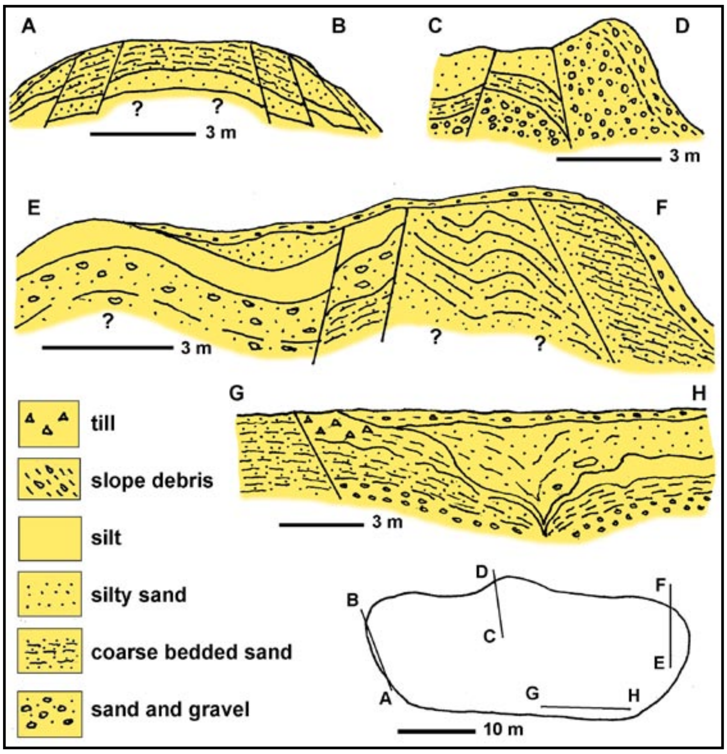

***Figure 11**. Four sketch sections of the esker sediments, and their relative locations in the Cedar gravel pit. Sections AB, CD and EF are transverse to the ridge axis; GH is longitudinal close to the southern margin. The transverse sections show how rapidly the sedimentology changes along about 40 metres length of the same ice-contact slope that defined the esker margin (modified from Evans, 1976).*

***Figure 12**. A section cut 2 metres deep into the former east face of the Cedar Pit in 2012; sited immediately below the esker crest at profile E in Figure 8.*

fluvioglacial sediments was exposed (Table 1), but the chalk bedrock beneath the esker was not exposed in the pit. In 2012 a small section near the eastern edge of the former Cedar Pit at the crest of cross profile E (Fig.12), was the only exposure along the esker and revealed a succession of seven beds close to the esker crest (Table 2). The presence of diamict confirms earlier reports that a flow till characterised the top of the esker sequence in places. Stone counts from the Cedar Pit (Evans, 1976) gave mean values across three sites (total count = 570) of 40% chalk, 27% flint, 10% Carboniferous sandstones, 7% igneous, with trace amounts of local Red Chalk and Carstone (Fig. 13). The Carstone breaks down to sand. In a boulder bed chalk comprised 61% of the clasts (N = 100), with just 6% of flint. The chalk clasts have a high proportion that are well-rounded and disc-shaped; since chalk has a low durability as bedload clasts, their transport distance was probably limited. Imbrication gave a mean direction of N 166°. Red Chalk crops out on the floor of the Wash 2-3 km northwest of the esker, indicating a minimum transport distance.

Upwards-fining sequence with boulder-sized clasts at the base grading into sandy silts at the top.
Consistent pattern of normal faults trending along the ridge axis with downthrows on each side of <1.15 m, giving an overall anticlinal flexure structure to the a-b cross section in Figure 9.
Localised synclinal sags within the sediments; see Figure 9 g-h.
Till inclusions within the sediments towards the top of the succession (Fig. 9c) and till beds <0.43 m thick on the flanks lying with a sharp contact onto bedded gravels beneath (not shown on the sections).

***Table 1**. Sedimentological characteristics of the esker, as exposed in Cedar Pit (after Evans, 1976).*

Diamict (till) forming a bulbous mass <0.5 m.
Massive silt <0.8 m.
Clast-supported coarse gravel, mainly chalk clasts <0.8 m.
Coarse angular gravel 0.8–1.15 m.
Massive fine sand / coarse silt with small angular chalk clasts 1.15–1.52 m.
Coarse sand-granules 1.52–1.80 m.
Medium sand with minor comminuted shell 1.80–<2.0 m.

***Table 2**. Sequence of sediments exposed in 2012 at the site of Cedar Pit.*

***Figure 13**. Sands and gravels exposed in 2012 on the floor of the old Cedar Pit; rounded chalk clasts dominate (the two largest have fractured due to recent freezing), and flint and Red Chalk are minor components; the coin is 22 mm across.*

The esker palaeontology

The esker sediments contain a derived marine molluscan fauna. Exposed in the Cedar Pit, only the core zone had <0.6 m of grey medium to fine sands with bands of small chalk clasts and a derived fauna (Evans, 1976). At present, finely comminuted and unidentifiable shell material can be found around rabbit burrows. However, whole shells have been collected from working pit faces in the past since the time of Carville Lewis's visit, and material from Cedars Pit is from Mesozoic and Pleistocene age groups (Table 3).

The presence of these faunas within the esker sediments is consistent with ice moving over the North Sea floor. Following a eustatic fall in sea level, the seabed would have had a veneer of abandoned marine and fluvial sediments reworked from earlier glacigenic materials. This mirrors the situation pertaining to similar Pleistocene faunas within the Irish Sea derived-glacigenic succession in Cheshire (Thompson & Worsley, 1966) and in Holderness at Kelsey Hill.

Pre Pleistocene (Mesozoic)

Jurassic: *Acroteuthis lateralis, Gryphaea arcuata, Ostrea* sp., *Rhynchonella* sp., crinoid ossicles.
Gault: *Neohibolites minimus*.
Red Chalk: *Terebratula capillata*?.
Chalk: *Belemnitella mucronata*.

Pleistocene

Ocenebra erinacea (L) (Sting-winkle),
Hinia incrassatus (Ström) (Thick-lipped Dog Welk),
Arctica [Cyprina] *islandica* (L), *Buccinium undatum* (L)
Cerastoderma edule (L.) [syn *Cardium edule*],
Cerastoderma sp., *Macoma balthica* (L), *Ostrea* sp.
Tellina sp. (this might be *Macoma*), *Venus* sp.,
Pomatoceros triquetor (L.), (a keelworm on a chalk clast).

Table 3. *The two age groups of fauna collected from Cedar Pit, by Evans (1976), except for the last six by the author.*

The esker's environment and age

Meltwater from the Hunstanton esker's drainage system discharged to the south. The esker terminates on a slope that extends 150 m down to the Ringstead meltwater channel, but there is no clear morphological link between the two. The main dry valley has a break in the long profile south of the esker's southern end, though an old trackway embankment across the channel clouds the picture. It appears that the esker drainage maintained its englacial course southwards from the preserved esker, and any sedimentary record was obliterated during ice wastage. Downstream, to the west, the meltwater channel is more incised into the chalk, and its asymmetrical cross profile is larger than would have been formed by the esker discharge alone. The channel extends east of the esker towards Ringstead, and carried the main flow of meltwater from sources that are unknown.

Modern examples of meltwater streams emerging from glaciers in southern Iceland

Figure 14. *An englacial meltwater stream emerging from a cave mouth about 3 m high onto the glacier surface, where it becomes supraglacial; at Svinsfellsjökull. This might be analogous to the deglacial environment at Hunstanton Park when its esker was being formed.*

Figure 15. *A subglacial meltwater stream resurgence under hydrostatic pressure at the apparent ice margin of Breiðamerkurjökull. The outflow immediately disappears beneath surface debris.*

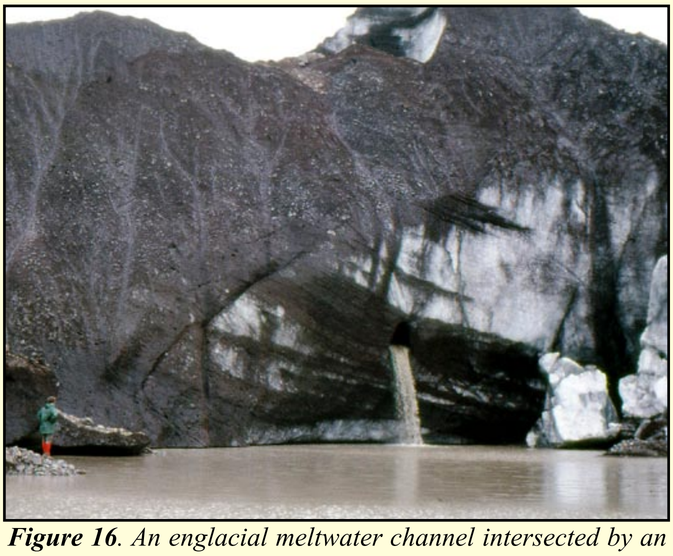

Figure 16. *An englacial meltwater channel intersected by an ablating ice cliff, at a stagnant glacier margin at Hrutajókull; the inclined debris bands indicate earlier ice marginal thrusting at the site.*

The precise position of the ice limit, during the Last Glacial Maximum, is difficult to establish since the irregular spread of glacigenic sediments, mapped as the Ringstead Sand and Gravel Member, has a feather edge with no end moraine (Moorlock *et al.,* 2008). The only contemporary feature in eastern England similar to the Hunstanton esker, is a long sinuous ridge near Keyingham in East Yorkshire (Penny, 1963), although little of the esker remains after quarrying. It is composed of the Kelsey Hill Gravels, which contain an abundant derived marine fauna, vertebrate material and the fresh water bivalve *Corbicula fluminalis* (Müller). The *Corbicula* is significant as it is now regarded as an indicator of Marine Isotope Stages 7, 9 or 11, all older than the Ipswichian interglacial (Meijer & Preece, 2000; Penkman *et al.,* 2013. The consensus view is that the Keyingham ridge consists of fluvioglacial sediments deposited as a subglacial esker southwards to a subaerial fan (Catt, 2007). Palaeocurrent indicators showing southward flow along the sinuous ridge, armoured mud balls and small peat-filled kettle holes all support this concept. However, a lithofacies log from the Kelsey Hills Gravels, showing 5 m of mainly flat-lying sands and gravels with a marine fauna sandwiched between the Skipsea and Withernsea tills, has been re-interpreted as signifying upper-beach-face gravels (Eyles *et al.,* 1994), hence re-opening the debate that arose a century ago over the origin of the Hunstanton esker.

Though it is clear that the esker in Hunstanton Park is a product of the Last Glaciation, available the amino acid assays suggest a Last Interglacial age for the derived fauna. Allan Straw has long maintained that the Last Glacial Stage in eastern England is divisible into two distinct glaciations, one forming the outer limits of the Holderness Formation in the early Devensian, followed by a more restricted ice advance in the Last Glacial Maximum. This has been challenged (Worsley, 1991), and Straw (1991) conceded that it was not yet certain whether the earlier advance took place in the early Devensian or whether both advances took place in the Late Devensian, but he later asserted 'the case for two glacial stadials in east Lincolnshire is a compelling one' (Straw, 2008). The most plausible age interpretation in the opinion of the writer is that the Hunstanton esker was deposited by meltwater close to an ice margin during the Last Glacial Maximum just before 20 ka BP. This view is supported (Clark *et al.,* 2009; Chiverrell & Thomas, 2010). Curiously, doubts linger in the minds of some workers about the relative ages of the Hunstanton and Blakeney eskers since a map of Norfolk's Devensian glacial features shows the Blakeney esker outside the ice limit yet coloured the same as the Hunstanton esker (Moorlock *et al*., 2008).

Hunstanton Park undoubtedly contains an excellent example of a small esker. The only other similar landform nearby is the Blakeney esker, but this has been damaged by quarrying and is certainly related to a glaciation that pre-dates the Last Glacial Maximum.

Acknowledgements

My interest in esker genesis matured while working in 1973 as a Leverhulme Fellow in European Studies in the Department of Physical Geography, University of Stockholm, which was then located in the 'Old Observatory' on the crest of a large sub-aquatic esker. I am grateful to Peter Allen, David Bowen, Andrew England, Steve Gurney, Judith Fox, Stephen Gale, Hilary Jensen, Jon Lee, Paul Madgett, Michael Meakin, Mike Paul, and Richard Preece for their help and encouragement. John Catt and Allan Straw kindly read and commented on the manuscript and Tony Waltham's editorial work went well beyond the bounds of duty. This paper is dedicated to the memory of Hywel Evans and my former research supervisor R. H. 'Chuff' Johnson.

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