Existence of Geomorphological Entity of the Description of the Southern Irish End Moraine

Introduction

The south-east of Ireland has been largely ignored up until very recent times by

Quaternary researchers in Ireland. This is in spite of the importance of the area if, as has often

been suggested since the beginning of the twentieth century, one of its characteristics is that

it contains the end moraine marking the limit of Midlandian glaciation. Recent articles

referring to sites on the south coast (Gallagher and Thorp, 1997; O'Cofaigh and Evans, 2001;

Gallagher, 2002) as well as one site-specific article on county Kilkenny (McCabe, 1998) have

thrown open the question of this, 'traditional' interpretation of this area in particular in

relation to the existence or significance of the Southern Irish End Moraine (SIEM),

(Charlesworth, 1928).

This paper aims to investigate the existence of a geomorphological entity of the

description of the Southern Irish End Moraine over the area of county Kilkenny, in the south

east of Ireland.

In the late nineteenth century, while Carvill Lewis was travelling through Ireland in order

to look at analogous but smaller-scale features to those marking the limits of glaciation in

North America, he recognised features that he believed marked the furthest limit of glaciation

in Ireland. A map he produced at the end of his first visit to Ireland in 1885 (Figure 1) was

never redrawn after the observations of his second visit in 1886 when he suggested that the

limit lay further to the south than previously drawn by him. The work that Carvill Lewis had

undertaken lay largely unknown due to his death in Manchester in 1888, his field notebooks

and maps being published posthumously in 1894 at the request of his widow.

It was from this work that Charlesworth's 1928 article followed, an article that was to

almost define the Late Quaternary history of the south of Ireland. Charlesworth, described

and charted what he saw as the end moraine of the last glaciation (Figure 2). He describes the

feature as:

a typical kettle-moraine, a tangle of marginal accumulations, presenting with its

rolling, choppy and knobby surface, pitted with countless hillocks and hollows, a

most striking appearance in the landscape of the country (p. 295).

Charlesworth drew what he saw as a complex feature running across Ireland from the

Irish Sea, near Wexford, to the Atlantic at Kilrush and Kilkee. While never mapped in detail,

the moraine was drawn as running through the middle of the county of Kilkenny (Figure 2),

1885). This represents the first suggestion of a 'Southern Irish End Moraine' in the literature, a limit

of last glaciation on land in the south of the island.

Hegarty

a striking feature, a few miles in width, east of [...] Goresbridge, by Dungarvan,

across the Barrow near Borris (its outwash extends to near Craiguenamanagh),

across the Nore north of Thomastown (the outwash spreading as far south as

Inishtioge), whence it ranges north-westwards on to the northern shoulders of the

SlieveArdagh Hills, its highest limit here attaining an elevation of about 900 feet

OD (p. 297).

Charlesworth provided little more description of the moraine, preferring to depend on

geomorphological evidence for its existence and importance. The article describes the retreat

of ice from the study area, suggesting that the Castlecomer Plateau emerged rapidly, forming

in the south-east of Ireland, overlaid on a hillshaded digital elevation model of south-eastern Ireland.

anunatak, while two lobes of ice flowed down either side, one along the Nore Valley and one

along the Barrow with meltwaters flowing down both of these rivers. Moraines of these two

lobes are said to occur north of Kilkenny City and at Bagenalstown (Charlesworth, 1928).

This was followed by further retreat, with moraines being deposited during halts of this retreat

to the north of Carlow on the Barrow and at Attanagh, to the north of Ballyragget in the Nore

Valley.

The area to the south of this morainic feature, which was interpreted as dividing the area

between the penultimate ('Munsterian') glaciation and the last ('Midlandian') glaciation, was

said to be characterised by an 'older', smoother landscape with gentle slopes and periglacial

features such as slope deposits and vertical stones within sections (Mitchell, 1976). The lack

of limestone clasts was also said to be characteristic of this 'Older Drift' of the Munsterian

glaciation, which was not overridden by ice during the last glaciation. This was thought to be

because the limestone would have weathered out by the periglacial churning of the sediments

during last glaciation. Ice-limits of the Munsterian glaciation is believed to lie offshore to the

south and west of Ireland (McCabe, 1987).

The idea of the SIEM, first proposed by Carvill Lewis (1894) and described by

Charlesworth (1928), was accepted by many and became part of the general theory of the last

Limits of Midlandian glaciation

Maximum extent of ice during the last glaciation within the study area according to

Charlesworth (1928), Finch (1971), Synge (1979) and Collins (1982). Other authors, such as Warren

(1992) and O'Cofaigh and Evans (2001) suggest that maximum ice limits lay offshore during the last

glaciation.

glaciation of Ireland (see Mitchell, 1976; Synge, 1979; McCabe, 1987; Lambeck, 1996; Mitchell and Ryan, 1997). Further refinements to the model in the south-east were made by Finch (1971) and subsequently by Collins (1982), both of whom used soil types to map what they considered to be the Southern Irish End Moraine in the extreme south-west of county Kilkenny (Figure 3).

As can be seen from the above discussion, there is little agreement as to the limit of the last glaciation within the study area. Both Finch (1971) and Collins (1982) identify areas of limestone till to the south of the area described by Charlesworth (1928) as the limit of the last glaciation, while researchers such as Warren (1992) and Ó Cofaigh and Evans (2001) postulate a limit which is on the modern bed of the Celtic Sea. Recent investigations by Gallagher (2002) have presented evidence for glaciofluvial processes off Waterford harbour discharging flows up to several orders of magnitude greater than those of present onto the continental shelf, with the suggestion that the palaeochannel was draining an ice sheet in the Midlands of Ireland during the Midlandian glaciation.

While new evidence is emerging about glaciation limits offshore, to date there has been no attempt to map the feature previously described as the Southern Irish End Moraine in the south-east of the island.

Methodology

As part of the Groundwater Protection Scheme for county Kilkenny (Buckley and Fitzsimons, 2001), the Quaternary sediments of county Kilkenny were systematically mapped. The mapping of the Quaternary sediments was carried out in three phases. The first involved the compiling of all existing known data on the Quaternary of the study area. This was followed by intensive fieldwork, involving a traverse of the field area, surveying all quarries, gravel pits, stream cuttings, drains, house foundations, trenches, road cuttings, ditches or any other cutting deep enough to gain some insight into the characteristics of the Quaternary cover. Following this, a drilling programme was carried out to gather information about sediment types.

A high-resolution digital elevation model (DEM) for the study area was obtained from Ordnance Survey Ireland (OSI). Sixty-six percent of the study area was covered by a 10 m DEM, with 1 m vertical accuracy (where each pixel covers a 10 m area and represents an average height of the topography within that 100 m2 area). The remainder of the area was covered by a 50 m DEM.

All information was incorporated into a GIS for ease of presentation and manipulation. Together this provided excellent cover of the ice-affected landscape of county Kilkenny. It was hoped that, with this information, a more accurate picture could be gained of the late

Quaternary history of county Kilkenny, and south-east Ireland, and a greater understanding

could be gained as to whether the limits of last glaciation are present within this area.

Evidence for SIEM from mapping

Morphology

Charlesworth (1928) first described the SIEM as a 'rolling, choppy and knobby surface,

pitted with countless hillocks and hollows, a most striking appearance in the landscape of the

country'. When the 10 m DEM of the area is hillshaded from the south-east, no evidence for

this is seen (Figure 4). If such a striking feature were to exist, one would expect to see it at

this scale of a DEM, with x, y, z points every 10 m. Other small-scale features such as

streamlined hills in the north-west of the county are visible, with their associated morainic

forms (Figure 5). If these morainic forms can be seen on this detailed resolution DEM, one

has to assume that other morainic forms, such as the limit of Midlandian glaciation, should

be visible also at this resolution and scale, if they exist in the area.

However, what is visible is the important barrier of the escarpment of the Southern

Uplands. According to Synge (1979), this marked the boundary of Midlandian glaciation.

This is a reasonably plausible hypothesis, as this escarpment does form a major boundary,

rising 70+ metres above the central plain of Kilkenny. However, what barrier this would be

to ice which, according to Hegarty (2002a) reached a minimum height of 290 m OD 30 km

to the north-north-west of this point, as is witnessed by the kame terrace at Spahill?

Sediments

According to Charlesworth (1928), the main evidence for the SIEM in county Kilkenny

was the presence of suites of glaciofluvial morainic sediments stretching from east to west

across the county. A map of the distribution of glaciofluvial sediments in the centre of

Kilkenny, the area within which Charlesworth (1928) mapped the SIEM, is presented in

of evidence for the existence of the SIEM within county Kilkenny.

Nore gravels

As can be seen from this map, the most impressive suite of glaciofluvial deposits is

centred around the Nore River. Because of the extent of the deposit and its well-sorted nature,

numerous sand and gravel pits have been operating in the area for many years, offering some

superb exposures into the gravels. Within Kilkenny the 'Nore River gravels' (Daly, 1992)

extend from the boundary with Laois to the north of Ballyragget (NGR 24660 17970) to

Thomastown in the south (NGR 25840 14180). The gravel complex associated with the Nore

continues northwards into Laois where it becomes much more extensive, becoming the

predominant sediment type in the county (Kilfeather, 2000).

The gravels within the Nore Valley generally form a series of gently southward dipping

cobble-gravel beds, mainly clast supported and sometimes grading into sands and silts. This

sequence is repeated both horizontally and vertically over the extent of the glaciofluvial

sediments within the Nore Valley.

Hennessy's gravel pit to the north of the town of Bennetsbridge (NGR 25505 15072)

displays these gravels well. Here extensive faces displaying horizontally to sub-horizontally

bedded gravels are exposed (Plates 1, 2). The working faces are some 15 m in height and,

according to the pit owners, the gravels extend vertically below the present bed of the Nore

River, which flows approximately 100 m to the east of the pit.

While bed dips are shallow, the beds within the sections in the pit are quite varied in their

direction of dip. Beds were observed to dip both to the east and to the west, while a general

direction of south-easterly flow was observed. As in other gravel pits in the study area, faces

in this pit were too high and loose to allow accurate measurement of the dip of beds safely.

To the north of the pit, some broadly cross-cutting beds can be seen. A beautifully developed

boulder pavement was exposed during field work to the west of the pit, just below the

entrance road (Plate 3). Some collapse structures are visible in the north-east of the pit, where

beds of sand dip steeply and are contorted. This deformation is thought to be associated with

a kettle hole close by.

Limits of Midlandian glaciation

Hillshaded digital elevation model of north-west Kilkenny, shaded from the south-east,

showing streamlined hills and morainic forms.

Hegarty

Interpretation

These sub-horizontally laminated coarse sediments are quite typical of sandurs or valleytrain

deposits and, as with similar sediments found along the Nore Valley, these sediments to

the north of Bennettsbridge are interpreted as representing outwash from icecaps to the north.

If the SIEM exists in the area, these sediments, therefore, postdate it, as at this stage the ice

has retreated to the north, and is emitting meltwater down this major drainage channel.

Therefore, the gravels in this area do not represent those mapped by Charlesworth in 1928.

As well as the presence of glaciofluvial sediments within particular areas in Kilkenny, the

absence of glaciofluvial sediments should also be pointed out. This is particularly true of

those areas where, in the past, a major end moraine has been interpreted (Charlesworth, 1928;

Mitchell, 1976; Synge, 1979; Lambeck, 1996).

Charlesworth, in his 1928 article, drew a series of features that he saw as forming the

Southern Irish End Moraine. It would now seem useful for the map of the Quaternary

sediments of county Kilkenny (Figure 6) to be compared with Charlesworth's diagram of the

SIEM features (Figure 2).

The first thing to note is Charlesworth's accuracy in depicting a belt of glaciofluvial

gravels to the north of the Slieveardagh Hills. This band of glaciofluvial sediments does skirt

the north-west of the Slieveardagh Hills and follows the Nuenna Valley into the Nore Valley.

In a later article, Charlesworth (1957) bowed to a suggestion made to him by Farrington that

this moraine was recessional. This view of these sediments is also adopted in this study, as

there seems to be no basis on which to substantiate the claim that these gravels represent the

end moraine of the last glaciation. While it is accepted that chronology has to remain

uncertain, nonetheless the presence of similar sediments to the north and the south of this line,

Plate 1: Hennessy's gravel pit, Bennettsbridge. Beds within the gravels are horizontal to

subhorizontal. The direction of flow varies from east - west to west-east, but generally trends north -

south (from the photo out to the viewer).

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such as the presence of tills of similar characteristics to the north and to the south of this line,

in particular around the area of Callan (Hegarty, 2002a), suggests that the glaciofluvial

sediments represent a stage during deglaciation when the ice was backed up against the

Slieveardagh Hills, and not a Last Glacial Maximum stage where the Slieveardagh Hills were

impeding southward movement of the ice sheet.

Plate 2: Sub-horizontally bedded and coarsely trough cross-bedded sands and gravels in Hennessy's

pit.

Plate 3: Boulder pavement within gravels in the southern face of Hennessy's pit. Stake is 1 m high.

Although the glaciofluvial gravels do follow the Nore downstream (where they are

interpreted here as a proglacial sandur), there is no evidence of these gravels continuing from

theNore to the Barrow Valley, as is suggested by Charlesworth (1928). Charlesworth

describes the moraine as crossing the Nore to the north of Thomastown, from where it winds

toDungarvan. As said above, the sandur of the Nore Valley extends south as far as

Thomastown. However, to the east of Thomastown no gravel is found (Figure 6).

The area of 'gravel' that Charlesworth describes at Dungarvan is now the site of a

limestone quarry. In fact, a band of limestone outcrop exists from an area to the north of

Thomastown to Borris in Carlow, passing through Dungarvan (Figure 6). What Charlesworth

observed in the field in this area as an area of hummocky gravels is in fact an area where

limestone bedrock is outcropping, thus giving the area a hummocky morphology.

As a comparison of Figure 3 and Figure 4 shows, Synge (1979) and others put the SIEM

as passing to the north of the Southern Upland area of Devonian sandstone and Ordovician

shales. Here again, however, there is a lack of glaciofluvial sediments. While it could be

argued that, if the glacier were backed up against this impediment, meltwater would have

beenchannelled away from the ice front by proglacial streams tapping the glacier from the

upland region, the lack of glaciofluvial sediments on this upland area would weaken this

argument and therefore the hypothesis set by Synge (1979) must be rejected. Field evidence

seems to suggest that there is no major end moraine running through the area as there is no

band of glaciofluvial sediments running across the area as Charlesworth (1928) suggested.

Discussion

The Southern Irish End Moraine was based on a map published by Charlesworth (1928)

that showed large swathes of morainic material stretching across the country and, of particular

interest here, across county Kilkenny. During mapping of the Quaternary deposits, it was seen

that some of the areas that Charlesworth interpreted as morainic gravels were in reality

bedrock knolls. A band of glaciofluvial sediments does not stretch across the study area

(Figure 6). While glaciofluvial sediments do exist in the Nore valley, they are not as extensive

asCharlesworth envisaged in 1928. These glaciofluvial sediments, confined to the modern

Nore valley, are in fact a sandur deposit, representing a proglacial meltwater system

discharging large volumes of water and sediment down the major drainage route of the Nore

during the end of the last glaciation. These deposits do not represent a morainic band of

gravels representing an ice limit, but rather represent a proglacial system discharging great

quantities of meltwater into the Barrow drainage system (see Gallagher, 2002). From this

mapping, no feature akin to the SIEM as Charlesworth (1928) envisaged it exits either

stratigraphically within the sediments of the area or geomorphologically on the landscape.

The morpho-stratigraphic framework of the SIEM, therefore, falls apart, as it can be

demonstrated that the features mapped by Charlesworth (1928) are not what he interpreted

them to be.

Questions also have to arise over the existence of the 'second model' of the SIEM, that

of Synge (1979). Synge (1979) mapped the Southern Irish End Moraine as existing to the

north of the Southern Upland region. As mentioned earlier, this is a reasonable assumption,

considering that the escarpment provides a barrier for any ice flowing from the north.

However, if ice were backed up against this escarpment, it would seem reasonable to expect

glaciofluvial sediments within the valleys that run from the escarpment to the south, which

seem ripe for collecting such sediments. While it has been demonstrated elsewhere

(Gallagher, 1997, 2002) that the Barrow was a major drainage system for ice from the

midlands during the last glaciation, nevertheless it would be expected that valleys such as

those that exist along the northern escarpment of the Southern Uplands would act as drainage

routes if an ice cap was backed up against this escarpment. However, no glaciofluvial

sediments are found either backed up against this ridge or within the valleys. It does not seem

plausible that ice was therefore backed up against this escarpment and that the Southern

Uplands acted as a barrier to contain the last ice sheet to cover the island. Thus, it is also

suggested here that Synge's model of the Southern Irish End Moraine be discarded.

The rejection of the Southern Irish End Moraine again throws open the debate on the

sediments of the south of Ireland. It has been determined elsewhere that sediments found on

the south coast are last glaciation in age (Gallagher and Thorp, 1997; O'Cofaigh and Evans,

2001). This adds further credence to the rejection of the SIEM paradigm. However, Bowen et

al. (2002) suggest that ice reached its maximum extent during the Midlandian (Devensian)

prior to the LGM, and obtained a 36Cl date of 37.5±1.5 ka from a site on the Southern Uplands

inKilkenny. Further dating would help to resolve the chronology of the last glaciation in the

south-east of Ireland.

Primary diamictons also exist in the study area and extend to the very south, although

there are large pockets of the study area that are free of any Quaternary deposits (Hegarty,

2002b). However, as there are Quaternary deposits to the south of these areas similar to those

found to the north (for example on the Southern Uplands) and striae exist on these sediment

free surfaces (McCabe, 1998), it is suggested that these too were glaciated, although no

deposits were laid down.

The suggestion that these more southern areas were glaciated during the last glaciation,

contrary to the idea of the Southern Irish End Moraine (Charlesworth, 1928), is also

supported by the presence of lodgement tills with well-preserved fissility in the very south of

the county (Hegarty, 2002a; 2002b). Previous models that suggested that the south of the

study area was not glaciated during the last glaciation based this premise on the absence of

lodgement tills in the south of Ireland, beyond the area of the SIEM, and in particular on a

lack of limestone clasts within the tills in the south. However, as has been discussed

elsewhere (Hegarty, 2002b), some tills in the south of the study area maintain all the

characteristics of lodgement, such as fissility, shearing and overconsolidation, which would

have been destroyed by long periglacial periods. Limestone clasts are also preserved intact in

many tills in the south (Figure 7). Therefore, on a stratigraphic basis, it also has to be taken

that, if tills exist in the south of the study area that have the same characteristics as tills in the

north which have been interpreted as last glaciation in age, then these southern tills must also

be interpreted as last glaciation in age. This is particularly the case for lodgement tills.

However, it does not necessarily follow that all areas in the south-east of Ireland were

glaciated by the same ice sheet, or that different ice sheets that may have existed within the

area were coeval. In a previous publication (Hegarty, 2002b), it was suggested that that two

directions of ice flow seem to exist within the study area. This would suggest that two ice

sheets might have been present within the study area during the last glaciation. One of these

ice sheets originated in the west of the country, in the area around Galway, as is suggested by

the presence of Galway granite clasts within the sediments of the study area, in particular to

the north-west, with Galway granites being found within glaciofluvial sediment in the Nore

valley, and also within tills in the north-west of the county (Figure 8). It is suggested that a

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further ice sheet, originating to the north of the study area, also flowed over the study area.

This ice left indicators of an ice flow from north to south in the east of the study area. The

postulated zone of suture of these two ice lobes is in the area of the Nore Valley.

of limestone clasts also within the tills of the south of the county. These tills are dominated by the

local Devonian sandstone bedrock, but contain amounts of limestone.

This would also explain the depth and the quantity of glaciofluvial sediment in this valley

that makes it different from the modern-day more important Barrow Valley. Although other

authors (Gallagher, 1997, 2002; Glanville, 1997) have suggested that the Barrow was a major

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drainage channel for midland ice sheets during the last glaciation, sediments within this study

area suggest differently, with the Barrow valley having little depth of sediments to the south

ofGoresbridge, while the Nore valley having up to 30 m depth and over 1 km width of

glaciofluvial sediments as far south as Bennettsbridge, with these glaciofluvial sediments

continuing, although not in as great a quantity, as far as Thomastown, where the modern river

becomes confined in a deeply entrenched rock channel.

The idea of two ice sheets in the study area during last glaciation needs further research

to be substantiated, with dating being particularly desirable to achieve some understanding of

the pattern of glaciation. If two ice sheets were present in the area during the last glaciation

it would go some way to explaining the areas of periglacial features in the south of Ireland,

as described by Mitchell (1973) as well as Hegarty (2002a), to the north of areas of 'fresh'

till. This complexity of sediments points to a complexity of the depositional environment,

where ice still exists in the south while areas to the north have become ice-free and are

undergoingperiglacial processes. The presence of two coeval ice sheets in the south-east of

Ireland, one originating in the west of the island and one with a northerly provenance, would

help to explain the spatial distribution of primary glacial sediments to the south of areas of

periglacial features.

Conclusion

The idea of the SIEM is seriously undermined if it is seen that the basis on which the model was founded (that a glaciofluvial moraine existed across the country and that this marked the limit of the last glaciation) is shown to be incorrect. It has been shown that a glaciofluvial moraine does not exist within the area of county Kilkenny, and that the major glaciofluvial assemblages that exist within this study area represent proglacial outwash deposited as the ice sheet was retreating at the close of the last glaciation. Charlesworth's 1928 SIEM complex neither exists in the sediments of Kilkenny nor as a geomorphic landform. Other re-drawings of the SIEM are likewise rejected on sedimentological evidence.

Therefore, the stratigraphic basis of the SIEM must be rejected.

Detailed mapping of the Quaternary sediments of the mainland of Ireland, as well as offshore, must continue if further insights are to be gained into the Quaternary history of Ireland. This is particularly true, given that the spatial complexity of the sediments in the south of Ireland most probably mimics the spatial complexity of ice masses in the area during the last glaciation. Ideally, mapping should be accompanied by dating of the sediments, to gain a better handle on the sequence of glaciations within this small area. This mapping should also aim to tie broader scale top-down mapping, such as that discussed in Clark and Meehan (2001), with traditional mapping techniques. This may be achieved by using

Geographic Information Systems as part of mapping techniques, particularly where these GIS

contain data such as digital elevation models and geo-rectified aerial photographs.