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MIDLANDIAN COLD STAGE DEPOSITS AT LOOP HEAD, SOUTHERN COUNTY CLARE

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Abstract

This paper discusses the nature of two suites of glacigenic sediments exposed at Bridges of Ross, southern County Clare. A lower diamicton suite is thought to have been derived from an ice sheet moving from the north-east and contains a previously unrecorded, organic, stadial deposit. The overlying limestone-rich glacigenic sediments appear to be derived from a later stage of glaciation, emanating from the east. A formal lithostratigraphic scheme is presented that includes two new formations, the Loop Head and Lehinch formations, both of which are likely to be of Midlandian age.

Introduction

There has been a great deal of debate concerning the extent of, and dynamics associated with, ice sheets that have affected western Ireland (e.g. Hoare 1991; Warren 1991a; 1991b). This is largely related to the paucity of reliable stratigraphic control in the region, together with the lack of inland exposure and the destruction of earlier parts of the record by extensive glaciation during the late Midlandian (Fenitian, Oxygen Isotope Stage 2). The glacial deposits of southern County Clare have been studied as part of an ongoing regional glaciostratigraphic programme (Natural Environment Research Council Small Grant GR8-03679) and detailed mapping by the Geological Survey of Ireland. As a result, a number of new sections have been studied, including an extensive exposure at Bridges of Ross (National Grid reference O73501504), near Loop Head. Here two glacigenic suites are exposed, the lower of which incorporates a previously unrecorded organic bed. This paper briefly describes the nature of the Bridges of Ross deposits and presents new evidence regarding the nature of palaeoenvironmental change during a phase of the Quaternary that is of fundamental importance for our understanding of the nature of landscape development in southern Ireland.

Midlandian cold stage deposits in southern Ireland

Many workers have expressed the opinion that the glacial sediments of south-west Ireland require reclassification (e.g. Hoare 1991; Warren 1991a; 1991b; Coxon 1996). The timing and nature of repeated phases of glacial

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activity represented by a complex array of Pleistocene glacial deposits found in the region require closer attention. The sediments record the activity of ice sheets emanating from two principal source areas—the Irish Midlands and the Kerry/Cork mountains. Current understanding of the significance and stratigraphic relationships of these deposits is derived from initial studies by Finch and Synge (1966) and Synge (1970; 1981) and the later, rigorous work of Warren (1979; 1985; 1991a; 1991b) and Warren *et al.* (1986). There has been a great deal of debate regarding the ages and extent of two lithologically distinct suites of glacial material in northern County Kerry and County Clare (Synge 1970; 1981; Warren 1985; 1991a; 1991b; Warren *et al.* 1986; Hoare 1991). Early work subdivided the glacial deposits in the region into Munsterian and Midlandian groups (Synge 1970). Later workers either largely concurred with these ideas (Hoare 1991) or suggested that the deposits could be subdivided into early and late Midlandian (Fenitian) suites (Warren 1985; 1991a; 1991b; Warren *et al.* 1986; Bowen *et al.* 2002). Diamictons that derived from ice sheets and glaciers centred on the Kerry/Cork mountains may be distinguished by igneous indicator erratics of the Dingle and Dunquin groups (Warren 1985; 1991a; 1991b; Warren *et al.* 1986). Recent work by Bowen *et al.* (2002) provided additional chronological evidence that largely supports the stratigraphic framework proposed by Warren (1985; 1991a; 1991b). Bowen (2002) cites ^{36}Cl ages for the two suites of glacial deposits at Loop Head that suggest that an initial advance took place between 19ka and 22ka BP, followed by re-advance (the 'Drumlin Re-advance' of Synge (1969)) later in the late Midlandian substage, between 15ka and 16ka BP. That work calls into question recent work that has stated that there was no 'Drumlin Re-advance' (Warren 1992).

The biostratigraphic framework for late Quaternary environments in Ireland has mainly been established through analysis of sediments recovered from regions outside of the study area. This work has largely concentrated on unravelling the floral and faunal characteristics of the last interglacial (Oxygen Isotope Stage 5e) and its relationships with the preceding, Gortian, warm stage (e.g. McCabe and Coxon 1993; Coxon and Waldren 1995; Coxon 1996). In addition, organic deposits of Midlandian age have been recovered from a number of locations. South of the study region, at Fenit in north-western County Kerry, organic sediments that underlie a suite of periglacial slope deposits present a flora typical of relatively cold conditions early in the Midlandian. These deposits have been associated with Oxygen Isotope Stage 5a, the Kilfenora Interstadial (Heijnis *et al.* 1993). At Aghnadarragh (McCabe *et al.* 1987) organic silts of interstadial origin overlie an extensive till. These organic sediments contain pollen and beetles characteristic of an interstadial woodland environment, deposited *c.* 50ka BP. Two subsequent cold phases are represented by organic muds at Hollymount (McCabe *et al.* 1978; 1987) and Derryvee (Woodman and Monaghan 1993). Pollen floras obtained from the sites indicate an open, treeless environment. The Hollymount sediments are thought to have accumulated *c.* 40ka BP, and the organic silts found between two tills at Derryvee are thought to have been deposited *c.* 25ka BP, shortly before the main Midlandian glacial advance (McCabe *et al.* 1987).

Description of sediments exposed at Bridges of Ross, Loop Head

The cove at Bridges of Ross (Fig. 1) lies 2.5km north of the village of Kilbaha in southern County Clare. The ground surface falls from 25m OD at the site (to what appears to be a raised wave-cut platform or glacially eroded bedrock surface that rises from *c.* 4m OD in the eastern sections of the cove) to an anticlinal feature at *c.* 8.5m OD at the head of the cove. The Pleistocene sediments exposed within the eastern cliffs of the cove that directly overlie this platform have not been extensively studied since the work of Finch and Synge (1966). On the basis of the lithological, geochemical and mineral magnetic characteristics of glacigenic sediments in counties Clare and Kerry, Richards (2002) largely confirmed the

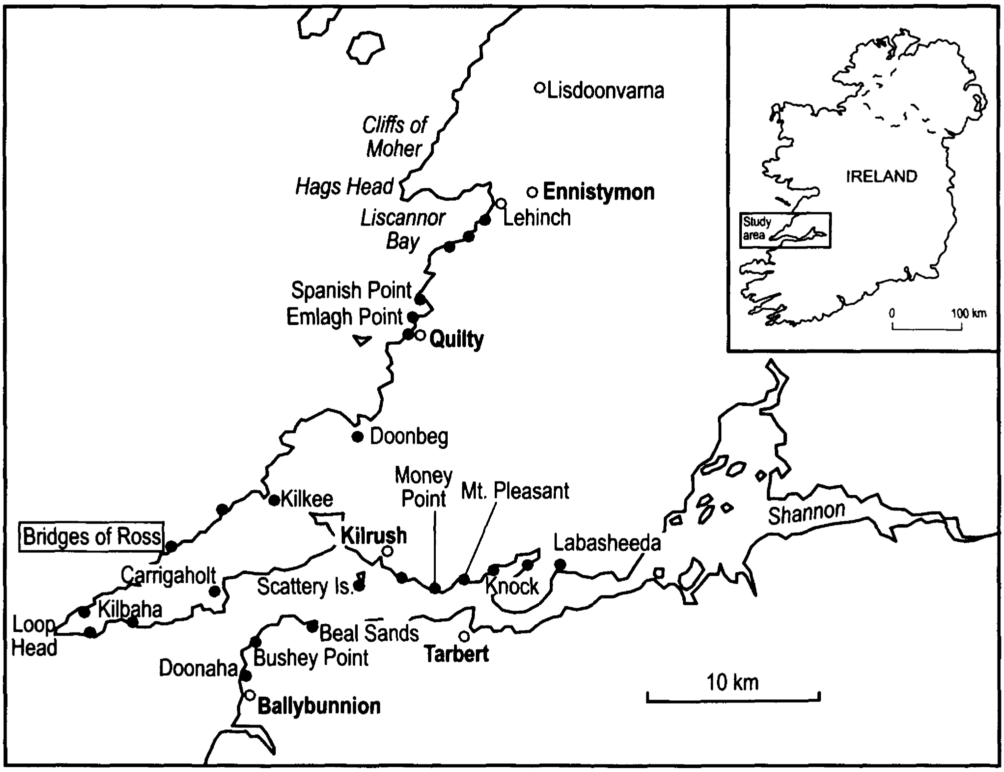

Fig. 1—Location of study area and sites discussed in the text.

stratigraphic subdivision of suites of glacial deposits in southern County Clare previously suggested by Synge (1970), Hoare (1991) and Warren (1991a). Richards (2002) has provided some framework for the interpretation of the complex sequence exposed at the site.

The Pleistocene stratigraphy at Bridges of Ross is summarised schematically in Fig. 2, and brief descriptions of the sediments are given in Table 1. The data indicate the relation of the units present and are compiled from eight sections that were recorded from summer 1999 to summer 2000.

Unit 1 is dominated by angular fragments that are derived from the local bedrock. The *a*-axes of the fragments range from a few centimetres to over 1m. The clast component is supported by smaller clasts in some locations, whereas areas of matrix support occur throughout the sediment. This deposit directly overlies a bedrock platform. Unit 2 also shows areas of clast and matrix support but is generally characterised by a smaller, angular clast content. This unit has a girdled clast fabric, which indicates shear stresses that emanated from the east-north-east (Fig. 2). The lithological composition of the 16–32mm clast fraction is dominated by locally derived Upper Carboniferous material, but there is a notable increase in further-travelled lithologies when compared to Unit 1. Unit 3 has very similar sedimentological and lithological characteristics to Unit 2. Its contact with Unit 2 is marked by the occurrence of a silt bed that extends throughout the sections. This bed is heavily deformed and contains attenuated folds, flow and boudinage structures. A further deformed silt bed occurs at the boundary between Units 3 and 5. In the north-eastern corner of the cove, a further unit, Unit 4, occurs between diamicton Units 3 and 5. Unit 4 consists of crudely bedded sands and gravels, with intermittent beds of clayey silt. Immediately south of the sorted gravels and

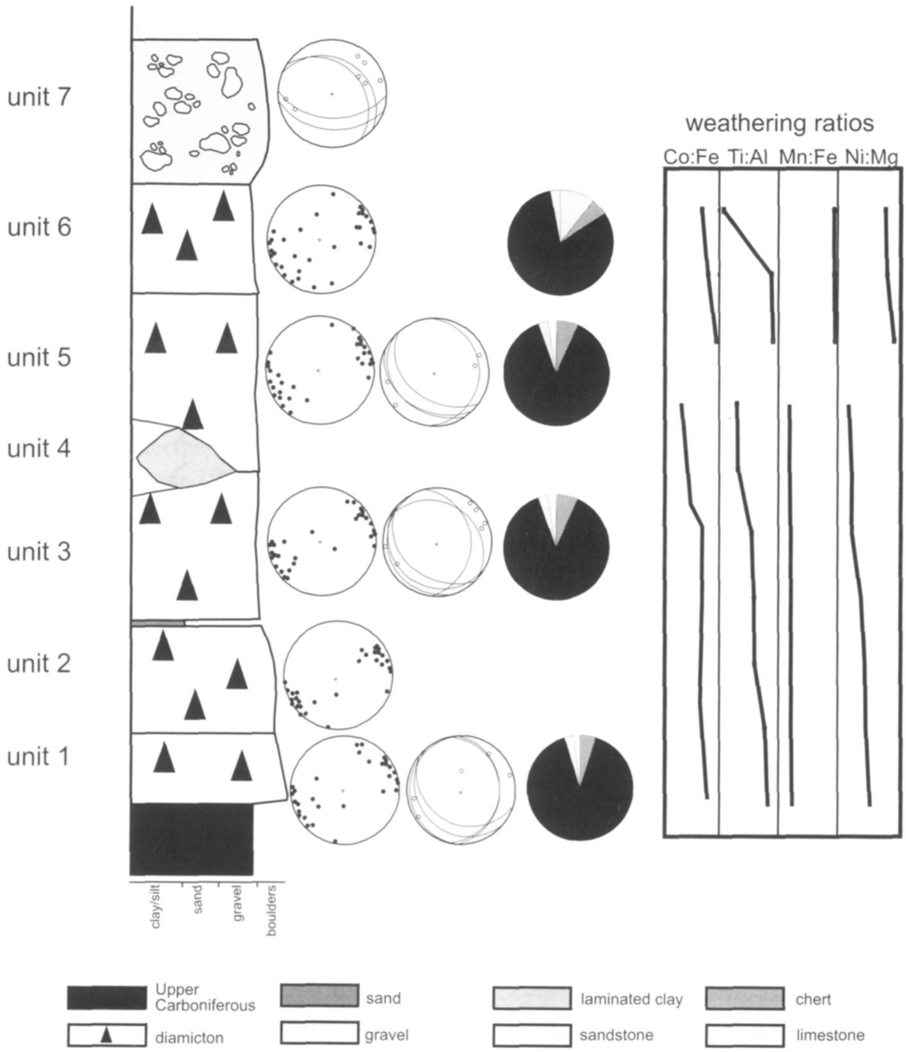

Fig. 2—Schematic representation of the lithostratigraphy at Bridges of Ross, including structural, lithological and geochemical data. The geochemical ratios that are given are believed to represent the degree of post-depositional weathering to which the unit has been subject.

sands a 1.1m-thick lens of silt occurs. The central 0.3m of the silt consists of 123 couplets (between 1mm and 3.5mm thick) of clayey silt and organic-rich silt laminae that overlie and grade into massive silts. The upper contact of the lens is erosional and is overlain by Unit 5. Unit 5 is characterised by similar sedimentological and lithological characteristics to Units 2 and 3. Units 6 and 7 are characterised by a change in colour and in lithological composition. Unit 6 is a poorly sorted, largely matrix-supported diamicton containing angular to subangular clasts with *a*-axes varying between 0.02m and 0.3m. This diamicton is overlain by up to 4m of coarse, subangular to rounded, crudely bedded, folded and sheared gravels. The style of deformation involves large-scale folds and localised thrust faults.

The lithological composition of Units 1–7 can be seen in Fig. 2. The lower diamicton units can be differentiated by a lack of limestone, which forms *c.* 20% of the clast component in Units 6 and 7. The geochemical signatures obtained from the diamicton units at

Table 1—Brief description and interpretation of the sedimentological and structural characteristics of the cold stage deposits exposed at Bridges of Ross, Loop Head, southern County Clare.

Unit	*Sedimentology*	*Structural characteristics*	*Lithology*	*Interpretation*
1	Diamicton consisting of angular clasts from 2mm to 1.5m within a coarse sand to silt matrix	Common brittle deformation	Upper Carboniferous shales	Comminution till
2	Diamicton consisting of subangular to angular clasts from 2mm to 0.6m within a coarse sand to silt matrix	Brittle deformation, meso- and micro-scale hook folds, boudinage, thrust nappes and tectonic lamination	Upper Carboniferous shales with rare sandstone, limestone and chert clasts	Deformation till
3	Diamicton consisting of subangular to angular clasts from 2mm to 0.6m within a coarse sand to silt matrix	Meso- and micro-scale hook folds, boudinage, thrust nappes and tectonic lamination	Upper Carboniferous shales with rare sandstone, limestone and chert clasts	Deformation till
4	Crudely bedded fine gravels with laminated clayey silts and organic silts		Gravels dominated by Upper Carboniferous shales with rare sandstone, limestone and chert clasts	Distal proglacial outwash or cold stage braided river environment
5	Diamicton consisting of subangular to angular clasts from 2mm to 0.6m within a coarse sand to silt matrix	Meso- and micro-scale hook folds, boudinage, thrust nappes and tectonic lamination	Upper Carboniferous shales with rare sandstone, limestone and chert clasts	Deformation till
6	Matrix-rich diamicton with rare clast support	Homogeneous, no evidence of structural deformation	Upper Carboniferous sandstones and shales with 10–20% limestone clasts	Deformation till
7	Deformed gravels with subrounded to subangular clasts between 2mm and 0.6m	Large-scale simple and recumbent folds with localised thrust structures	Upper Carboniferous sandstones and shales with 10–20% limestone clasts	Glaciotectonised glaciofluvial outwash

the site also reflect a difference in provenance, with Unit 6 showing lower Al and Ti and elevated Mn contents (Fig. 3). Figure 2 also illustrates variations in the Co:Fe, Ti:Al, Mn:Fe and Ni:Mg ratios obtained from analysis of the fine sand to silt fraction (125μm to 63μm) of Units 1, 2, 3, 5 and 6. While illustrating broad compositional differences between Unit 6 and the lower diamicton units, these ratios all decrease with increased weathering of the diamicton fine fraction and can therefore be used to indicate hiatuses in till deposition (Burek 1979).

Biostratigraphy of Unit 4

The pollen content of the laminated clayey silts within Unit 4 at Bridges of Ross has been investigated. Samples (*c.* 1cm^3) were extracted

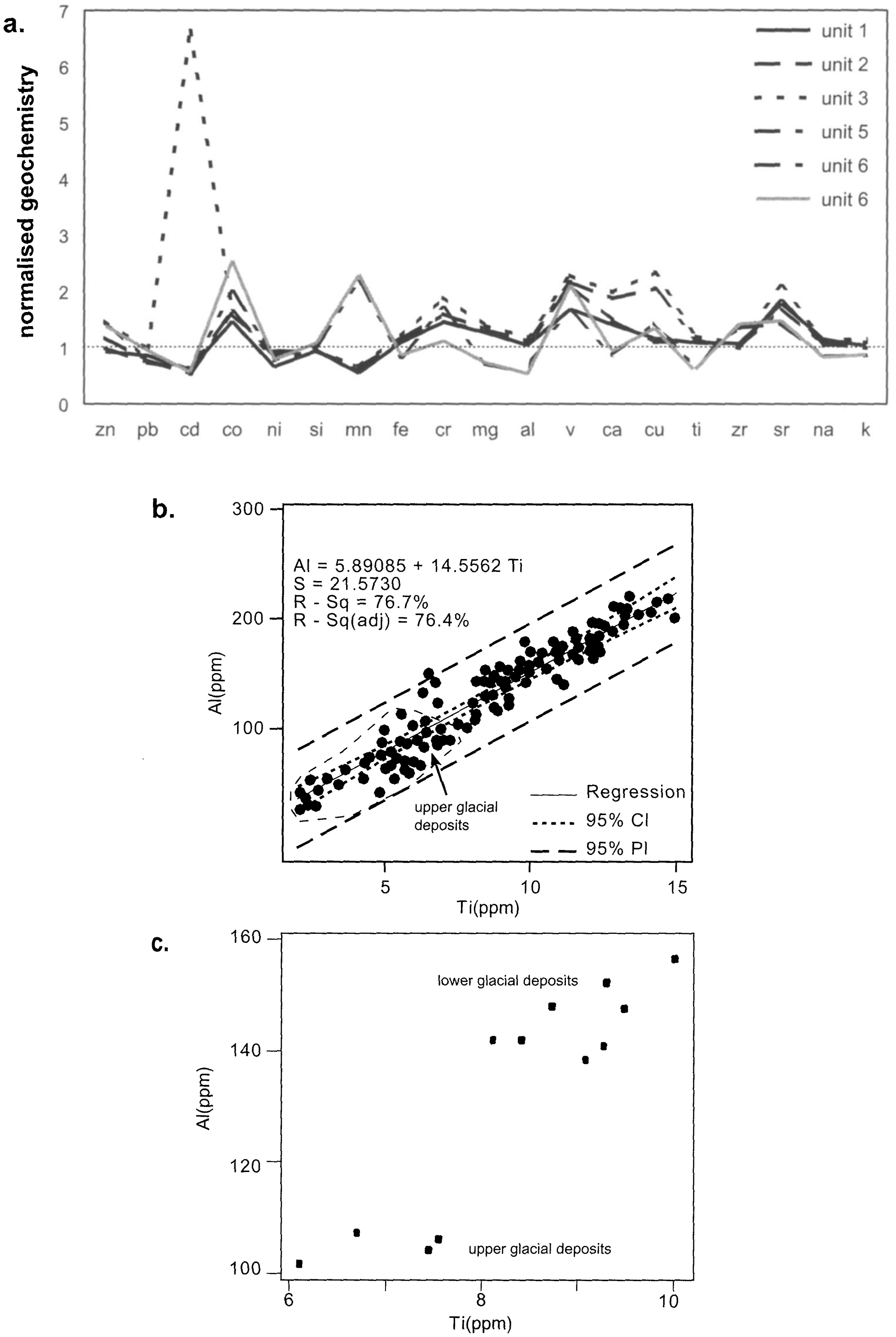

Fig. 3—(a) Normalised geochemical content of the 63–125μm fraction of diamictons exposed at Bridges of Ross (1 represents the average content of elements within diamictons of County Clare and County Kerry). (b) Aluminium and titanium contents of the diamictons of southern County Clare. (c) Aluminium and titanium contents of the diamictons exposed at Bridges of Ross.

at 5cm intervals and prepared using standard techniques (Moore *et al.* 1991). Pollen counts mostly exceed 300 total land pollen grains (TLP), and the nomenclature follows Bennett (1994). Tree pollen is scarce (<7.5%TLP), which, along with high values for, and diversity of, the herbaceous pollen, suggests a stadial flora. There is no evidence of extensive reworking of either Quaternary or, surprisingly, pre-Quaternary (e.g. Carboniferous) microfossils. Not only are obviously (e.g. pre-Quaternary microfossils) reworked grains absent but the preservation status of the grains was generally good. However, given the latter and the unusual nature of the assemblages, the possibility of contamination from modern vegetation needs to be considered. The face was cleaned back before sampling, and there were no clear indicators, such as root penetration. Therefore, for the purposes of the account below, the pollen flora has been presumed to be largely derived from vegetation contemporary with the sediment.

From 100cm to 45cm the representation of taxa is relatively consistent between samples. Poaceae (24–52% TLP) and various *Plantago* species, but particularly *P. coronopus* (maximum 32%) and *P. maritima* (rising to 19% TLP), are dominant. *Spergula*-type, Chenopodiaceae and *Armeria maritima* are also regularly recorded. Above 45cm, although Poaceae and the *Plantago* species remain well represented, peaks occur in the abundance of other taxa. Initially Asteroideae (23% TLP) and Brassicaceae (14% TLP) values peak, followed by a rise in Fabaceae cf. *Ononis* (to 17% TLP). Very high values (45–98% TLP) of Ericaceae (mostly attributable to *Calluna vulgaris*) were recorded at 15cm and 20cm. At 5cm there are peaks in *Spergula*-type (29% TLP), *Potentilla*-type (44% TLP) and *Campanula*-type (19% TLP).

The virtual absence of aquatics and the presence of laminations suggest periodic deposition in active channel environments such as bar-tail pools (West 2000). In such circumstances pollen is likely to be fluvially transported and may be derived from distance, in addition to the floodplain vegetation, and West *et al.* (1993) noted variations in the pollen content between the inorganic and organic flotsam layers. Such changes in sedimentation may account for the differences between the lower and upper assemblages at Bridges of Ross, with the peaks in representation associated with the inwash of organic matter.

A number of the taxa found at Bridges of Ross are halophytes (most notably *Plantago maritima*, Chenopodiaceae and *Armeria maritima*). The occurrence of such taxa in stadial floras is well known (e.g. Bell 1969; West 2000) and has been attributed to saline soils or a reduction in competition. Also present are taxa with affinities for grassland (Poaceae, *Helianthemum*, *Campanula*-type and *Plantago lanceolata*) and disturbed ground (*Ranunculus acris*-type, Lactuceae). Heathland elements include not only the Ericaceae but possibly also the *Potentilla* pollen. Other interesting records include the occurrence of Poaceae grains with large annulus diameters. If of stadial origin, they are likely to belong to the genus *Glyceria* or possibly *Elymus*.

Few stadial floras have been published from Ireland. Of the cold stage sites listed by West (2000), most stadial spectra are from contexts immediately preceding or succeeding interglacials (e.g. Baggotstown, Gort) or interstadials (e.g. Aghnadarragh). The characteristics of the Bridges of Ross assemblages, such as the high *Plantago* and Ericaceae values, appear unprecedented (perhaps suspiciously so). Indeed, on a wider scale, West (2000) commented that, although *Plantago coronopus* pollen has been identified from fifteen sites in Britain and Ireland, it has only been recorded at low frequencies.

Future work will include resampling Unit 4. Sedimentological and plant macrofossil investigations are intended. It is hoped that the latter will not only allow greater taxonomic resolution but also enable sufficient material to be obtained for accelerator mass spectrometry radiocarbon dating.

Brief palaeoenvironmental interpretation

A schematic representation of events recorded at the site is given in Fig. 5. On the basis of its lithological composition, sedimentology and structural characteristics, Unit 1 is a product of subglacial rigid-bed deformation and therefore

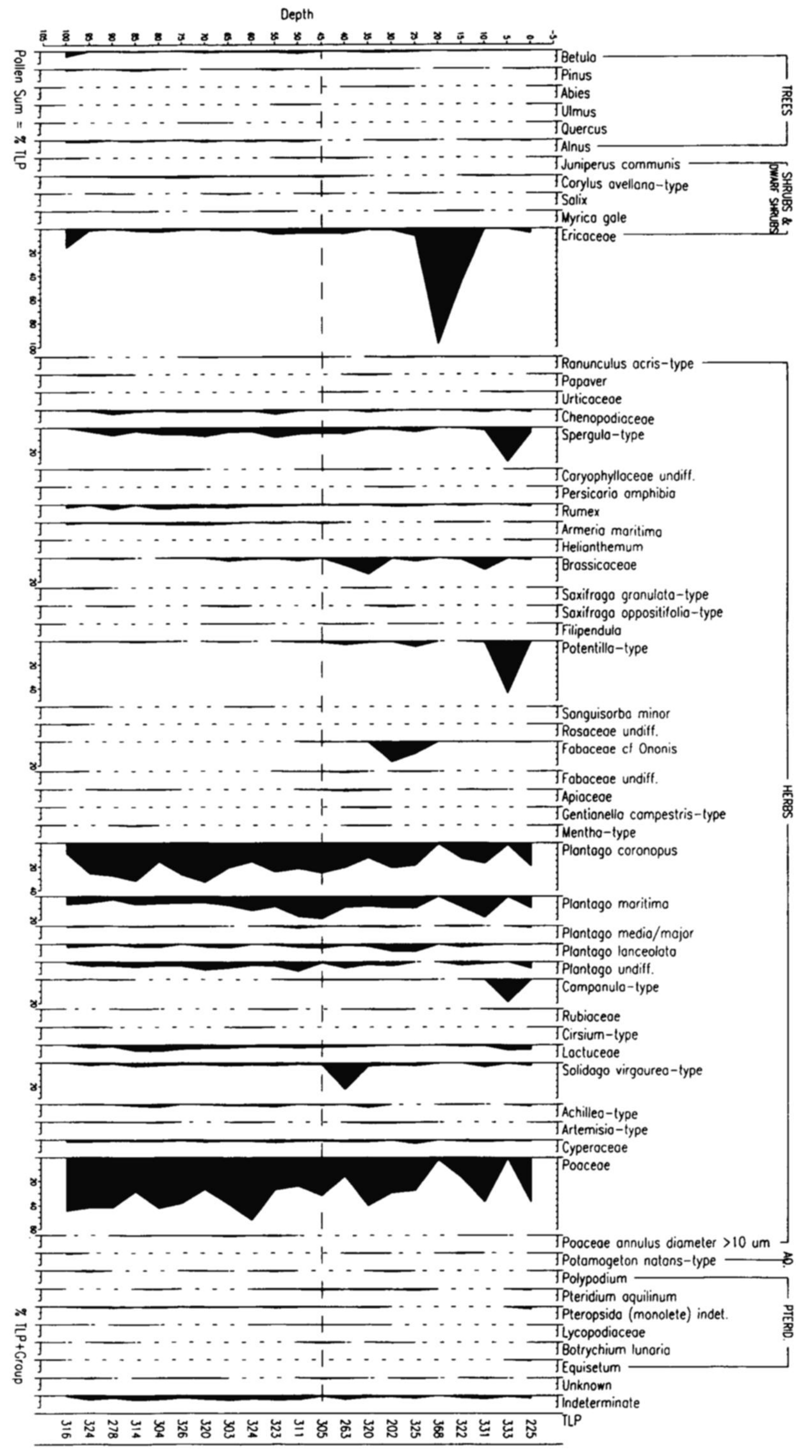

Fig. 4—Pollen spectra obtained from Unit 4 at Bridges of Ross.

may be interpreted as a comminution till (cf. Benn and Evans 1996). Although the structure of this unit is very complicated and the sediment represents the early stages of glaciodynamic strain, the structures and fabric suggest shear stresses propagated from the

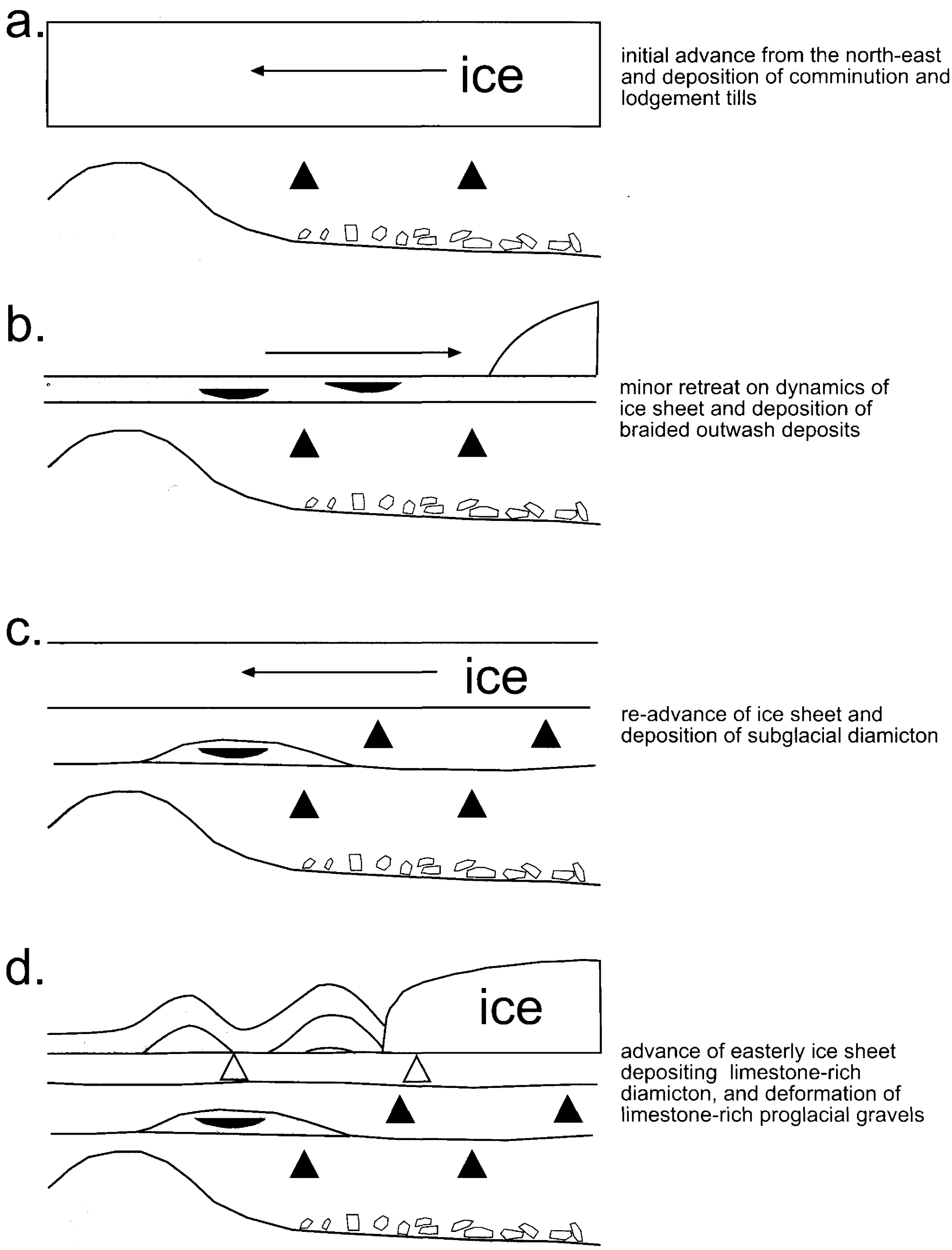

Fig. 5—Schematic representation of Midlandian cold stage glacial dynamics at Bridges of Ross.

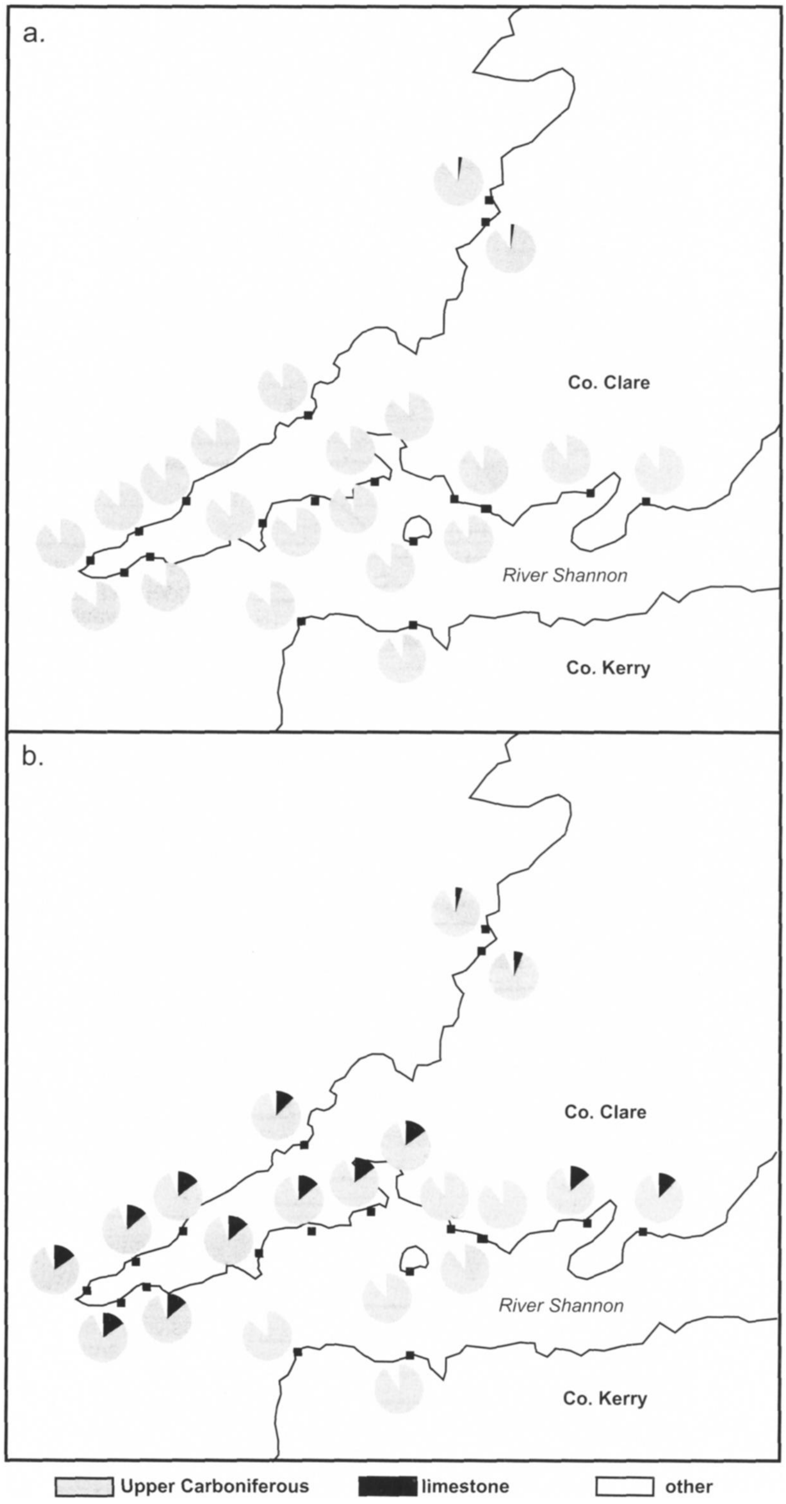

Fig. 6—The lithological composition of upper and lower glacigenic suites in southern County Clare. (a) Upper Carboniferous-rich diamicton suite. (b) Limestone-rich diamicton suite.

east-north-east (Fig. 2). The underlying contact with bedrock may represent a raised wave-cut platform or, as is more likely, may have been formed entirely by glaciotectonic stripping. The lithological characteristics and similar sedimentological structures of Units 2, 3 and 5 suggest subglacial lodgement by a common ice sheet. The heavily sheared silt beds that form at the boundary of these units may represent successive phases in the dynamics of the ice sheet or may be coeval kinetostratigraphic units derived from a post-depositional phase of glaciodynamic stress (see following section). The hook structures, flow structures and attenuated folds within these units all suggest shear stresses emanating from the east-north-east. The occurrence of Unit 4, which contains evidence of slack water deposition, perhaps in a proglacial environment, suggests that there was a phase of withdrawal and re-advance during glaciation.

Units 6 and 7 are likely to have been deposited by a later glacial advance. Although the structural characteristics of both units, and the fabric of Unit 6, suggest movement of the depositing ice sheet from the same direction as the lower diamicton assemblage, the lithological and geochemical properties of these units may indicate a later advance of an ice sheet with a different origin. Similar gravels to Unit 7 can be found near Kilkee and between Kilbaha and Loop Head lighthouse, where they are mixed with sand and locally glaciotectonised bedrock. In addition, limestone-rich diamicton suites form the upper units of sections elsewhere in southern County Clare (Fig. 6). The glaciotectonic forms present at Bridges of Ross are likely to have formed as a consequence of compression against the anticlinal bedrock structure formed in the western margins of the cove. Therefore, the structural properties of the glacigenic deposits at Bridges of Ross may be misleading as indicators of regional glacial flow patterns. It should be noted, however, that acid groundwaters may have leached the carbonates from the lower glacigenic materials, as recognised at other sites in south-west Ireland (see Warren 1985). However, the sudden increase in limestone clasts between Units 5 and 6 may be difficult to explain with this theory.

Stratigraphic importance of the site

The deposits exposed at the site have important implications for the number, extent and timing of glaciation in south-west Ireland. Though the subject of ongoing analysis, Unit 5 appears to represent a rare cold stage organic deposit, which has accumulated during a phase of recession in the ice sheet that deposited Units 1, 2, 3 and 5. The period of time represented by this unit is difficult to ascertain. However, if the couplets reflect seasonal influences, this phase lasted at least 100 years.

It is likely that two distinct glacigenic formations are represented at the site. Similar stratigraphic relationships are present at other localities in southern County Clare where lower Upper Carboniferous-dominated glacigenic units are overlain by diamictons with high limestone contents. Although many authors have interpreted the lithological differences as a function of leaching by groundwater (e.g. Warren 1985), geochemical indices also suggest that the suites have differing provenance areas (Richards 2002; see following section and Figs 6 and 7). The upper deposits at Bridges of Ross appear to have been deposited close to the margins of the ice sheet, and the structures in the upper gravel are consistent with proglacial deformation. This inference is borne out by the limited spatial extent of other limestone-rich glacigenic deposits in the area, as the suite does not extend into northern County Kerry. Finch and Synge (1966) also concluded that this part of Loop Head was not glaciated during the Midlandian. Striae measurements played an important part in the debate on penultimate vs ultimate glaciation. Finch and Synge (1966) restricted north-east/south-west-flowing ice to the last glaciation and east–west-flowing ice to the penultimate glaciation. Unpublished observations by O. Bloetjes show more complex striae patterns, which cannot be accounted for by east–west flow alone. Striae have been found beneath different till facies that are variable over very short distances. These differences can be explained by (a) deviatory

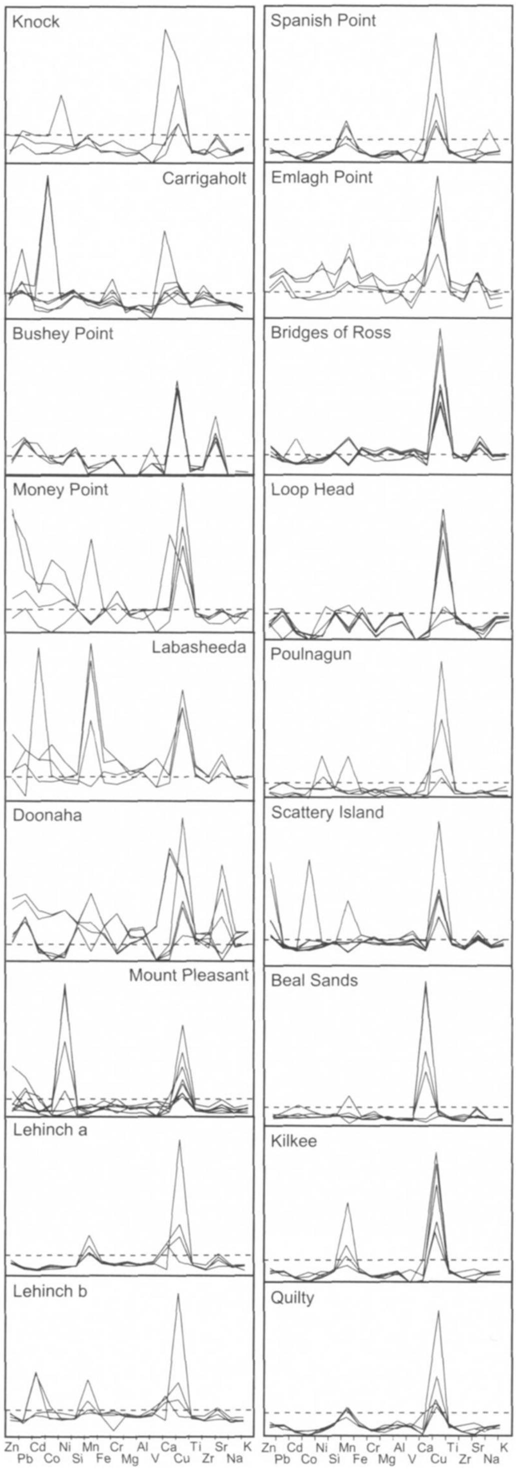

Fig. 7—Spidergrams of the normalised geochemistry of diamictons in southern County Clare. 1 represents the average element concentrations for diamictons of southern County Clare (see Fig. 1 for sampling locations).

flow around obstacles, (b) ice-margin oscillations, (c) the dominance of coalescing ice lobes (with striae patterns reflecting which ice lobe is stronger) or (d) changes in ice-flow patterns over time. Striae readings taken in the eastern part of the Shannon Estuary exhibit a consistent east–west direction. This suggests that the area was affected by two ice lobes, one emanating from the Shannon Estuary and one derived from the north/north-east. The general lack of periglacial features in the region suggests that at least the latter phase of glaciation occurred in the late Midlandian.

Lithostratigraphic framework for the glacial deposits of southern County Clare

In County Clare, a lower suite of glacial deposits is represented by a diamicton assemblage with large percentages of Upper Carboniferous clasts, relatively high levels of Al, Ti, Pb, Zn, Cu and Ni, low carbonate contents and low magnetic susceptibility values (Richards 2002; Figs 6, 7, 8). The type site for these deposits is exposed at Lehinch (Richards 2002), after which the formation is named. It appears that the ice that deposited these diamictons was derived from the north-east and that this glaciation was more extensive than previously recognised by other workers (Fig. 9). The organic bed exposed at Bridges of Ross is formally recognised here as the Bridges of Ross Member of the Lehinch Formation. The lower diamicton assemblage is overlain at a number of sites in south-western County Clare by limestone-rich glacigenic facies. Tills that form part of this suite are characterised by higher Ca, Sr, Mn and Mg contents, higher $CaCO_3$ equivalents and higher lfmss values (Richards 2002). This suite is formally designated as the Loop Head Formation, after the location at which its lithostratigraphic characteristics and stratigraphic relations are best demonstrated (Richards 2002). From geomorphological studies (Finch and Synge 1966) it appears that the ice sheet responsible for depositing these units emanated from the east and, again, extended further than previously thought.

Figure 8 outlines a formal classification of the glacigenic deposits of southern County

<table>
<tr><td>Warm stage</td><td colspan="3">Alluvial deposits</td></tr>
<tr><td rowspan="2">Cold stage</td><td colspan="2">Loop Head Formation
(type section at Bridges of Ross)</td><td>Ice-sheet advance from the east, with associated, localised, kinetostratigraphic members.

75–90% Upper Carboniferous clasts; rare limestone clasts; exotic component includes Galway Granite. High levels of Al, Ti, Pb, Zn, Cu and Ni. Lfmss readings typically 0.1–1; $CaCO_3$ content 0–35%.</td></tr>
<tr><td>Lehinch Formation (type section at Lehinch)</td><td>Bridges of Ross Member (stadial deposit at Loop Head)</td><td>Ice-sheet advance from the north-east with associated, localised, kinetostratigraphic members.

8–20% limestone clasts; Upper Carboniferous component generally less than 75%; Galway Granite absent. High levels of Ca, Sr and Mg; low levels of Al and Ti. Lfmss readings typically 0.8–2; $CaCO_3$ content 35–65%.</td></tr>
<tr><td>Warm stage</td><td colspan="3">Raised beach deposits</td></tr>
<tr><td>Cold stage</td><td colspan="2">Ballybunion Formation</td><td>Glacigenic deposits

Limestone and shale-rich till</td></tr>
</table>

Fig. 8—Proposed lithostratigraphic framework for the glacigenic materials of southern County Clare.

Clare, following the recommendations of Salvador (1994). It also includes a brief description of the compositional attributes of the units in order that they may be accurately distinguished. This framework is based on lithostratigraphic criteria, setting aside chronostratigraphic determinations or inference, and is limited to the lithostratigraphic characteristics of glacial deposits, ignoring the characteristics of periglacial deposits (both *in situ* deposits and those derived from slope processes). It will permit the incorporation of new litho- and biostratigraphic evidence resulting from ongoing and future work, avoiding the complete reinterpretation that often follows the application of, often problematic, relative and absolute chronostratigraphic results.

Conclusions

The sediments at Bridges of Ross and the surrounding area incorporate units that record the dynamics of two distinct ice sheets during stadials of the last, Midlandian, cold stage. Recent work by Bowen *et al.* (2002) suggests

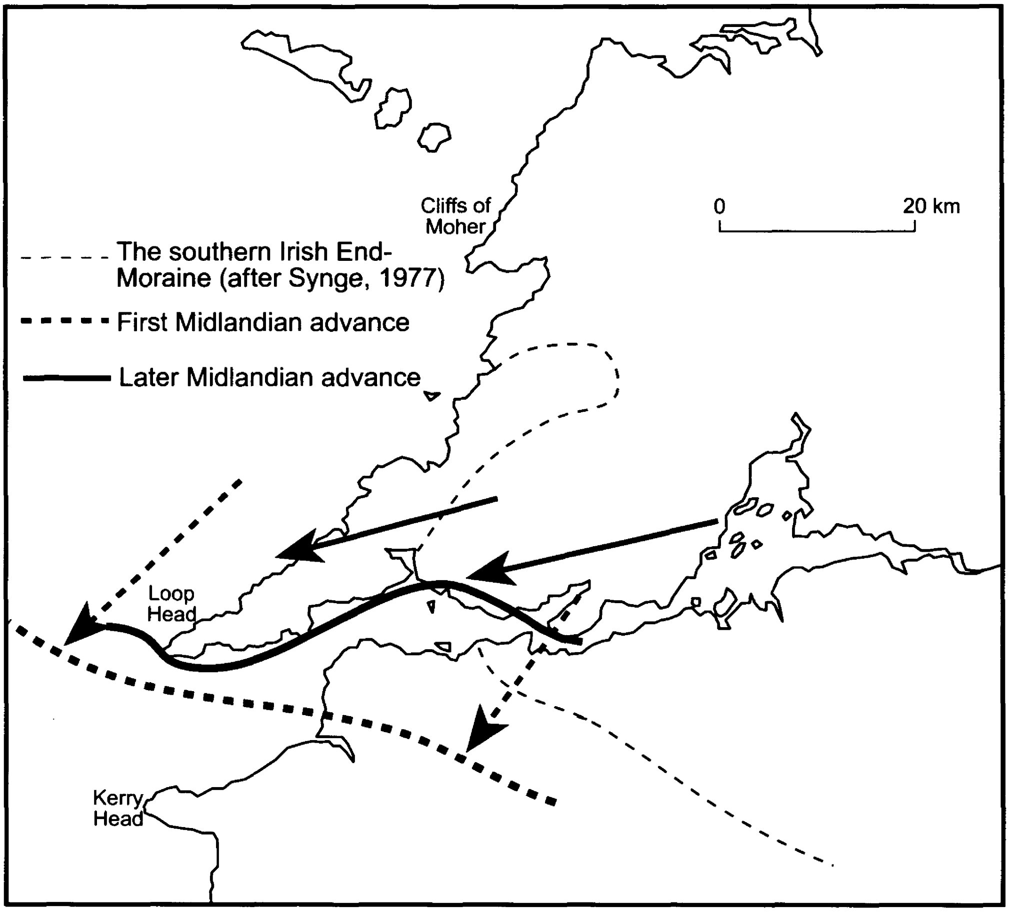

Fig. 9—Projected Midlandian ice limits in southern County Clare.

that the two suites of glacial deposits that overlie the Loop Head Peninsula are likely to have been deposited during the Glenavy Stadial of the late Midlandian cold stage. The earlier, glacigenic materials of the Lehinch Formation are likely to be associated with the late Midlandian 'Main Event', peaking at 20–24ka BP, while the overlying deposits of the Loop Head Formation are probably associated with the Drumlin Re-advance of Synge (1969), which may have been associated with Heinrich Event 1 as postulated by McCabe *et al.* (1999).

Further work should concentrate on this region, as it offers arguably the best record of late Quaternary environmental change in southern Ireland. The stratigraphic framework proposed here may act as a basis for further work, which must include further detailed studies of the Bridges of Ross Member of the Lehinch Formation. If this, tentative, chronological interpretation is correct, the Bridges of Ross Member represents fluviatile sedimentation during the later Midlandian, immediately before the Drumlin Re-advance. After resampling, ongoing analysis of plant macrofossil, diatom and radiolaria content of the unit will present further evidence regarding the nature and age of the stadial environment, cold stage sea-level change and the relative age of glacial advances that have affected south-west Ireland.

Acknowledgements

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