Uíbh Fhailí ⁊ Iar Chill Dara

Offaly & West Kildare

IQUA

Treoir Allamuigh Uimhir 10

Field Guide No. 10

UIBH FHAILI AGUS IAR CHILL DARA
OFFALY AND WEST KILDARE

le/by

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le dréachtaí ó
with contributions from

C. COXON AND M. TUBRIDY

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Cumann Staideár Ré Cheathartha na h-Éireann
Irish Association for Quaternary Studies

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PREFACE

"How can one educate people to regard the Midlands as a interesting landscape in a cultural climate which values dramatic scenery?" (question posed by M. Tubridy on page 62). How can we convince people, particularly Midland people, to appreciate the Midland environment in an economic climate where unemployment is high and consumerism is dominant. These questions may seem far removed from the science of Quaternary deposits, yet IQUA may have a role to play in ensuring a favourable outcome.

Three of the dominant physical features of Offaly and west Kildare are Slieve Bloom, the esker ridges and the peatland, and these also dominate this field guide and the two-day field excursion (Fig. 1). Only Slieve Bloom is generally appreciated for aesthetic and leisure purposes; the eskers and peatlands have tended to be appreciated for their economic and energy values. Environmentalists and conservationists need to understand the beneficial economic changes to the Midlands brought about by the development of the peatlands. About 5,000 people are employed directly by Bord na Móna in the Midlands, hundreds more are employed by the ESB and there are thousands of service workers and families who benefit from peatland development. The benefits are not just economic, they are social as well. For instance, it could be argued that the All-Ireland football and hurling titles won by Offaly in the last twenty years are directly related to the improved economic conditions. There is however a nagging fear about the future economic and social consequences when the peat resource has been exhausted in 15-20 years time. This situation is not conducive to peatland conservation. How can it be overcome? Pride in one's own home area by Offaly and Kildare people, assisted by attempts to provide alternative employment opportunities in the future, are essential. Condescension or patronising attitudes by outsiders must be guarded against. How can IQUA help?

Many Midland people are becoming more aware and proud of their own environment and heritage. This sense of pride has not only been aided by Offaly Vocational Educational Committee and Offaly County Council, but also the work of David Bellamy (Bellamy, 1986), John Feehan (Feehan, 1979) and the Environmental Sciences Unit, T.C.D. (Turbidy and Jeffrey (eds), 1987). IQUA members, by producing this field guide, arranging the field trip and hopefully by encouraging and assisting future studies, will increase environmental awareness and the sense of pride of the local people, and in a small way, by visiting the Midlands with their friends, will benefit the local economy.

(DD)

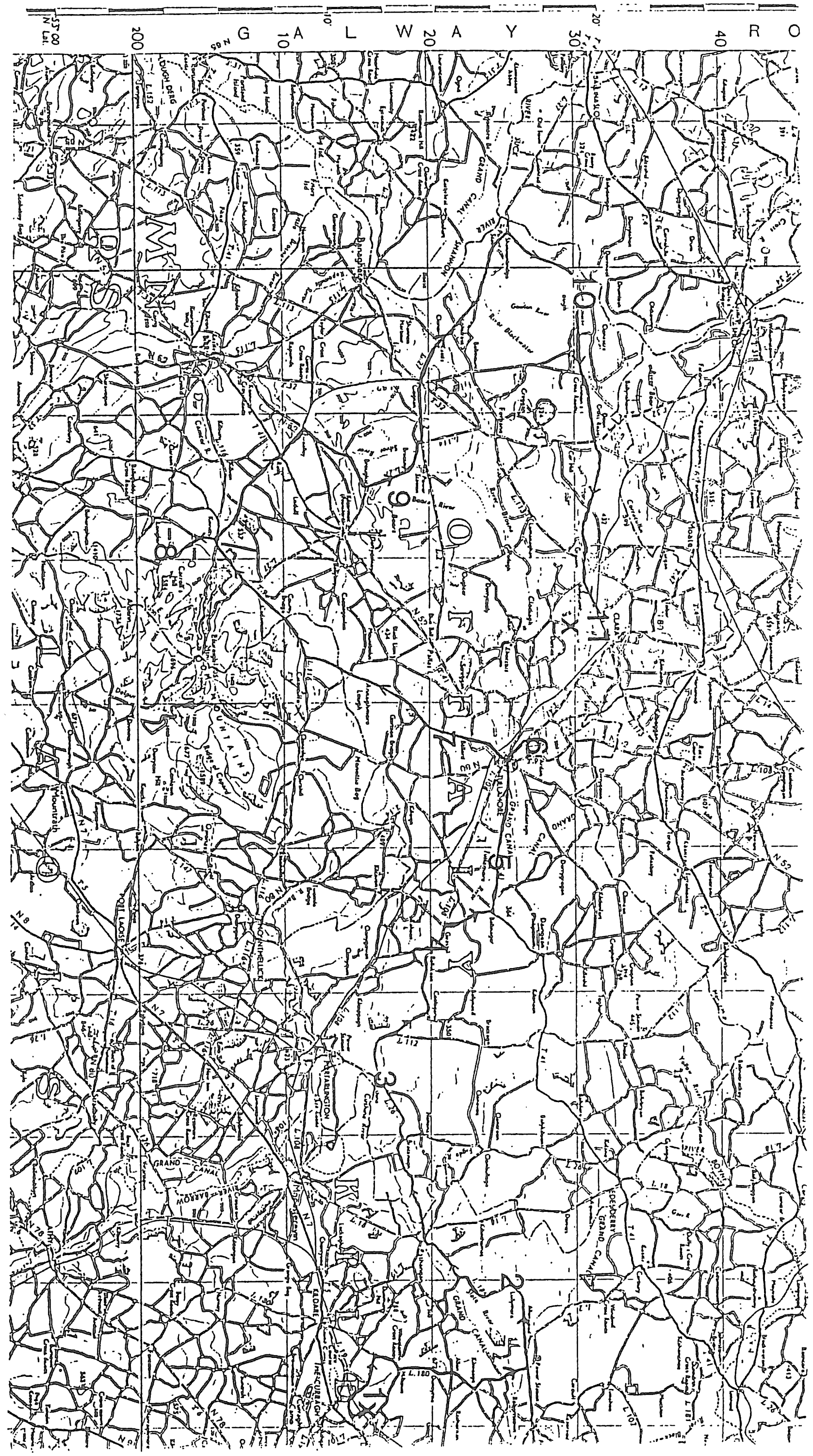

Fig. 1 Localities of sites described in the guide

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BEDROCK GEOLOGY OF COUNTY OFFALY

INTRODUCTION

Offaly forms part of the Central Lowland of Ireland, which has an undulating topography of Quaternary deposits floored mainly by limestones. The higher topographic features - Slieve Bloom, Croghan Hill, Bellair Hill, Cor Hill, Endrim Hill and the smooth sloped hills in east Offaly have rock at or close to the surface. However the bedrock in most of Offaly is masked by the Quaternary deposits - peat, sand, gravel and till - which form many of the lower irregular topographic features.

The rocks are folded with the axes of the folds trending NE-SW. The older sandstone rocks are present in the anticlines at Slieve Bloom, Moneygall, the Cloghan-Ferbane-Lemanaghan area and near Clonmacnoise. The remainder of Offaly consists of a variety of limestones with a small area of volcanic rocks forming Croghan Hill. Two sets of faults are present, the dominant set trends NE-SW and the subsidiary set trends NW-SE.

A bedrock geology map is given in Figure 2. It is a simplified map compiled from the following sources:

P. Bruck, C.V. McDermot, C. Young;
Geological Survey one-inch maps;
Aquitane Mining (Ireland) Ltd.;
Amax Exploration Irl. Ltd.;
Irish Base Metals Limited;
Rio Tinto Finance and Exploration Ltd.;
Tara Prospecting Ltd.

SILURIAN ROCKS

These rocks, the oldest in County Offaly, are present in the core of Slieve Bloom and near Moneygall. They consist of grey and grey-green clayey sandstones and slates (slig). They were slightly metamorphosed by a phase of folding at the end of the Silurian Period.

DEVONIAN ROCKS

Overlying the Silurian rocks in Slieve Bloom are a mixed sequence of red sandstones, siltstones, mudstones and occasional conglomerates, which were deposited on the Devonian land mass by meandering rivers. These in turn are overlain by coarse-grained pale grey or yellow sandstones. These

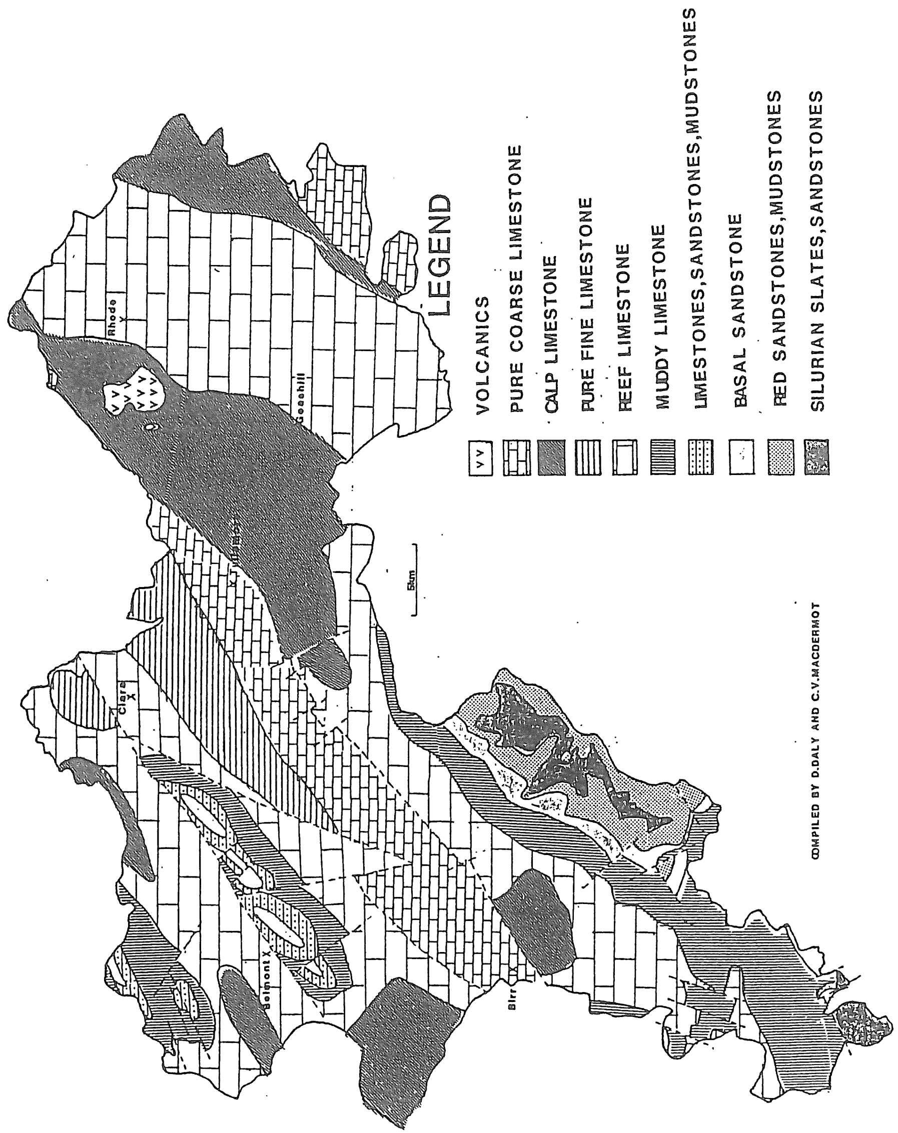


Fig. 2 Bedrock geology of County Offaly

sandstones, called the Basal Sandstone, are also present in the Cloghan-Ferbane-Lemanaghan area and north of Clonmacnoise, although they are seldom exposed at the surface.

CARBONIFEROUS SEDIMENTS

At the beginning of the Carboniferous Period, a sea gradually spread northwards and inundated Offaly. All the remaining rocks - mainly limestones - were deposited as sediments under a range of marine environments caused by variations in sea depth and the amount of mud washed in.

The onset of marine conditions caused the deposition of an alternating sequence of limestones, sandstones and mudstones which now occur in the Cloghan-Ferbane-Lemanaghan area and near Clonmacnoise. These are overlain by dark muddy limestones, which also surround Slieve Bloom and stretch southwards to Moneygall.

The "reef" Limestone is the most abundant rock type in County Offaly, stretching as three broad bands across the county in a NE-SW direction. It is a light to medium grey, fine-grained, poorly bedded limestone containing many fossils. It was deposited as interfingering mounds of fine organic, probably mainly algal, material in a pure sea when the sediment input from the land was minimal. The area of "reef" in the east of the county also includes overlying pale, poorly bedded, pure limestones and oolites called the Allenwood Beds. However, there are insufficient data to allow them to be delineated on the map. Dolomite is also common in this area (Dolomitization is caused when magnesium (Mg) is introduced into limestone ($CaCO_3$) forming dolomite ((Ca, Mg) CO_3). This results in a theoretical reduction in volume of the rock which frequently leaves it soft and friable).

Throughout most of Offaly the Reef Limestone is overlain by a dark grey or black, well bedded, muddy limestone called the Calp Limestone. It is rarely fossiliferous and often contains chert. However, north-east of Clara and between Clara and Tullamore, a pure limestone, which is mainly fine grained and fossiliferous, with thin chert horizons and nodules in the lower part, is present.

The youngest limestone forms the spine of the county stretching from Birr northeastwards through Kilcormac and Tullamore to the border with Westmeath. It is a pure, pale, thick-bedded, coarse-grained limestone which is locally dolomitized. A small area of similar limestone, although with

thin shale bands, is present in the south east of the county at Bracknagh.

CARBONIFEROUS VOLCANICS

The highest hill in east Offaly - Croghan Hill - is an extinct volcano which was active in Carboniferous times. It consists of dark grey or black basalt and dark green volcanic ash.

(DD)

PLEISTOCENE GEOLOGY

MORPHOLOGY

The central midlands, including counties Offaly and Kildare exhibit a topography that is dominated by glaciofluvial landforms relating to the final deglaciation of the area at the close of the last glacial stage, the Fenitian. The most prominent features among these are the extensive esker chains that extend across the two counties as far west as the Shannon (Fig. 3) and continue westward into the heart of County Galway (Fig 4). Apart from the eskers, there are large spreads of glaciofluvial outwash gravels and glacio-lacustrine sands and gravels. The Curragh of Kildare is composed of a complex suite of glaciofluvial, glaciolacustrine and glacial sediments in excess of 60m thick. Its present surface expression, a rolling plateau standing less than 30m above the surrounding topography was probably formed by inwashing of glacial and glaciofulvial debris into a dead ice, or interlobate, basin during deglaciation.

Natural sections or exposures are rare in the glacigenic sediments and the reliance geologists are forced to place on anthropogenic sections, particularly in gravel pits, may give the impression of more sand/gravel than in reality exists. Reconnaissance work in County Offaly shows that many of the sand/gravel units are small and are interbedded with diamictons and in places it is not possible to map out separately the sand/gravel units and the diamicton units during a reconnaissance mapping project. This has led to the term "Till with gravel" being employed to categorise the sediments over extensive areas (Fig. 3). This situation is not unusual in sedimentary suites deposited in a deglacial environment where both the environment and the sediment associations have often been termed chaotic. As well as gravel and "till with gravel" large spreads of diamicton (interpreted as till) are common.

Apart from the esker chains, the surface form of the sediments is rarely expressed in easily identified morphological units, exceptions include moraines associated with eskers near Tullamore (Farrington and Synge, 1970), a thick band of hummocky "morainic" terrain along the western flanks of Slieve Bloom, a washboard moraine sequence south of the Tullamore esker in Offaly and some discontinuous moraine ridges in west Kildare. None of these features can be easily extended beyond the immediate localities in which they have been identified. On a broader scale the surface morphology as reflected in the drainage pattern is expressed north of the Slieve Blooms in a series of east-west trending low ridges and valleys while west and southwest of the mountains the trend of similar, though smaller scaled, features is northwest-southeast. As the raised bogs occupy the lower ground the Quaternary sediment map (Fig. 3) picks out this alignment. More significantly, it also reflects the pattern of esker alignment and, west of Slieve Bloom, the striae orientation. Whether this topography is an expression of ice moulding/streamlining or glaciofluvial outwash systems it reflects the pattern of ice movement during deglaciation.

PETROGRAPHY OF THE DEPOSITS

The glacigenic deposits in the Midlands are derived largely from the underlying Carboniferous limestone. Where they directly overly limestone in County Offaly the total limestone and chert content of the glacigenic deposits averages 80-90% with small amounts of Devonian sandstone, Silurian shale and Carboniferous shale. Galway granite is a common erratic particularly in the flanks of Slieve Bloom where as much as 1.0% of phenoclasts (in a count of 400 stones) in the 5.6-11.2mm size range have been recorded as granite in petrographic analysis of the glacigenic deposits. Such erratics have been recorded in till, glaciofluvial gravels and morainic gravels and in south Offaly are commonly found as surface boulders. They have been found as far north as Clara (in the Clara esker) and extend south of Shinrone.

Petrographic anlaysis of the phenoclasts in the glacigenic deposits show that limestone and chert have been carried over the Devonian sandstones and Silurian shale of the Slieve Blooms as the dominant petrographic type for a distance of about 3km. After this distance the limestone proportion begins to drop suddenly and within 5-6km it has disappeared entirely from the 5.6-11.2mm phenoclast range. This is very similar to the situation that obtains on the northern flanks of the Galty Mountains in south Limerick

(Synge, 1970). It is clear that two interdependent factors contributed to the rapid disappearance of the limestone component: 1) an exponential distance decay in carry-over and 2) a rapid decalcification of the sediments after the calcerous component has fallen to a critical level. Further complications in this mechanism are outlined below. Generally speaking the glacigenic deposits and the periglacial slope deposits of the Slieve Blooms above about 250m OD are dominated by Devonian sandstone and/or Silurian shale and are noncalcareous.

STRATIGRAPHY

Outside the deep glens of the Slieve Blooms it is difficult to view the stratigraphy of the glacigenic deposits of County Offaly. There are no properly logged borehole records and no clear stratigraphic record. Within the Slieve Bloom glens coarse, often poorly sorted, gravels are often seen to overly strongly compacted diamictons. The diamicton varies from a grey, silty limestone-rich till to a red, sandstone dominated till. These tills are generally over-consolidated, colour banded and sub-horizontally jointed. They are almost certainly basal deposits and the colour banding suggests they may be melt-out deposits although there is in places evidence of shearing and phenoclast lodgement so that it is likely that both lodgement and melt-out facies occur. Fabric analyses and erratic transport indicate an ice movement from the west.

The overlying coarse gravels have similar petrographic composition to the underlying tills. The sedimentary structures in these gravels, which are often as much as 20m thick, have not been examined in detail. They are interpreted as proximal glaciofluvial (possibly in part glaciolacustrine) gravels deposited during the down-wasting of the ice sheet. In places they are morainic, contain diamicton lenses and are clearly ice-marginal deposits. There is no evidence that they are associated with any specific glacial halt stage or readvance. It is more likely that they simply accumulated in a convenient topographic position between the mountains and the ice during general deglaciation and it need not be expected that there is an equivalent "moraine" on the lower ground to the north or to the south. Thus there is no evidence of any more than one glacial event in County Offaly.

The deposits of west Kildare offer a little more insight into the glacial history of the area. A reverse circulation borehole at the Curragh Camp showed 63m of Quaternary sediments. These included three diamicton units separated by sand and gravel units. Persistent Wicklow granite in one of the gravel units suggests a fluvial or glaciofluvial imput from the east after initial glaciation but before final deglaciation of the area. Thus, there must have been either an early ice advance from the east into west Kildare or a period between two glacial events during which river gravels were deposits by a river flowing west from the Wicklow Mountains.

THE PATTERN OF GLACIATION AND DEGLACIATION

All the evidence points to a strong ice movement from the west across north Offaly and into Kildare. This ice overtopped the Slieve Blooms but was partly deflected by them to flow southwestward across southern Offaly. The pattern of the esker chains and the Galway granite erratic distribution indicates that during deglaciation the ice-front retreated westward to Galway. There is no evidence of any significant readvance of the ice-front or change in direction of ice-movement during deglaciation.

There is evidence of considerable ponding of melt-water during deglaciation in the clays that drape the tops of many of the eskers and the large deltaic deposits associated with many of them. It is possible that many of the diamictons in the low-lying areas are subaqueous deposits although it should be noted that no clear evidence of drop stones has been observed.

After the ice had melted, periglacial conditions obtained for some time as is evidenced by involutions in the esker gravels at Geashill. At this time also it is likely that the diamictons on the steep slopes of the Slieve Blooms were reworked by gelifluction. This is evident from recent sections exposed in building forestry roads.

In the postglacial period extensive alluvial deposits accumulated in the flat river valleys (Fig. 3). Shell marls also accumulated (Appendix 1) and peat began to develop on the poorly drained lowlying areas.

THE ESKERS

Eskers (a corruption of the Gaelic term eiscir) are typically long sinuous sand/gravel ridges. They are composed of glaciofluvial sediments which accumulated in subglacial or englacial tunnels or, in part, close to the glacier snout in ice walled channels. They reflect the chief meltwater routes taking water from the glacier system to its margins and usually parallel the most recent direction of ice movement. They commonly contain a variety of sediment types ranging from very coarse boulder gravels to

lacustrine silts and clays. The coarsest sediments reflect very high energy environments consistent with subglacial tunnels while the finer deposits may relate to subglacial or ice-marginal ponding. The sediments are often faulted towards the sides in response to the removal of a supporting ice-wall. More complex faulting also occurs reflecting ice-melt under the deposit at ice-push of one form or another.

The eskers of the Midlands are among the finest in the world although Charlesworth, (1928) mistakenly regarded many of them as moraines. They gave the term to the scientific literature and have a pedigree in Irish literature that extends back to Old and Middle Gaelic sources. Following an ancient tradition, many roads across the Midlands have been built on the eskers which provide excellent foundation through otherwise boggy or difficult terrain.

The eskers of the Irish midlands may be regarded as the original or proto-type eskers. They are known and visited by geologists from all over the world. It is unfortunate that so many of them are being systematically (and often haphazardly) destroyed for the purpose of sand/gravel extraction. It is hoped that the recent raising of awareness of the amenity value of midland bogs will be accompanied by an equal awareness of the essential contribution which the eskers make to the Midland landscape and to our aesthetic and scientific enjoyment.

(WPW)

HOLOCENE GEOLOGY

PEATLAND

Peatland covers 16.2 per cent of the land surface of Ireland. Peat is a biogenic deposit developed in the postglacial (Holocene) period within the past 10,000 years. Three basic peat formations are recognised in Ireland:

1) raised bogs of the Central Plain;
2) blanket bogs of the western seaboard and the upland regions;
3) fen peats.

The emphasis here is on the formation of fen and raised bog landscape units as characteristic elements of the Midlands.

Peat began to form in Ireland early in the postglacial period. Climate throughout the postglacial varied and peat deposits reflect these changes either by a change in the peat sediment type or by fossil pollen assemblages preserved within the peat. These relationships between climatic changes and peat type are outlined Table 1.

Table 1: Chronology, post-glacial climate and sediment type for Ireland.

Years before present (1950)	Climate	Period	Sediment Type
12,000	Cold	Lateglacial	Clay
	Mild		Limnic/telmatic (aquatic/ semi-aquatic)
	Cool		Clay
10,000	Temperature rising	Pre-boreal	Limnic (aquatic)
9,600	Warm-dry	Early boreal	Limnic/telmatic (aquatic/ semi-aquatic)
8,000	Climatic optimum	Late boreal	Terrestrial
7,500	Warm-wet	Atlantic	Mainly ombrogenous terrestrial
5,100	Warm but rather dry	Sub-boreal	Mainly ombrogenous terrestrial
2,500	Increasing wetness and falling temperature	Sub-Atlantic	Mainly ombrogenous terrestrial

The mire (wetland) types which occur in Ireland can be classified into two broad groupings (a) ombrogenous mires (raised and blanket bogs) where continued growth is due to the influence of atmospheric precipitation and (b) topogenous mires (fen peat types) where development is controlled by the topography and the groundwater table. The origins of topogenous mires and the subsequent development of raised mires vary from one location to another. Variables which influence these formations are related to the local hydrology e.g. continuity of supply, nutrient content, depth, rate of flow and the climatic factors of sunshine, temperature and evapo-transpiration. These affect the productivity of the eco-system(s) by influencing the phyto-sociology and bio-mass production in a given location.

Raised bogs are complex structures of organic debris attaining thicknesses of nine to twelve metres in the undrained state, depending on the underlying topography. The stratigraphy of the sediments which comprise a raised bog fall into three categories: a basal tier of peat types formed under the influence of minerotrophic groundwaters; and sub-surface and upper tiers comprised of humified and poorly humified **Sphagnum** peats respectively, formed under nutrient conditions of base-poor atmospheric precipitation.

Fen peats are ubiquitous, occurring as the basal tier of raised bogs, in river valleys, in poorly drained hollows and at the margins of raised bogs. Extensive development of ombrogenous **Sphagnum** peat has never taken place in these locations because of continued flushing by base-rich ground waters preventing the development of oxyphilous plant species.

Undisturbed fens are rare in Ireland, especially in the Midlands and those still in existence are being severely threatened by agricultural developments. Most fens have been drained and cultivated in the past but have reverted to poor pasture. In some areas drainage has deteriorated to the point where plant species are more characteristic of the undrained fen.

In the Midlands from west Kildare to the River Shannon the peatland landscape is collectively known as the Bog of Allen. The in situ raised bog, once a characteristic feature of the landscape, formerly covered 311,300ha.

Over the past two to three centuries it is calculated in gross terms that 252,000ha of raised bog have been modified through turf cutting. This is divided into 172,000ha hand-cutover and a projected 80,000ha of industrial peat areas. A further 92,000ha of previously drained fen peats under varying qualities of permanent pasture also occurs throughout the country. In Table 2 areas are given for unreclaimed and reclaimed hand-cutover raised bog and reclaimed fen for the principal midland counties containing larger areas of peatlands.

Across the Midlands the physiographic relationship between peat (organic) and mineral soils is shown in Figure 5.

A distinct separation can be made between the peat materials associated with hand cut-over raised bog and those of industrial peat and drained fen areas (Table 3).

TABLE 2. Total peatland areas and human modified categories for Midland counties.

County	Peatland Area(ha)	% Total Soil Resource	Cut-over Unrecl.(ha)	Raised bog Recl.(ha)	Fen
Kildare	24317	14.4	6136	364	5844
Offaly	64146	32.2	13520	1457	13901
Laois	20859	12.3	5787	1012	5140
Meath	10289	4.4	1643	2835	3901
West meath	37278	21.5	9012	7569	11026
Longford	21759	20.9	7345	1345	1232
Roscommon	45782	18.7	27579	1080	4828
Tipperary	33953	8.0	4395	1165	4298

TABLE 3. Peat type categories associated with human-modified peat areas.

Hand cut-over raised bog (red bog)	Sphagnum Sphagnum dominant Calluna dominant Sphagnum peat decomposed Cyperaceous dominant
	Wood fen
Industrial fen and reclaimed fen (black bog)	Carex sedge Phragmites

Raised bog peats formed in low nutrient and fen peats in relatively high nutrient environments. Data characteristics of these different peat materials are shown in Table 3.

In comparison to mineral soils, peat materials are characterised by their high water holding capacity, lower bulk density and their ability to be worked at higher moisture contents due to their low plasticity index. Those of raised bog origin have compared to fen lower values for bulk densities, ash pH, total nitrogen and exch. Ca/Mg ratio. Peat types containing Sphagnum have higher rubbed fibre values. In practical terms raised bog peats require larger application of ground limestone to raise top soil pH to 5.5 and in general given equality of outfall they are more difficult to drain. A wide variation in hydraulic conductivity exists between the different peat types, Galvin (1976) gives figures for the

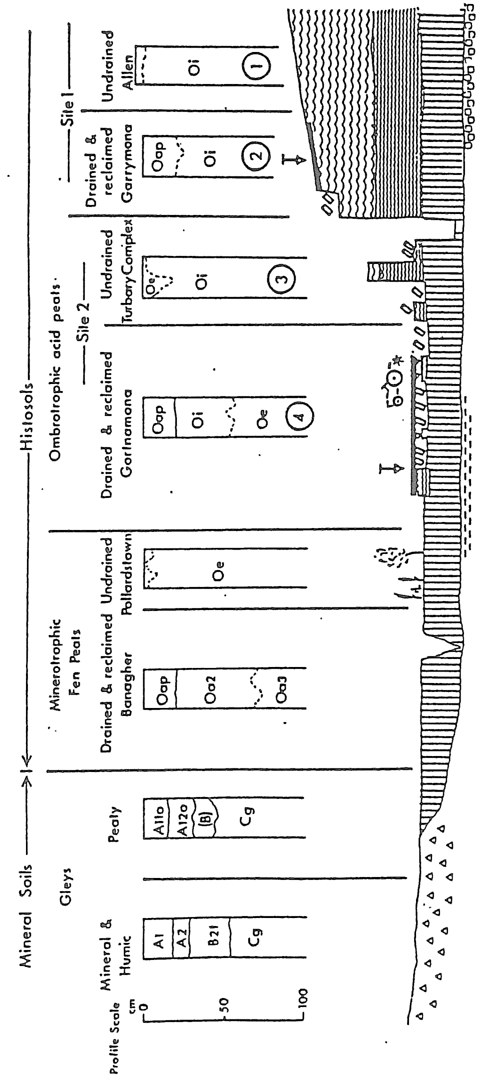


Fig. 5 Schematic cross section of typical landscape with organic soils in the Irish Midlands showing the positions of the study profiles.

different peat types as follows:

Sphagnum peats	209mm/day
Humified Sphagnum	28mm/day
Wood-fen	561mm/day
Phragmites fen	126mm/day

The drainage potential of the peat types listed in Table 3 is in the order: Sphagnum peats Sphagnum dominant Calluna/humified Sphagnum/ cyperacous for hand cut-over areas and for the industrial and reclaimed fen areas wood-fen Carex sedge Phragmites.

The drainage requirements for any particular area has to be judged on its geographical position, past history of turf cutting and previous land development.

Development of these peatlands has given rise to a major industry employing about 5,000 people and producing about 4×10^6 tonnes of peat fuels and 1.3×10^6 m^3 of peat moss per annum. There is an increasing interest in the future role of peatlands in the agricultural, horticultural and sylvicultural industries, either as private or state run enterprises. Their significance for conservation and amenity is also extremely important in long term national planning. Raised bogs, once typical of the Central Plain, have virtually disappeared.

Future land use options for industrial peat areas will be based on the physical factors associated with the different units and political planning decisions for social and economic infra-structures in the Midlands. Options to be considered are as follows:

Agriculture - grassland or arable in combination or separate entities.

Forestry - mainly coniferous

Leave derelict - self-generating plant and wildlife habitats.

Planned - amenity/recreational/leisure areas, flood areas for water pursuits, establish camping areas and walking routes.

This field trip will, it is hoped, allow many of the aspects of peatland conservation and utilisation to be viewed and discussed <u>in situ</u> in association with the glacial features of the landscape surrounding the fen and raised bog formations.

(RFH)

WATER: AN INFLUENTIAL COMPONENT OF OFFALY AND WEST KILDARE

INTRODUCTION

Many of the site localities on this field excursion will examine the influence of water on the physical environment. For instance, at Pollardstown we will stand on a deltaic ridge, close to a spring which feeds the Grand Canal and Guinness Brewery and overlooking a fen containing peat, marl and lacustrine clay. At Clonmacnoise, close to the River Shannon, we will view an esker ridge, a floodplain raised bog, and callow land with limestone pavement in close proximity. As eskers and peatlands are two of the main physical characteristics of Offaly and west Kildare, it is evident that water is an influential component.

WATER: A PARENT MATERIAL OF PEAT

"The ground itself is kind, black butter
Melting and opening underfoot"
(from Boglands by Seamus Heaney, 1969)

To anyone who has worked barefoot when cutting turf Seamus Heaney superbly evokes the physical quality of peat. His concept of the hydrodynamics of peat, given below, is attractive but not accurate, although it summarises the certainty of Midland people who often speak of wetter parts of the bogs as having "no bottom":

"The bogholes might be Atlantic seepage.
The wet centre is bottomless".

Peat is a fascinating and extraordinary rock type although seldom studied by geologists in Ireland. A most striking characteristic is its high water content. Five metres of fibrous peat may contain 4.7m of water and as little as 0.3m of solid plant material. Galvin (1976) examined different Irish peat types and found the natural moisture content varied from 88.9%-91.3% by volume or 821-1607% dry weight. Water in peat (as with other rocks) is present as free water in the pores, but unlike other rocks it contains a significant quantity of water bound physically, chemically, colloidally and osmotically such that the water is an essential part of the structure of the peat. Only a small proportion of the water is mobile although this varies with the hydraulic conditions. One consequence of this is that the Darcy equation on flow of water in porous media probably does not apply to peat, particularly well decomposed peat.

PERMEABILITY OF PEAT

The permeability of peat varies with the degree of decomposition. Well decomposed peat which is present below the upper layers of bogs generally has a low permeablility - 10^{-1} to 10^{-3} m/d. Cracks due to subsidence and the presence of woody material can increase this, but in general peat is relatively impermeable, allowing little water movement through it. Consequently, recharge to aquifers through peat is likely to be small. Also, in Offaly and Kildare, the peat is often underlain by shell marl and lacustrine clays which have a low permeability.

EFFECTS ON STREAM FLOW HYDROGRAPHS

Undrained and drained bogs have different effects on stream flow hydrographs:

1. During rainfall periods, flow from undrained areas is fast and strong with high peaks. Flow is more uniform from drained areas with the flood peaks delayed and flatter.
2. During dry periods, runoff from undrained bogs is very low or non-existent whereas drained bogs have higher and more regular runoff. Consequently, low flows are greater in drained areas.

Undrained bogs contain large stores of water. However, this water is not available for runoff because of the low permeability of the peat and the absence of drainage channels. Consequently base flows are very low in summer. The installation of drainage channels allows the mobilization of this stored water (or groundwater). This results in higher base flows in summer, particularly in the period immediately after drainage commences. After a period of time (2-10 years reported in the literature) equilibrium conditions occur. As a result of drainage an unsaturated zone is created in the peat. Consequently this increased storage capacity reduces and delays winter floods and contributes groundwater as baseflow during summer and autumn.

In general, undrained bogs have high peaky flow in winter and minimal low flows. Drainage has a levelling influence, decreasing flood peaks and increasing summer and autumn baseflow.

EFFECTS OF DRAINAGE ON PEAT (from Daly, 1981)

Drainage of peat formations means a disturbance of the natural

conditions. It removes excess water, stops peat accumulation, causes peat subsidence and changes physical properties, such as permeability. Drainage and the consequent peat subsidence has changed the appearance of many areas by lowering the ground surface, reducing the area of peatland, changing the ecology, changing the soil type and occasionally though not typically, adding to the scenic value of areas such as the Fens of East Anglia and the Netherlands where windmills were built to pump water from the lowered land surface to canals carrying water to the sea.

Peat subsidence is an unavoidable consequence of drainage. It is caused by shrinkage, consolidation, contraction and oxidation. Oxidation, which converts the organic matter into water and carbon dioxide, is the most important process.

Subsidence rates are positively correlated with the depth of the groundwater table - the higher the water table, the lower the subsidence rate - and this is probably the single most important factor in causing subsidence. Subsidence rates also depend on thickness of peat, climate, type of peat, land use and fertiliser application. Thicker peats subside more than thinner peats. Higher temperatures increase the rate of oxidation, consequently, climate is important. Fen peats subside more rapidly than bogs. Peat under grassland and forestry subside at a lower rate than peat under arable crops. Fertilizer application especially lime and nitrogen can aid the subsidence of peat.

An Foras Talúntais researchers estimate that subsidence in Ireland will be 4cm/a in the first few years, 2.5cm/a or less over the next seven years and it could be down to 0.9cm/a or less later on (Cole, 1973; reported in Barry et. al. 1973).

Drainage causes an increase in decomposition of peat and a decrease of the primary permeability. However, peat shrinkage and contraction cause crack formation and a considerable increase in permeability.

PEAT AND ENVIRONMENTAL PROTECTION

Peat has exceptionally high absorption and filtering capacities and consequently can purify and attenuate pollutants in industrial, sewage, septic tank and tip site effluents. In particular in Offaly and west Kildare, cut-over bog areas are commonly used for the location of tip sites or dumps. The advantages and disadvantages of these sites are listed in Table 4.

Table 4

Advantages	Disadvantages
1. Low land-use value, therefore cheaper to buy.	1. Bogs invariably are wet and difficult to operate.
2. Low population density in area.	2. Has low load bearing capacity.
3. Peat relatively impermeable, therefore can be containment sites.	3. No clay cover material on site.
4. Peat has high cation exchange capacity (CEC) which would assist in attenuating leachate.	4. Peat is a fire hazard.
5. Adjoining peatland could be used to treat the leachate	5. Further research and trials are necessary to test their suitability.

(from Daly, 1983).

At a time when local authorities are constrained financially these sites could be a cost-effective means of disposing of refuse in an environmentally safe manner.

GROUNDWATER AND PEATLAND CONSERVATION

The study of biological aspects of peatland generally provides the main reasons for conservation and biologists have been to the forefront in campaigning for conservation. However, the key elements in the actual conservation of the peatland is often the understanding and control of the hydrology. For instance, lowering the bottom of a river during arterial drainage could affect a bog miles away. Cutting and extracting peat leaving a turf bank or lowering the water table by pumping groundwater from boreholes could have damaging affects on bogs. Yet studies to date have concentrated on the botanical and ecological aspects. The influence of hydrological, hydrogeological and hydrochemical factors are not understood and are little investigated. This must change. Without a clear understanding of the hydrodynamics of a peatland, the conservation of that area could not be guaranteed even if it was purchased by the state - it could be ruined by a change in the hydrology in an area where the state might have no control.

GROUNDWATER: A VITAL SOURCE OF DRINKING WATER IN COUNTY OFFALY

About 50% of potable water comes from groundwater sources - mainly boreholes but also springs. The most important aquifer is the Pure, Coarse Limestone which provides high yields from boreholes at Blueball, Rahan, Kilcormac, Ballydaly and near Tullamore. The Basal Sandstone, which overlies the Old Red Sandstone, is also a major aquifer. The anticipated yield of four boreholes at Clonaslee is 2270m^3/d (0.5 mgd), which will be used to augment the Tullamore water supply. High yielding public supply boreholes are also present at Gallen, Ferbane. The gravels have the potential to yield large quantities of water but, as yet, they are underutilised. Esker gravels provide public water supplies at Belmont, Ballycumber and Geashill.

The other rock types are classed as poor or non-aquifers, generally only yielding domestic supplies. However, occasionally higher yields are obtainable from fissured zones, which can be located by surface geophysical techniques. High iron concentrations can be a problem in the Old Red Sandstone, Muddy Limestone and Calp Limestone.

The impact of human activities on groundwater quality seems to be negligible, presumably due to the protection provided by the extensive glacial overburden cover.

(DD)

SITE 1 - POLLARDSTOWN FEN

INTRODUCTION

Pollardstown Fen is an area of peatland located about 3km west of Droichead Nua at NGR N770160. It is 220 hectares in extent and is a lowlying, flat, wedge-shaped area surrounded by gravel hills (Figure 6). Around the perimeter of the fen, 36 springs provide water to canal feeders which join to form the Milltown Feeder which, in turn, joins the Grand Canal near Robertstown.

This area is of national importance because:

(i) It is the main source of water for the Grand Canal;

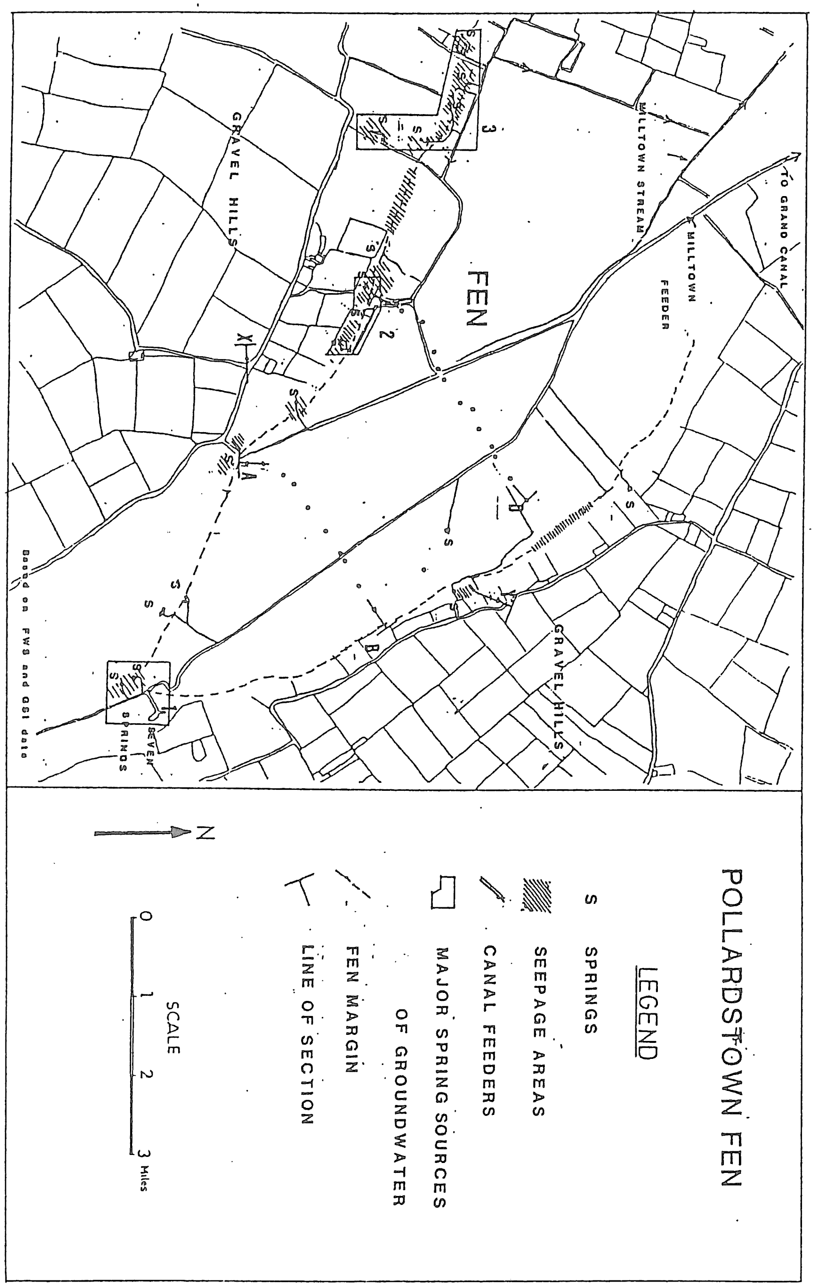


Fig. 6 Pollardstown Fen

(ii) It provides the water for Guinness Brewery and Allenwood Power Station;

(iii) It is an Area of Scientific Interest (A.S.I.) of International Importance.

In the sixties drainage commenced in the central part of the fen and a large area was converted to grassland. Following a protest campaign and the preparation of reports by the Forestry and Wildlife Service and the Geological Survey of Ireland (Daly, 1981), the drained area was purchased by the Forestry and Wildlife Service and drainage ceased. However, part of the fen is still owned privately and so is at risk from possible future drainage.

GEOLOGY

The geological succession in the area is as follows:

Age	Type of Deposit	Thickness
Holocene	Peat and marl	1-5.5m
	Clays	0-2.0m
Pleistocene	Sands, gravels and clays	up to 65m
Carboniferous	Limestone	

A geological section across the fen is shown in Figure 7.

Pleistocene Deposits

During the Pleistocene this area was covered by an ice sheet that moved generally eastward and southeastward across the midlands and pushed against the Wicklow Mountains to the east. There is some evidence that an ice movement from the east approached if not reached the area of the Curragh.

The gravels here are interbedded with three major diamicton units. Two of these occur in the top 12m of the sediments being separated by 1-2.5m of gravel at the Curragh Camp. The lower diamicton occurs 41-50m below the surface. In the intervening gravels, granite (probably Wicklow granite) occur between 30m and 36m and there are probable granites and concentrations of mica in the gravels underlying this diamicton unit between 56m and 62m below surface level. The diamictons are probably tills but as they have

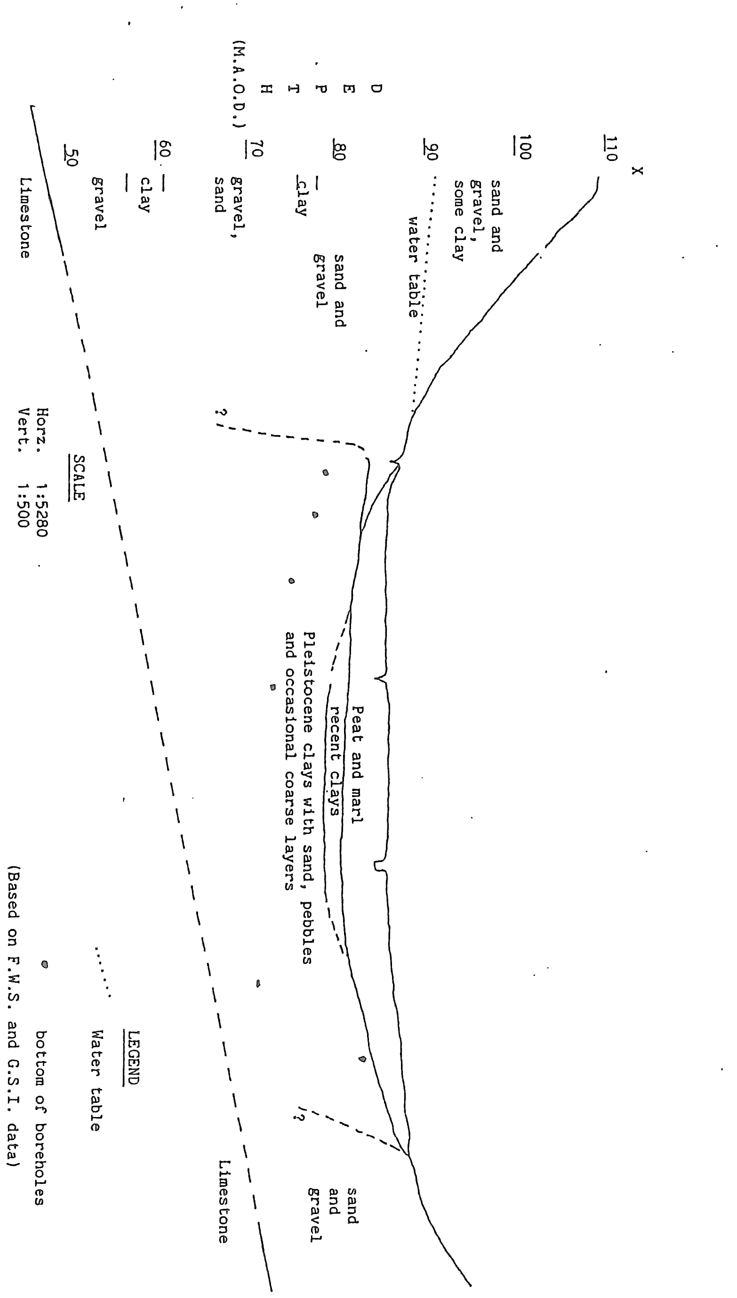


Fig. 7 Geological cross-section at Pollardstown Fen

been identified in borehole samples, this cannot be certain. However, it is not clear what sort of tills they might be. Close interbedding with fine and coarse sand and medium-fine gravels suggests that some of them may be flow tills or supraglacial melt-out deposits.

During final deglaciation the ice front retreated generally towards the west and it is likely that the sorted sediments are glaciofluvial and glaciolacustrine relating to this event. Tills are likely to be supraglacial melt-out and flow till types (see Cohen and Stanley, 1982). Surface glaciolacustrine clays are likely to be distal sediments deposited as the ice margin moved further west and the pro-glacial lake size increased.

Recent Deposits*

After the ice retreated completely, a lake formed in the valley and lacustrine clays were deposited. These are grey in colour, sticky, faintly laminated, with some organic matter, stones, shells and marl bands. They are overlain by marl and peat.

A vertical section (Figure 8) indicates marl deposition occurring in the deeper central areas, with peat deposition around the margins of the fen. This was followed by peat deposition virtually free of marl throughout the fen. The uppermost layers consist of a variable mixture of peat, peaty marl and marly peat.

The marl consists of calcium carbonate. It is cream or rusty white in colour and varies in organic content, grain size and shell content. Mollusc shells are frequently present, but their concentration is usually low. The deposition of marl is caused by chemical and bio-chemical precipitation of calcium carbonate when hard, limy groundwater enters the fen from the springs.

A summary of research on marl formation by Dr. Catherine Coxon is given in Appendix 1.

The formation of fen peat at Pollardstown is caused by the hard, limy water issuing from springs around the valley sides, which, due to poor drainage, inundated the area and formed waterlogged conditions, thereby preventing degradation of the organic matter.

HYDROGEOLOGY

The Curragh sand and gravel deposit is a major aquifer providing the groundwater that feeds the springs, the fen peat and the Grand Canal. A

* The interpretation of these deposits was made by Dr. J. Cohen.

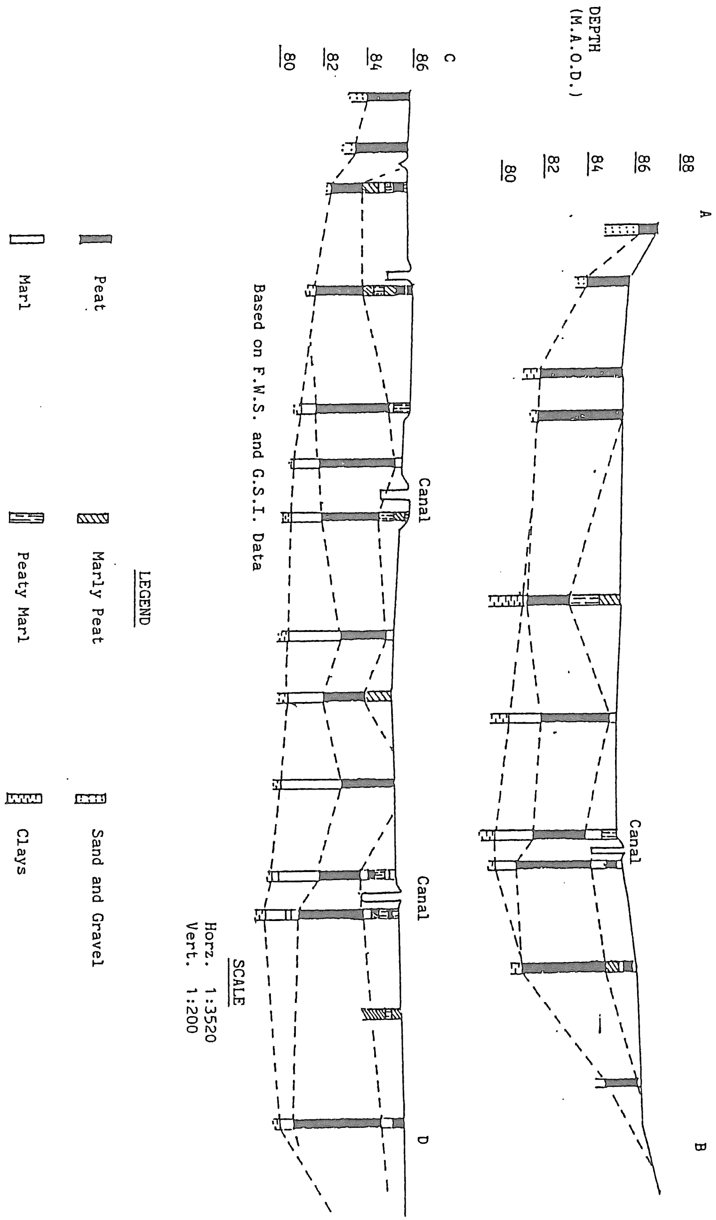


Fig. 8 Cross sections in peat and marl at Pollardstown Fen

borehole at the Curragh Camp yields about $4546m^3/d$ (1mgd).

Using the water table information for the area it was estimated that the groundwater catchment area (or recharge area) providing water to the fen is about $21km^2$ in size and stretches as far south as the Curragh Camp (Daly, 1981).

The average flow from the springs was calculated to be about $25000m^3/d$ (5.5mgd).

DRAINAGE OF FEN

Drainage of peat removes excess water, stops peat accumulation, causes peat subsidence and changes physical properties such as permeability.

The drainage at Pollardstown has caused peat subsidence in the centre of the fen. Since drainage has ceased, the central area is now usually inundated with water.

In the report by Daly (1981) the following predictions were made:

(1) Drainage would reduce spring flow under every practical land-use management alternative. However, the reduction could be rectified by pumping water from wells into the canals.

(2) The effects of drainage on the canal feeders would depend on the land use. However the most likely land use alternative - use as grassland with little control of water levels - would result in instability and leakages which would be very costly if not impossible to rectify.

(3) The effects of drainage would not be significant in the short term but would cause major problems in the longterm (decades).

These conclusions still apply to the area of the fen along the western boundary, which is still in private ownership.

POLLARDSTOWN FEN - THE FUTURE

The fen and springs are vulnerable to the impact of human activities. Developments in the recharge area surrounding the fen could affect the springs and consequently the fen in two ways:

(a) By reducing the flow in the springs;

(b) By polluting the groundwater.

As the flow of water from the springs is related to water level changes in the aquifer, any lowering of the general water table could cause significant decreases in the flow in the springs. Any water abstracted from the groundwater catchment area could result in an equivalent reduction in flow to the canal feeders.

There are three main potential sources of pollution:

(1) agricultural activities;
(2) tip sites; and
(3) spillages.

Tip sites should not be allowed in the catchment area. The N7 national primary road between Droichead Nua and Kildare crosses the catchment, consequently there is a risk of pollution from spillages.

Actions to protect the fen should include the following:

1. Purchase of the remaining part of the fen by the Forestry and Wildlife Service.
2. An investigation to assess the hydrogeology of the Pollardstown Fen area in more detail. Large groundwater abstractions should not be allowed in the meantime.
3. Regular monitoring of stream flows, groundwater levels and groundwater quality.
4. Management or structure plans for the Curragh area should take account of the need to protect the fen and the springs.
5. The local authority Emergency Plan for the Curragh area should contain instructions that spilled materials be contained and 'mopped up' rather than washed off into the ground.

(DD, WPW and RFH)

SITE 2. AN FORAS TALUNTAIS
PEATLAND EXPERIMENTAL STATION
LULLYMORE, RATHANGAN.

INTRODUCTION

The Peatland Experimental Station at Lullymore (N 705 257) is part of the Johnstown Castle Research Centre which is concerned with the factors which affect the productivity from land with particular emphasis on soils and crops/grassland production.

The station at Lullymore has undertaken investigations into many aspects of peatland resource evaluation and crop and animal production on midland milled over raised bogs since the mid-1950's. The current research programme is examining the following factors associated with the future land use of milled over peatland.

1. More innovative techniques of controlling water table levels by placing tile drains in the more permeable strata which occur in the underlying glacial sediments.
2. The factors which can modify the influence of molybdenum in animal production at the soil/plant and plant/animal interfaces are receiving detailed examination.
3. Production of arable crops from new varieties, herbicide trials, and the role of nitrogen. The following crops, onions, carrots, potatoes, parsnips and artichokes are used to research these different factors.

Stop 2A.

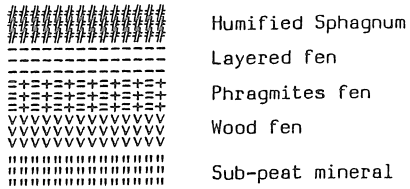
Industrial peat working modus operandi and profile section. Brief stop to illustrate different techniques and landscape associated with each method of extraction (milled peat and sod peat). Milled peat produced is used for the manufacture of briquettes at the Lullymore briquetting plant (output 70,000T p.a.) visible on the horizon and the Ballydermot Bog Group producing 160,000T of sod turf sold on the domestic market and to the ESB Allenwood power plant (110,000T).

Stop 2B.

Sub-peat mineral soils and deep drainage technique for grassland developed on shallow milled-over wood-fen peat material residues. 35ha, grassland in the area of Lullymore West Td., utilised for dry stock beef production using continental cross steers and bulls producing beef at two years of age; finished over winter on silage and concentrate rations.

The distribution and occurrence of the different peat materials in human-modified areas can show large variations in their extent and thickness. This is a direct result of the many permutations associated with mode of formation underlying bog floor topography and type of technique used to remove fuel peat in the past.

The distribution of peat types in the industrial areas follows a generally defined pattern according to the topography of the bog floor. Woody peats occur at higher levels with various combinations at intermediate levels to Phragmites peat in basin positions. The sequence of peat types in the Lullymore Bog Complex is shown schematically in the following figure.



The peat soils in the grassland areas are developed from peat materials circa 5,000 years old comprised of a matrix of humified plant material embedding larger woody debris which varies randomly in depth from nil to over 100cm in places depending on the topography of the underlying bog floor. From experience this peat type is friable and offers no serious obstacles to water relations. The removal of the larger trunks, mainly bog oaks causes management difficulties at times e.g. silage harvesting. Due to shrinkage timber remains are exposed at different times. Chemical analyses show that virgin peat areas are deficient in the macro-nutrients and in addition copper must be applied in the form of copper sulphate for adequate plant growth. Calcium levels vary as to situation of the areas under development e.g. calcium levels at Lullymore are sufficient.

The sub-peat mineral material (relict soils), have developed from the underlying calcareous glacial sediment. Underlying the grassland area they are representative of shallow relict soils with no free carbonates in the solum (Fig. 9).

Towards the western margin the underlying sub-peat mineral materials are very thin raw soils with free carbonates at or very near to the surface. The occurrence of sub-peat mineral materials at or very close to the suface necessitates the incorporation of peat materials to allow amelioration of these materials to improve their physical condition and build up fertility.

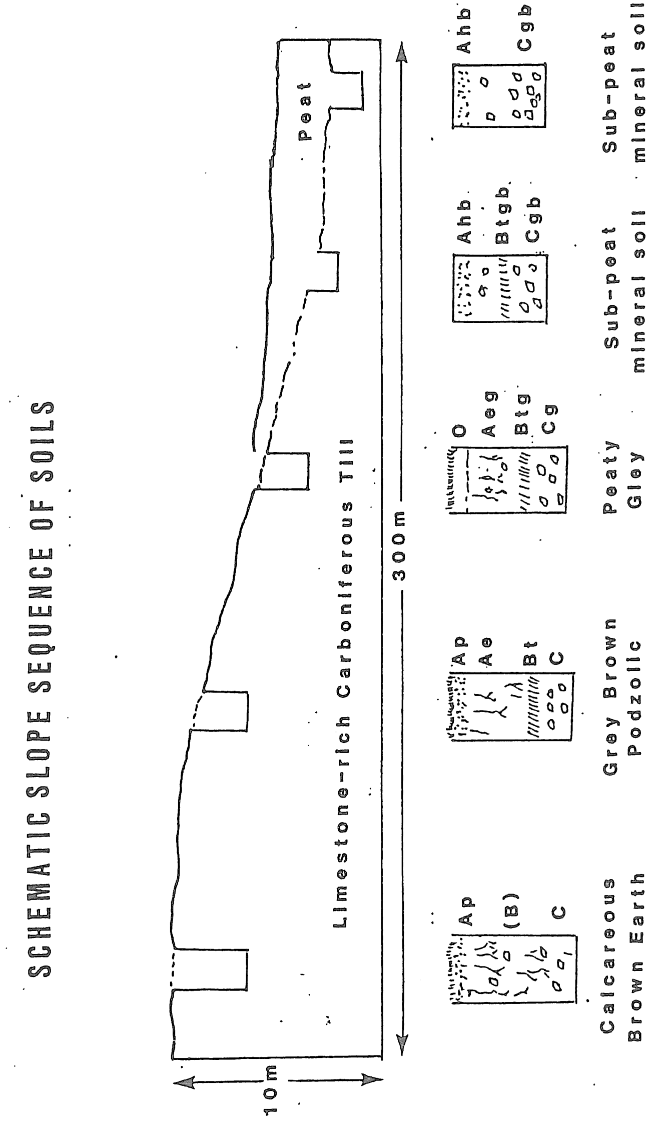


Fig. 9 Schematic slope sequence of soils at Lullymore

Profile Description Lullymore West 1

Location: East end of grassland area in drain cutting Lullymore West Td.
Elevation: 74.6 metres
Land Form: (i) physiographic position: beneath milled peat
(ii) surrounding land form; very gently undulating milled over peat
Slope on which profile is sited: Almost flat, land slopes downwards very gently east to west.
General information on the soil:

a. Parent material: Calcareous, compact till predominantly Carboniferous limestone.
b. Drainage class: Imperfectly drained - Class 4
c. Moisture conditions in profile: Moist throughout
d. Depth of ground water: Influence solum during winter months

Brief description of the profile.
Shallow sub-peat fossil soil imperfectly drained exhibiting grey to olive grey colours with clear A2 horizon. Structure massive throughout. Texture increases down the profile from loam/sand loam, in surface to loam/clay loam in the B2t.

Horizon	Depth(cm)	Description
Wood-fen	40-0	Peat; black (5YR2/1); friable wood-fen peat material; recent rooting within peat from grass cover of Yorkshire Fog and Fescues; abrupt smooth boundary to:
A2bg	0-7	Olive grey to light olive grey (%Y5, 5/2); sand loam; massive coherent structure; wet slightly sticky: occasional relict fossil roots; sparse recent rooting;clear smooth boundary to:
B2tbg	7-12/15	Olive (5Y4/3); clay loam; light olive brown (2, 5Y5/4),few to common, fine, faint diffuse mottles; common fine discontinuous, random inped tubular pores; wet sticky; very sparse recent roots; occasional sub-fossil roots; clear smooth slightly wavy boundary to:
C1bg	12-15/25	Grey (5Y5/1); stony sand loam; dark brown (7.5YR4/4); few coarse, prominent sharp mottles; massive coherent structure; in pockets massive non-coherent; wet slightly sticky; vigorous effervescene; gradual smooth boundary to:
C2bg	25+	Grey (5Y5/1); stony sand loam; massive coherent structure; wet slightly sticky; vigorous effervescene.

In the horticultural area peat depths vary from less than 30cm to more than 120cm. The peat types on which the crops are grown vary from wood-fen as occurs in the grassland area through layered fen dominated by Menyanthes trifoliata (Bog Bean) and non-Sphagnum moss remains. Deeper peats are required to grow good quality arable field crops as they ensure a stone free, afriable rooting medium to produce good shaped root crops. The positive factors are the absence of stones, a friable soil allowing good root development, and good water holding. The management of peat soils has however to take into account the risk of early and late frosts. Therefore early frost-tender crops cannot be grown and the ability of peat soils to absorb herbicides means higher rates have to be applied to control weeds in crops.

Profile Description Derrybrennan 1
Location: Derrybrennan Td. Bay 29/30
Elevation: 76 metres
Land Form: (i) physiographic position: milled over peat bog
(ii) surrounding land form; very gently undulating milled peat fields
Slope on which profile is sited: Almost flat.
General information on the soil:
a. Parent material: peat material ombrotrophic origin
b. Drainage class: Class 4
c. Moisture conditions in profile: Moist throughout
d. Depth of groundwater: Influences lower part of solum in winter

Brief description of the profile.
Well drained soil with the upper layers derived from acid Sphagnum-derived peat materials strongly acid in character. The sub-surface tiers are

derived from peat materials formed under minerotrophic conditions characterised by strong layered structure dominated by macro-fossil remains of Menyanthes trifoliata (Bog Bean), non Sphagnum mosses, sedges and grasses.

Horizon	Depth(cm)	Description
Oap	0-15	Peat; dominantly Sphagnum with Eriophorum and Calluna remains; dark reddish brown (5YR2/2); moderately well humified; moist friable; non-greasy; abrupt smooth boundary to:
Oel	15-48	Peat; dominantly Sphagnum with Eriophorum and Calluna remains; dark reddish brown 2, SYR4/4); moderately well humified; wet, non-greasy; clear smooth boundary to:
Oelg	48-83	Peat; dominantly Sphagnum with Eriophorum and Calluna remains; dark reddish brown 2, SYR4/4); moderately well humified; wet, non-greasy; clear smooth boundary to:
Oe2g	83-109	Peat; strongly layered; dominated by remains of Menyanthes trifoliata with some non-Sphagnum mosses, grass and fine twiggy remains; dark reddish brown (5YR2/2); moderately well humified; slightly greasy; clear smooth boundary to:
Oe3g	109-160	Peat; layered structure; non-Sphagnum mosses and grass remains predominate with some Menyanthes trifoliata residues dark reddish brown (5YR2/2); moderately well humified; non-greasy; clear smooth boundary to:
Oa2g	160-210	Peat; heterogeneous matrix comprising herbaceous plant remains with wood remains embedded, these can be locally abundant and massive in size; peat matrix colour darkens rapidly on exposure to air (5YR3/ = 5YR2/2); well humified slightly greasy; strong smell of sulphides; abrupt wavy boundary to:
Alg	210-	Buried relict mineral soil

Stop 2C.

Horticultural cropping on deeper peat residues.

The horticultural programme at Lullymore was and still is based on the premise of the wide alternative land uses option. Horticultural field crops could be considered in the long term planning of the cut-over raised bogs as one of the viable enterprises. This concept will only work out if the requisite depth and type of peat remain for this purpose.

The area under crops is three hectares in extent. Soils are derived from peat materials of fen origin and have been cropped in rotation since the late sixties. The area under arable crops has been successively reduced from the mid-seventies to remain static at the level of today. Crops research is being conducted on carrots, onions, potatoes and artichokes. The emphasis is on varieties suitable for peat soils in each case but in the case of potatoes the effect of different rates of nitrogen on yield and dry matter content.

Husbandry utilises tried and tested herbicide/nutrition programmes but in the case of onions research, observations are still being conducted on herbicides to control the growth of Annual Meadow Grass which is a persistant and obtrusive weed both on peat and mineral soils. However, in the case of peat soils the efficacy of herbicides in the control of this grass is not so good as on the mineral soils.

(RFH)

SITE 3: CUSHINA/CLONSAST.

On leaving Site 2 the route to Cushina/Clonsast crosses the western edge of the Ballydermot/Lullymore Bog complex, skirts the flood plain of the Slate River and passes along a ridge of glacigenic deposits, which separates major bog complexes, to Rathangan. From Rathangan the route runs parallel to the Slate River along another ridge of glacigenic deposits to Bracknagh. On crossing the Figile River, a tributary of the River Barrow, at Bracknagh the topography thereafter is very gently undulating to almost flat. On this landscape there has developed a complex pattern of mineral and organic soils.

This stop is at Cushina (N 553 155) near Clonsast, an area of gently rolling topography interspersed with sharp kame features. At Cushina there is a low escarpment aligned almost north-south. West of this is a limestone dominated diamicton and the escarpment delimits a spread of fine-medium calcareous sand (Table 5) which extends eastward. Derryvilla Hill, a kame-like feature occurs on the escarpment and is composed largely of sands but these are not nearly so well sorted as those at Cushina (below). The kame also includes diamicton pods and gravels interbedded with the sand.

The section being visited is in the Derryvilla Hill kame. Exposure is not very good but it will be seen that the feature is composed mainly of sands and fine gravels with large diamicton pods towards the base. All of the sediments with the exception of the upper solum are calcareous. At the southern end of the pit some folding is seen in the bedded sand and gravels. There was not sufficient exposure to classify the folds and it is possible that they simply relate to slumping during sand extraction. Further excavation may show whether there are other structures and exposures of the complete fold structure will reveal whether it is overturned or monoclinal. If it is overturned it would appear that the axial plane dips to the notheast and that some lateral pressure was exerted from that direction.

Interpretation of the Cushina sands is open to a number of possibilities. Its very limited particle size range in the medium-fine sand range suggests a wind-blown deposit, while morphological expression suggests an ice contact deposit. It is possible that it is a wind-blown deposit, derived from glaciofluvial sediments (similar to those that form Derryvilla Hill) that accumulated against the margin of a dead ice-block during deglaciation. Alternatively, it may be glaciofluvial, derived from an already well-sorted sediment that had been entrained in the ice sheet.

In the depressed topography to the south of Clonsast Bog sandy deposits underly the peat. Portarlington is underlain by "rabbit sand". Sand deposits west of Portarlington in Tinacrannagh Townland were extracted for use in foundry casting at McArthy Foundry at Mountrath, Co. Laois. This suggests that fine-medium sand deposits are quite widespread in this area. They may be wind-blown sediments deposited close to the ice margin during deglaciation or they may represent earlier well sorted, possibly wind-blown, deposits that were widespread before the last glacial event.

Particle size analyses (J.F. Collins, unpublished data) were carried out on a number of the Cushina sand samples collected in a cutting along the railway line running to the E.S.B. power station. The data from 24 samples taken at the one location appeared to fall into two groups with average values in Table 5 below:

Table 5: Particle size analyses of sand samples expressed as a percentage of the oven dry material 2mm.

	V. coarse sand	coarse sand	medium sand	fine sand	v. fine sand	silt	Clay
	2-1mm	1-0.5mm	0.5-0.25mm	0.25-105μ	105-50μ	50-2μ	2μ
A	-	0.75	40.3	54.0	4.5	0.2	0.2
B	-		3.4	73.2	21.9	0.3	0.3

Soil formation on these glacigenic deposits, especially the kame structures, has given rise to complex profiles. Their character is essentially that of the Grey Brown Podzolic soil group with however an overriding influence in some instances of podzolisation depending on topographical position, water regime and thickness of overlying organic matter. Where the groundwater regimen and organic matter conditions are met, a humus podzol has been mapped as on Nugents Island in the middle of Derryounce Bog to the south west of Cushina Hill (Fig. 10). A series of schematic soil profiles are shown in Figure 11 illustrating the various soils which occur beneath the peat and the relative upland mineral areas. Ryan and Walsh (1966) attribute the pedogenesis of the upland mineral soils to the role of differences in the vegetation cover throughout the postglacial period and using the sub-peat mineral soil as a base reference (cf. Lullymore Site 2). Vegetation cover, it is postulated, varied from the indigenous forest to the effect of clearing the forest cover (anthropogenic factor) and establishing open grassland and heathland vegetation.

The removal of the forest cover occurred over long periods of time and such changes in the vegetation would have effected pedogenesis for varying lengths of time resulting in differences in profile development.

An example of a soil profile (Ryan, 1963) developed on the Cushina kame structure is given below and the distribution pattern of the soils in the area is shown in Figure 12 with a north/south schematic cross section showing the inter-relationship between the underlying glacial drift materials and the peat cover associated with the bogs to the north and south of Site 3.

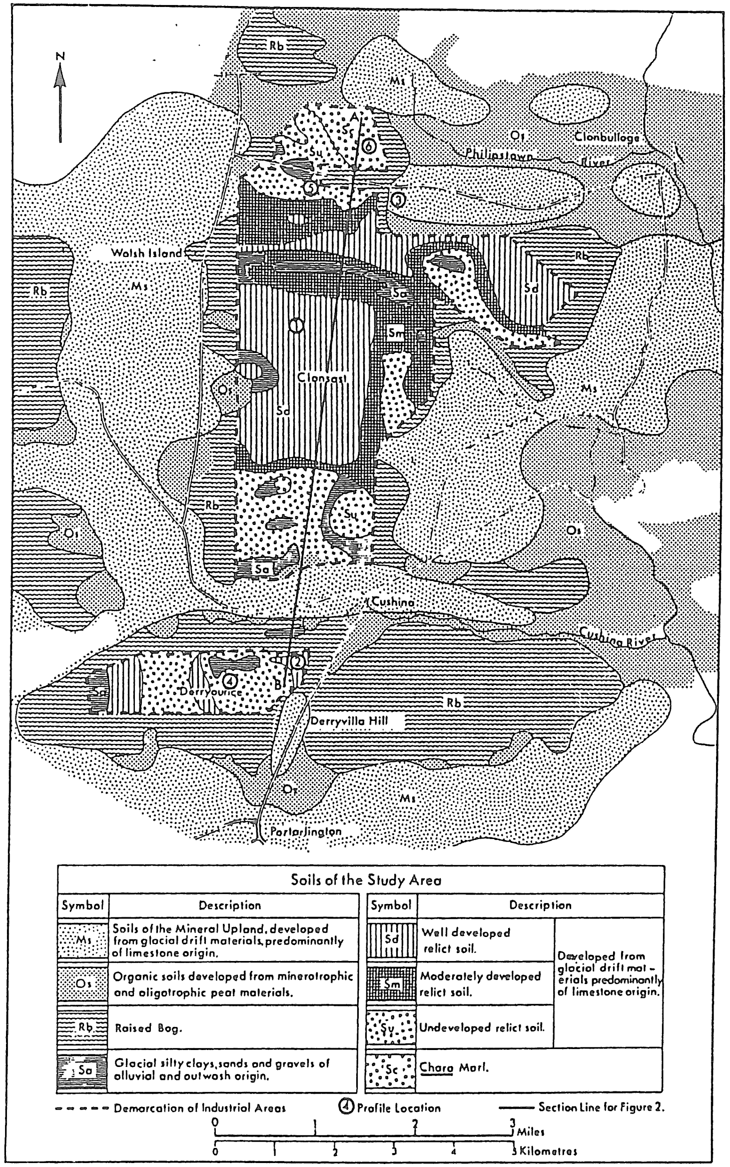


Fig. 10 Soil map of Clonsast-Cushina area

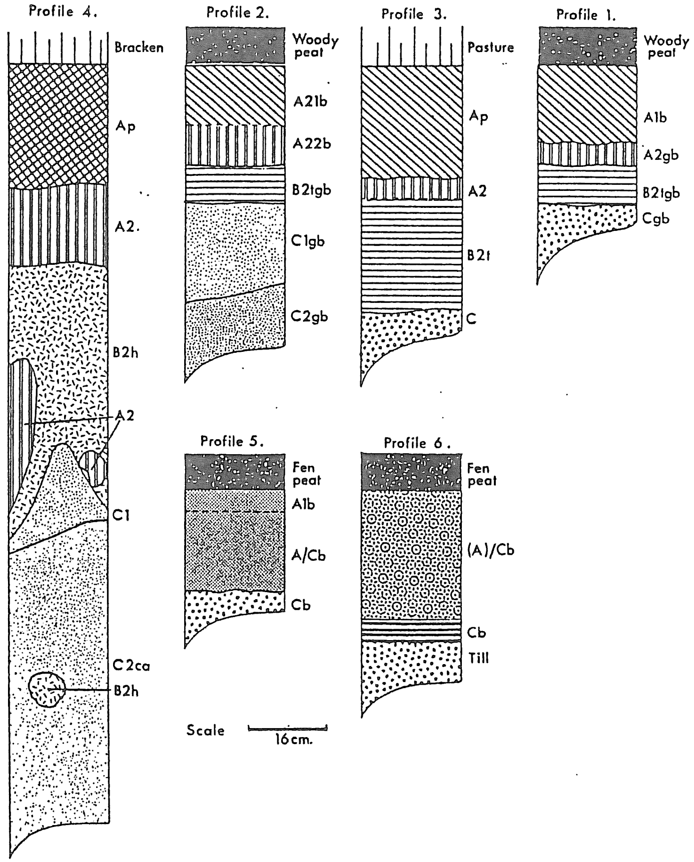


Fig. 11 Schematic profiles of soils beneath peat at Cushina/ Clonsast

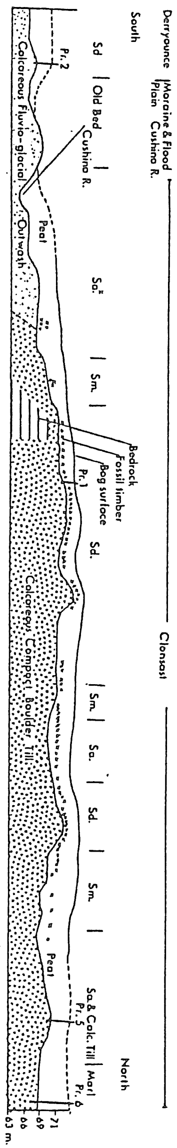


Fig. 12 Schematic cross-section through the deposits at Cushina/Clonsast (see Fig. 10)

Profile Description.

Location: Cushina Cross, Co. Offaly

Land Form:

(i) physiographic position:

(ii) surrounding land form:

Slope on which profile is sited: 10-12°

General information on the soil:

a. Parent material: Glacial outwash sands with some boulders and till included

b. Drainage class: I

c. Moisture conditions in profile: Moist throughout

d. Depth of ground water: 1.2 metres

Horizon	Depth(cm)	Description
A11	0.20	Fine sandy loam; dark greyish brown (10YR4/2); weak coarse crumb structure; very friable; some washed and corroded sand grains; very extensive and diffuse rooting; calcareous; gradual smooth lower boundary to:
A12	20-30	Loamy sand to fine sandy loam; dark brown (10YR4/3); weak medium crumb structure; very friable; some washed and corroded sand grains; common diffuse rooting; calcareous; fairly clear smooth lower boundary to:
A21	30-43	Fine sandy loam; brown (10YR4/3 - 5/3); single grain structure; friable to loose; abundant washed and corroded sand grains; rooting sparse and vertical; calcareous; fairly clear slightly wavy lower boundary to:
A22	43-51	Fine sandy loam; brown to pale brown (10YR5/3 - 6/3); single grain structure; loose; numerous washed and corroded sand grains; very sparse rooting; clear wavy lower boundary to:
B2t	51-60	Sandy clay loam; brown to dark brown (7.5YR4/4); coarse sub-angular blocky structure; firm (dry) friable (moist); coated sand grains; clay skins in crevices; sparse diffuse rooting; slightly calcareous; clear strongly wavy lower boundary to:
C	60+	Mainly fine sands with gravels; highly calcareous.

Mechanical analysis data Cushina Profile

Horizon designation	Percentage of Coarse sand 2-1mm	2mm material oven dry Fine sand 1mm-50μ	Silt 50-2μ	Clay 2μ
A11	23.2	39.4	21.0	5.0
A12	28.4	30.6	19.8	4.0
A21	26.3	40.6	19.5	5.5
A22	22.6	45.6	22.0	6.3
B2t	13.4	36.8	21.0	28.3
C	27.7	36.7	14.3	4.0

SITE 4: THE GEASHILL ESKER

This esker runs in a northwest-southeast direction close to the Tullamore-Portarlington road at the village of Geashill (N 452 208). A distributary branch esker lies to the south at Raheen (Fig. 13). It approaches the Geashill esker about 1km southeast of Geashill.

The main feature to be examined here is a silt-clay unit that rests on top of the esker gravels. The unit is approximately 1m thick. It is light brownish-grey in colour and is generally high in carbonates except in the depleted A and B soil horizons which generally do not go below 0.5m at this site. This is one of the sites at which Ryan and Walsh (1966) have described a dual soil development, an initial grey- brown podzol with (in this case) a modified surface horizon but in other more open structured deposits the original grey-brown podzol has been modified to an advanced podzol. In their consideration of this type of soil development Ryan and Walsh did not address the problem from the point of view of the influence, in some localities, of a pre-existing clay/silt cap on the glaciofluvial gravels. Indeed their profile showing the esker gravels as the parent C horizon suggests that they regarded the silt-clay unit as a product of pedogeneses derived from the gravels.

Two sections will be viewed at this locality. The first is in a small gravel pit immediately southeast of the junction of the road to Walsh Island with the main road from Tullamore to Portarlington. Here a small exposure

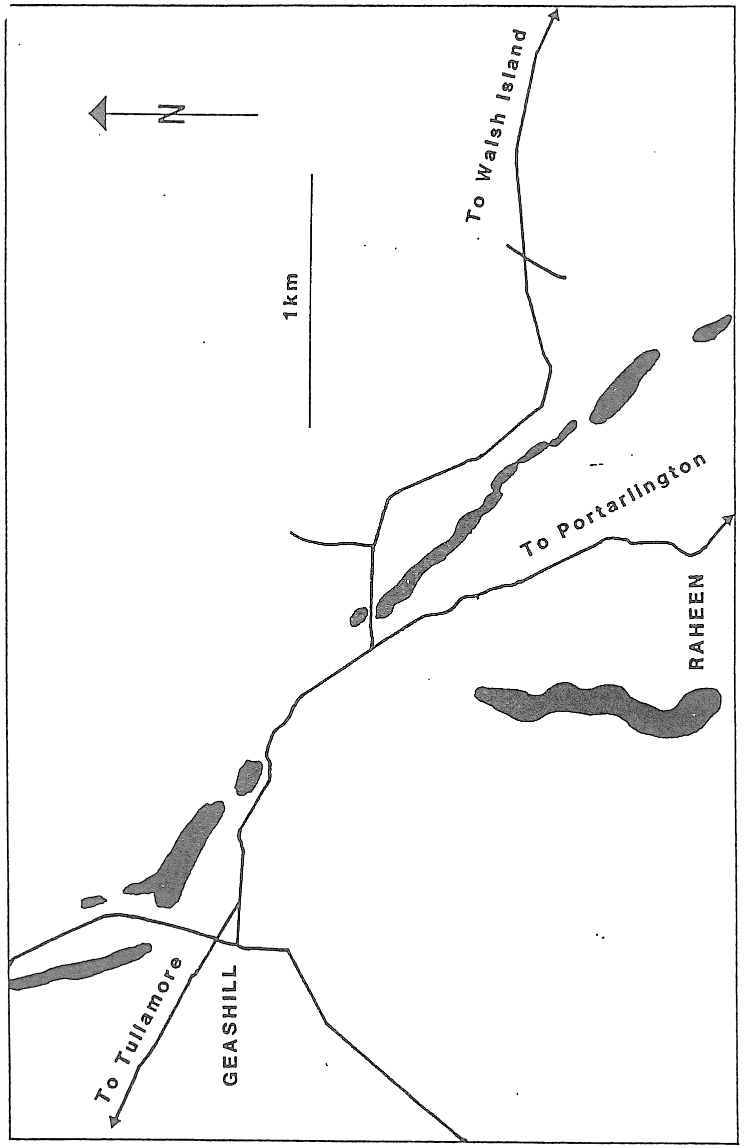


Fig. 13 Eskers at Geashill and Raheen

of massive, silt/clay with very few stones, 1.3m thick, rests on top of the esker. It extends about 50m along the esker top. To the north, where gravels reach the top of the esker, periglacial involutions and frost shattered stones are seen. At the second section, in the Raheen esker, a similar silt/clay unit 1.0m thick was seen extending for at least 100m along the top of the esker. Note the presence of coarse foreset beds in the esker gravels.

It is extremely unlikely that this unit simply represents soil development in the esker gravels. It is generally very calcarcous and in place calcarcous to the top of the solum, there are no deeply weathered limestone clasts within the deposit and where there has been decalcification of the soil above the B_2 horizon, the silt/clay deposit is usually seen as the underlying parent material (C horizon). It is more likely that they are proglacial lake sediments, deposited after the esker gravels had been deposited and the ice-front had retreated. Such lakes would be expected to fluctuate in surface level depending on the position and type of outlet, dead ice distribution and other factors; so that the lake sediments capping on the esker would be discontinuous and of varying thickness. We have not observed clear laminations or drop-stone structures within this unit. But if they are proglacial lake sediments it is likely that thicker exposures will come to light which will help towards a more definite sedimentological identification.

(WPW, RFH)

SITE 5: CAPPANCUR

This is a brief stop (N 377 249) to view from the road a series of washboard moraines which are aligned north-south and crossed by the Tullamore-Dangean road south of the Tullamore esker. The individual moraines are 2-5m high and between 50m and 150m apart. They occur two main groups about 700m apart. The term washboard is used here purely as a descriptive one with no specific genetic implications. Wheter they are subglacial or ice marginal deposits is open to question. However, given that they occur in association with sediments indicative of a deglacial environment (Tullamore esker to the north of an ice contact escarpment which marks the southern boundary of thick glaciofluvial and dead-ice features) it is likely that they relate to the deglacial phase of the ice sheet. It is likely that they are disintegration features as suggested by Gravenor and

Kupsch (1959) with regard to similar features in Canada but that, in reflecting a separation of the ice sheet along thrust planes, they reflect a flow direction normal to their elongate shape as proposed by Gravenor and Kupsch (1959). Figure 14 illustrates the pattern of these features in outline and suggests an final direction of ice movement from a point slightly south of west.

(WPW)

SITE 6: TULLAMORE

The large esker ridge which runs in an east-west direction north of Tullamore, though commonly known as the Tullamore esker is known in the literature as the Ballyduff esker (Sollas, 1896; Farrington and Synge, 1970). It is almost 500m wide in places and is sedimentalogically a very complex feature.

Morphologically it is a sharp, often winding ridge. It usually contains one crest but in places this bifurcates and in others it is broad and gently rolling (Fig. 15).

The gravel pit (N 320 262) at present being worked just west of Ballyduff, between the Clara road and the railway exhibits some of the variety of sediments to be seen in the esker. A core of very coarse gravels runs close to the northern margin of the esker, this represents a very high-energy environment, probably a subglacial stream. It contains thick beds of very coarse to boulder gravels with open interstices and no sediments less than medium gravel size. In places an abrupt lateral change from this kind of sediment to planar and ripple bedded fine sands and silts is seen indicating a sudden change in depositional environment, probably at the mouth of a subglacial tunnel. The rest of the pit shows, inter alia, a variety of sediments including planar gravel beds, large scale cross bedded gravels, rippled fine sands and silts, laminated silts, crossbedded sands and very large foreset gravel beds. A variety of environments may be interpreted which range from confined high-energy channel flow to braided stream to glaciolacustrine. Very complex faulting is also seen in these sediments. Some normal faulting towards the edges of the esker are consistent with the melting of supporting ice walls. Graben faults further into the sediments may also reflect the loss of lateral support but they may also relate to collapse due to melting of buried ice blocks. Persistent

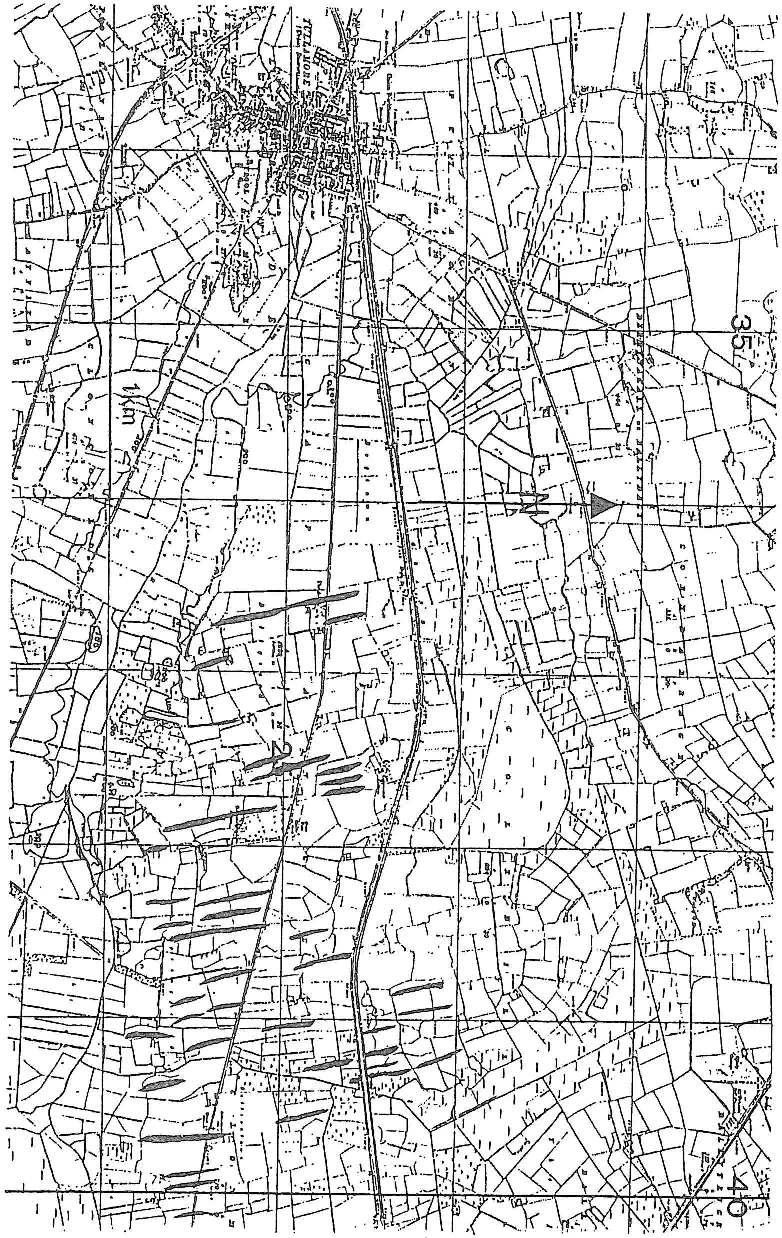


Fig. 14 The major washboard moraines at Cappancur

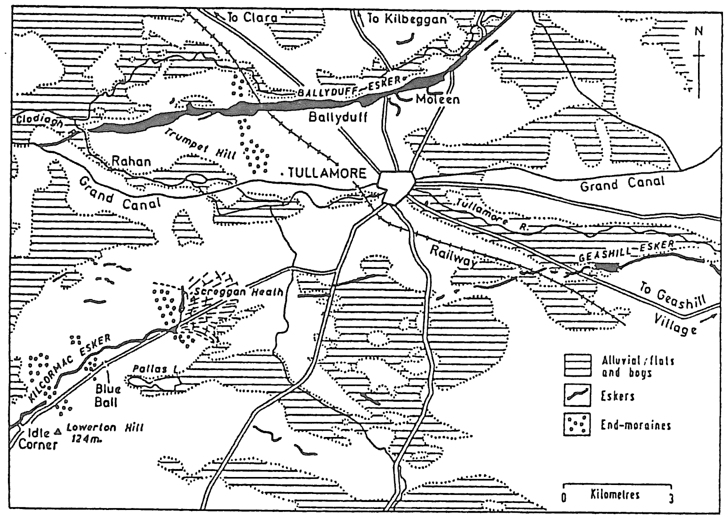


Fig. 15 Eskers of the Tullamore area (after Farrington and Synge 1970, with alterations)

high angle reverse faults however indicate some form of lateral compression whether due to forward ice movement or collapse of large blocks of ice onto the esker margins. More complex fault patterns may reflect tectonic events of differing ages.

This pit is currently being worked and most of the walls are unstable and large collapses are frequent. You are advised to observe the structures in the pit from a safe distance and not to approach the edges from the top.

(WPW)

SITE 7: DERRYAD WOOD

The east-west oriented esker on which Derryad Wood is situated lies surrounded by bog. To the north of the esker raised bog development has taken place whilst to the south the topography is very gently undulating with fen peats in the depressed areas and gleys and peaty gleys developed on knolls of variable glacigenic deposits. The area to the south could be considered part of the original lagg area of the raised bog. This site (N 340 185) combines several features of interest. In historic time the mineral uplift was relatively inaccessible, surrounded by waterlogged peat landscape units keeping anthropogenic influences to a low level. The relative well drained elevated site provided by the esker supports the growth of mature oak woodland and beneath the canopy a ground cover vegetation characterised by the presence of Vaccinium myrtillus (bilberry - fraochán) and the development of a humus iron podzol soil from calcareous sand parent materials. This situation is analogus to that postulated by Ryan and Walsh (1966) in their explanation of soil development on glaciofluvial deposits of Fenitian age.

In the area mature woodland has been clear felled and the oakwood stand at Derryad remains relatively intact at the present time. As the anthropogenic factor has modified the woodland in the most recent past so it has in the past two or three centuries modified the peatland landscape units surrounding the esker. Drainage must have caused significant shrinkage in the fen landscape unit and the area now supports permanent pasture of varying quality. Drainage and fringe peat cutting of the raised bog has also influenced soil water equilibria in the immediate environs.

The net drainage effect has meant a marked lowering of watertables and ultimately the role of water in the pedogenesis of the soils on the lower slopes of the esker. The raised bog and fen in their undrained state several centuries ago would have maintained water tables two or three metres above their present level. The raised bog undrained would have maintained a hydrostatic head which would have connected with the underlying mineral substrate and influenced the weathering processes in the mineral materials on the esker. Slightly acidic waters would have had a solution effect on the calcareous materials and fluctuating water tables between winter and summer would have a net effect of removing weathering products. With the indigenous vegetation adding acidic humus products to the surface of the soil and eluviation of material through the sandy derived profile podzolising processes have proceeded to the stage where we now find humus podzols in this location.

In the following table are given some physical and chemical analyses (Hammond, 1968) of a humus podzol sampled in the oakwoods of Charleville Estate 3-4 kilometres north of Derryad on similar sandy textured glaciofluvial materials.

Table 6: Physical and chemical data from Humus Podzol, Charleville Td. Tullamore

Horizon	L	F	H	A2	Bh	Bir	Ortstein	Clca	C2ca
Coarse sand	28	26	30	25	14	10	11	3	10
Fine sand	49	50	45	54	49	49	40	43	31
Silt	19	20	20	19	23	28	33	41	49
Clay	4	4	5	2	14	13	16	13	18
pH	5.1	4.3	4.3	4.8	4.8	6.0	6.6	8.0	8.2
TNV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.1	46.8
CEC	36.0	32.0	16.6	4.6	22.2	8.6	17.8	3.6	3.2
Free iron%	0.2	0.3	0.4	0.3	0.8	0.8	1.6	0.6	0.4

The data shows the clear contrast between the clacareous parent material and the upper solum where physically fine and coarse sand make up more than fifty per cent of the oven dried and sieved less than 2mm material. The mechanical analysis data indicate an increase in clay content in the B horizon along with humus and iron contents. The higher clay content can be attributed to illuviation of clay and also a probability of weathering of in situ increased humus in the Bh is reflected in the increased cation exchange capacity.

(RFH, WPW)

SITE 8: SLIEVE BLOOM

KINNITTY

The first stop in the Slieve Bloom area is at a section cut by the Conicar River almost 2.5km south of east from Kinnity (N 210 043). The most important part of the section shows a diamicton sequence overlain by a thick sequence of sands and gravel. The diamicton is a single sedimentary unit showing a continuity in deposition. It is overconsolidated, horizontally jointed and colour banded with alternating grey and pink facies. The grey facies is dominated by Carboniferous phenoclasts in a very calcareous matrix, and the pink facies, while also limestone dominated, contains a large amount of Devonian sandstone phenoclasts and its matrix colour is due to the inclusion of commuted sandstone although it too is calcareous. Close inspection will show that each of the facies contains thin bands of the other and that they represent a process of continuous sedimentation. The diamicton unit is a till deposited, as indicated by its fabric and erratic suite, by ice from the west. The colour banding almost certainly reflects the mixing of dirt bands in the glacier as ice moved off the Carboniferous limestone on to the Devonian sandstone and Silurian shale. The precise mode of sedimentation is unclear but the till is interpreted as a basal till and, although the gradational banding suggests a basal melt-out process, there is some indication of shearing along the joints, and this suggests there may have been some lodgement.

An important aspect of this locality is that it indicates a significant input of the underlying sandstone and shale within 2km of the limestone/sandstone junction. A further 2km up-valley limestone has dramatically ceased to be dominant in the tills which again are banded (Figure 16). On this occasion the dominant facies is brown/red and almost devoid of limestone, while the brown/grey bands though calcareous are no longer limestone dominant although limestone accounts for about 40% of the phenoclasts. Within 5km of the limestone/sandstone junction there is no

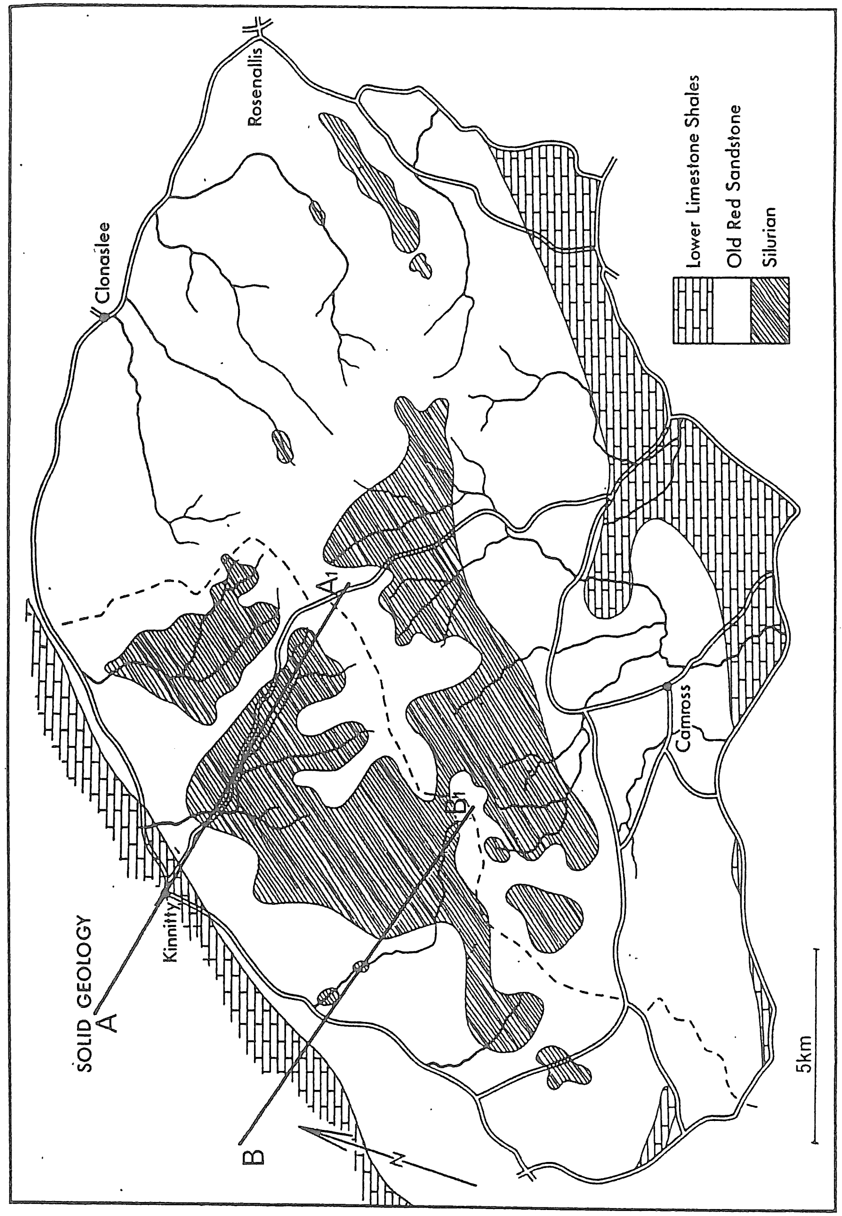


Fig. 16 The bedrock geology of Slieve Bloom (after Feehan, 1979 with alterations). Lines A-A_1 and B-B_1 refer to Figure 17

limestone in the tills. This pattern of petrographic variation in the tills is illustrated in Figure 17.

The interpretation of this pattern is complex, for although limestone has ceased to be a component of the tills 5km from the limestone/sandstone bedrock junction, they retain a small chert component and occasional large limestone blocks can be found at the surface. Quite clearly two processes have operated. There has been the expected fall-off in the carry-over of limestone phenoclasts which seems to be exponential, and limestone has been leached from the sediments. The relative amounts of chert (illustrated in Figure 17) give a clue to the importance of either process. Generally as limestone amounts fall the amounts of chert fall in tandem as would be expected with such closely associated erratics. But where limestone levels drop very suddently chert amounts at first rise and then fall but not as rapidly as the limestone. This clearly indicates that when the limestone content falls to a critical level (which is impossible to identify precisely in the field) leaching suddenly becomes the dominant process in the diminution of limestone amounts.

The influence of topography and groundwater conditions are crucial controls which determine where and how the leaching process will take place. Clearly the thickness, permeability and stratigraphic relationship of the deposits is also of crucial importance. Thus thin till deposits will tend to be rapidly leached whereas the lower levels of thicker ones may not, even though their lithological composition may be the same. The full implications of this situation will be written up elsewhere.

The gravels overlying the tills show a similar decline in their petrographic composition although the pattern appears to be more complex. They are interpreted as deglacial ice-proximal glaciofluvial deposits associated with the rapid down-wasting of the ice sheet. They are likely derived largely from englacial sediments and, as might be expected, seem to have a slightly larger carry-over distance than the tills. Their high permeability makes them more susceptible to acid leaching in some topographic situations than tills, but less so in others, thus providing at times a very erratic carry-over pattern. The gravels exhibit a moundy topography and generally do not rise above 250m contour. These mounds form a gravel belt along the western slopes of the mountains which has been regarded as an important moraine line by some authors (Charlesworth, 1928; Synge, 1970b).

One far-reaching implication of the decline in limestone content in the glacigenic sediments is seen when they are compared to those on the north-

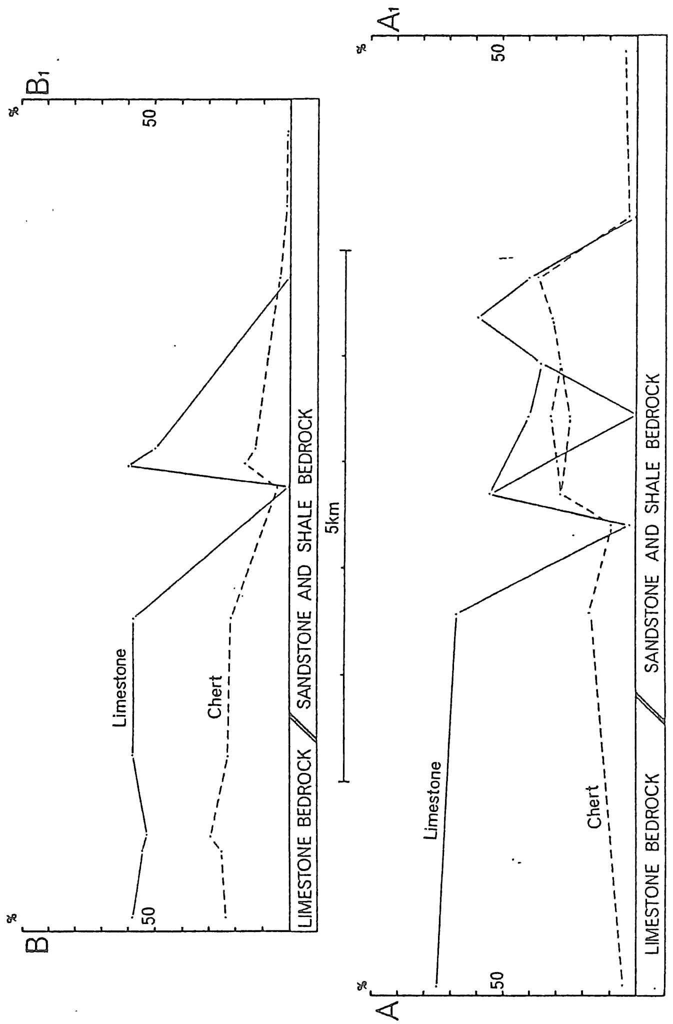


Fig. 17 Percentage limestone and chert in glacigenic deposits near Kinnitty (B-B1) and Glendine (A-A1). In each case the data was plotted for points dropped perpendicularly on to a line representing the direction of ice movement. See Figure 16 for the lines.

western flanks of the Galty Mountains in south County Limerick. Here Synge (1970a) recorded a very similar decay pattern in the limestone component of tills in an area of very similar topographic and bedrock conditions. Synge (1966, 1970b) used the rapid decline in limestone which is also coincident with a broad band of gravel mounds (Ballylanders Moraine) as supporting evidence that this moraine represented the southern limit of last glaciation ice. This has since become one of the major basis for support of the so-called Southern Irish End Moraine (Charlesworth, 1928) as the end moraine of the last glaciation ice (cf. McCabe, 1985). The implications of the evidence of the sediments in the Kinnitty are either that last glaciation ice did not rise above 250m OD on the western side of Slieve Bloom or that the rapid fall-off of the limestone content of glacigenic sediments in this situation (which is replicated over large stretches of the Southern Irish End Moraine) is not in any way indicative of the limit of last glaciation ice. The latter interpretation must, in the context of what is the known minimum extent of this ice event both to the east and south, be the only logical one. This is further evidence (see Warren, 1985) that the basis upon which the Southern Irish End Moraine and/or its approximations (see Mitchell et al 1973), are designated the end moraines of the last glaciation are inadequate.

TULLA

This stop (N 189 002) shows a thick sequence of silts, sand and gravel overlying grey limestone-dominated diamicton. The sequence is the same as that seen further north near Kinnitty, thus confirming that the sequence is not confined to one area. The gravels here can be seen to have a very variable petrographic composition but they are difficult of access for close examination. However, a close inspection of the river gravels here should show that Galway granite erratics are common. These are obviously derived from the deeply incised glacigenic deposits of Glendine.

GLENDINE

A drive up Glendine illustrates that as we approach the head of the glen limestone ceases to be a component in the tills although chert may be found. Galway granite is found in the glacigenic deposits right up to Glendine gap (S 230 993). The forestry road at the head of Glendine has provided cuttings which show periglacial slope deposits (derived in part from till) overlying the till deposits. The contrast between the

Devonian/Silurian dominated tills at the head of the glen with the Carboniferous dominated till at Tulla is striking and, quite clearly, it can be seen how similar situations in the Galty Mountains area were so striking as to suggest to previous workers that the deposits belonged to separate glacial stages. It is important to appreciate that such strikingly different till facies represent simple lateral variation in deposits of a single glacial event.

SOILS (Extracted from Conry & Hammond, 1984)

The major differences in the soils (Fig. 18) of the Slieve Bloom mountains can be attributed to parent material, climate and to relief.

Parent material is a very important factor in accounting for soil differences. Thus, the best soils on the Slieve Blooms are the Grey Brown Podzolic soils derived from limestone drift which has been carried on to the shale and sandstone rock during the last glaciation; shale materials give rise mainly to free draining brown podzolic soils while soils derived from sandstone bedrock or sandstone drift are predominantly poorly drained.

The sandstone soils are by far the most important group of soils in the Slieve Bloom region because they account for over 54.2% of the hill soils. They are derived from glacial deposits which have been carried on to the hills from the west. The presence of chert erratics indicates that the deposits originally contained a proportion of more soluble limestone. However, almost all this limestone has been removed by post-glacial weathering and the parent material of the vast proportion of the sandstone soils, therefore, consists of till composed of coarse-grained sandstone and chert with some shale, Galway granite and other erratics.

Soils derived from shales form an important group of soils in the Slieve Blooms not because of their extent but because they are some of the best soils in the hill area. They are found chiefly in the central part of the mountains where deeply incised valleys are a noted feature of the landscape.

Most of the shale soils are derived from glacial deposits, composed mainly of Silurian shale with a small admixture of sandstone and some Galway granite and other erratics. In the more elevated areas and especially where the slopes are very steep, the drift mantle has been eroded away and the soils are derived therefore from the underlying shale bedrock.

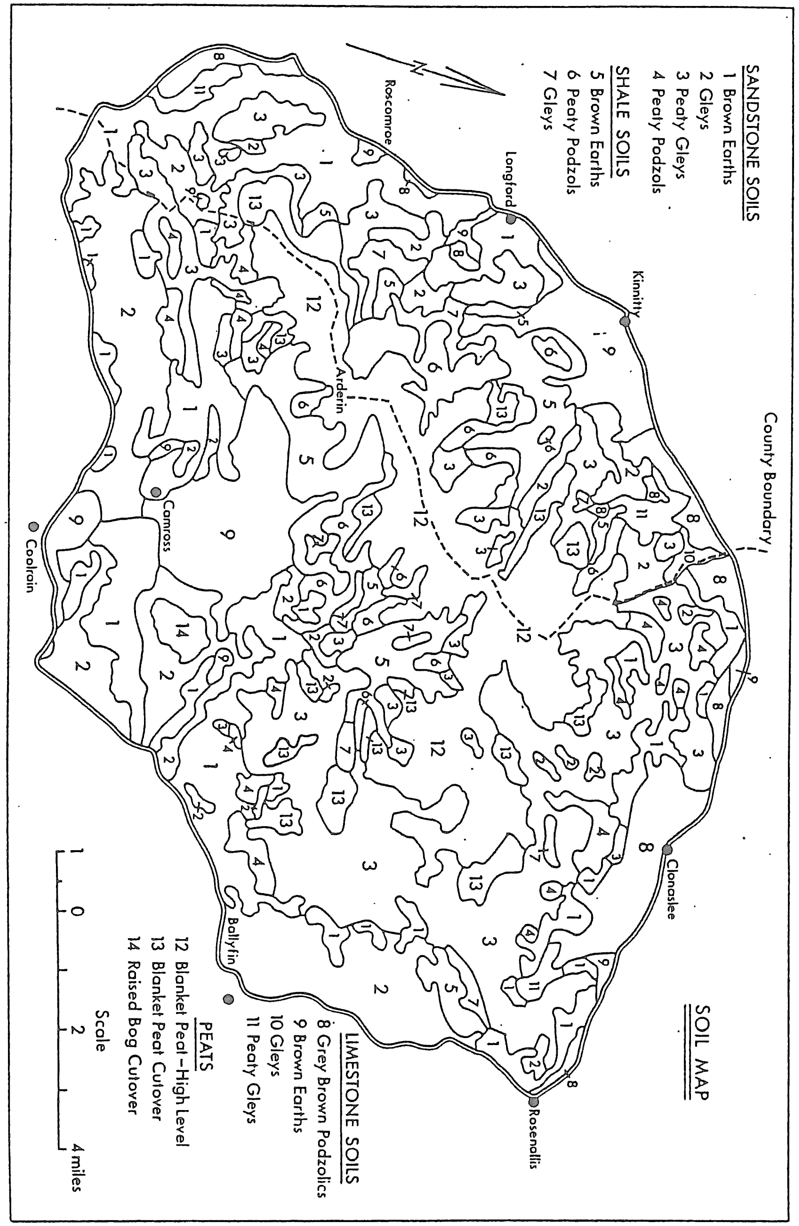


Fig. 18 The soils of Slieve Bloom

Grey Brown Podzolics: Grey brown podzolic soils occur on the northern and north-western side of the hills. They are derived from limestone till which has been carried on to the sandstone and shale bedrock formations around the lower slopes of the Slieve Blooms. They are moderately deep and well drained with a loam to sandy loam texture. The soil profile consists of a brown, friable surface horizon overlying a heavier texture layer known as a textural B horizon. The soil varies in depth from 75 to 100 cm but in some cases it may be as shallow as 40cm. These soils have been mapped in Counties Laois and Offaly as the Patrickswell and Fontstown Series.

Brown Earths: Sizeable areas of gravel soils have been mapped both on the northern and southern sides of the Slieve Bloom foothills covering a total area of 2,682 hectares (7.5% of the area). They are derived from glaciofluvial gravels and sands.

Large areas of gravel soils (Carlow-Baggotstown Complex) also occur on the northern and north-western side of the mountain (33%). The are derived mainly from gravels and sands containing a very high proportion of limestone and a small proportion of sandstone and shale. The higher lime content and the generally higher fertility of these gravels is reflected in a higher resistance to bracken infestation even when pastures are neglected.

Gleys: Small areas of poorly drained soils comprising a total of 412 hectares (1.1% of area) and derived mainly from limestone till, occur on the northern and southern side of the Slieve Bloom foothills in depressional areas which receive seepage waters from higher ground. These soils have a greyish brown loamy surface horizon overlying grey and mottled subsoil horizons.

Peaty Gleys: Like the gleys above, small areas of peaty gleys derived from limestone till clay occur on the northern side of the mountain. They are rather similar to the gley soils but they have a peaty surface due to the more lowlying situation in which they occur.

SITE 9: LOUGH BOORA

On draining Lough Boora (N 160 180) as part of the ongoing exploitation of the surrounding bog, Bord na Móna engineers reported a 250m long stoney ridge in the lake basin to the National Museum. It was though that the ridge might be anthropogenic, put as there was some doubt about this, the late F.M. Synge and this author were asked to comment. Trenches dug across the ridge revealed it was a beach.

During the examination of the ridge and the area around about an early Mesolithic occuption site was found by Museum personnel (Ryan, 1980). In all fourteen patches of charcoal within which were found burnt animal bones and many small blades, flakes and microliths worked from chert. The artifacts are very similar to those found at Mount Sandal, Co. Derry (Woodman 1981) and an early Mesolithic age is confirmed by four radio-carbon dates which approach 9,000a bp. The site ocurrs on a clay/silt unit behind the beach ridge in what was once probably a lagoonal area in which, as indicated by radio-carbon dates, peat development was well advanced by 8,100 bp (Ryan, 1984). The beach ridge occurs at approximately 52m OD, and an examination of Bord na Móna records shows that a lake at this level would have been considerably larger than the modern (now drained) Lough Boora.

The chief archaeological importance of the site is that it indicates that Mesolithic people extended to the interior of Ireland far from the coastal areas to which all previous evidence of them had been restricted.

The site is too difficult of access to visit on this excursion but the archaeology report with a contribution on the geology is being prepared for publication.

(WPW)

SITE 10: CLONMACNOISE - LANDSCAPE CONSERVATION AND THE HERITAGE ZONE

INTRODUCTION

The Clonmacnoise Heritage Zone lies beside the Shannon in West Offaly and is centred on the National Monument at Clonmacnoise (N 012 306) (Fig. 19). The National Monument receives 40,000 visitors each year but most spend less than one and a half hours in the area. The Heritage zone concept envisages that the local inhabitants, visitors, tourists and students should be encouraged to appreciate the other conservation items in the immediate area - Mongan Bog, the River Shannon, Fin Lough, the eskers and woodlands. It is argued that this type of conservation unit would provide a greater experience for the visitor and benefit education, tourism as well as stim- ulating small scale industry. An account of the Heritage

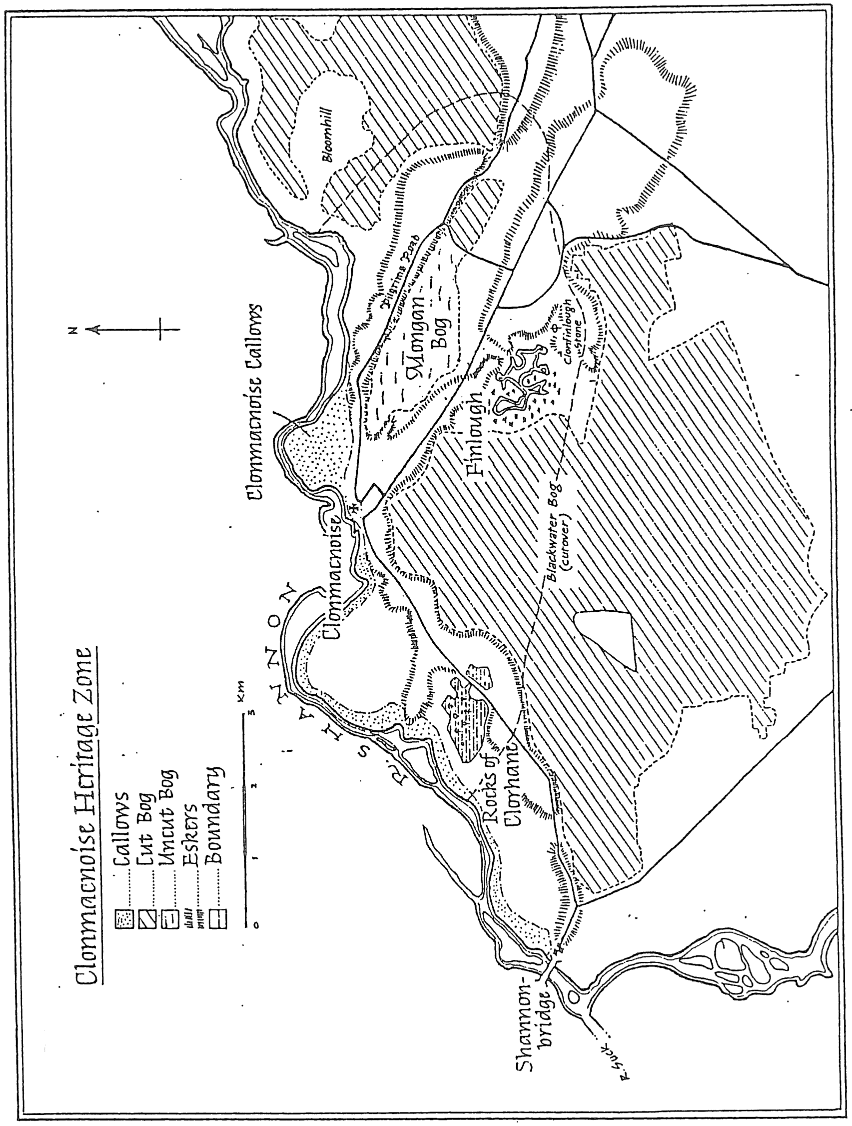


Fig. 19 Clonmacnoise Heritage Zone.

zone is provided by Tubridy and Jeffrey (1987). Various research reports have also been prepared for the EEC on nature conservation (Tubridy, 1983), economic aspects (Matthews 1986) the local community (Tovey, 1986) and in 1986 aconference was held in Tullamore to discuss the Heritage Zone proposal with interested agencies (Tubridy 1987). These are available on request from the Environmental Sciences Unit, Trinity College, Dublin.

FEATURES OF THE ZONE: THE RIVER SHANNON AND ASSOCIATED WETLANDS

To the west of the Zone lies the Shannon bordered by floodplain raised bogs and callow land. No floodplain raised bogs remain intact in the area and the main conservation interest centres on the Shannon and its floodplain, called callow (Gaelic, Caladh = river-meadow). This was originally covered in a fen woodland but is now managed for hay or pasture. A particularly interesting example of callow land lies just to the north of the National Monument which is surrounded on three sides by the Shannon, (a buried channel runs below the esker at this point). While it is owned by 30-40 different farmers, all of them manage their strips solely as hay meadow. This type of management has allowed the development of species rich grassland of native species which is an important breeding area for waders and corncrakes in spring. In winter it turns into a lake supporting many internationally important populations of ducks, wildfowl, geese and swans.

Farming is compatible with conservation in most cases although recent trends of earlier hay cutting, increased application of fertiliser and fashions in herbicide usage give cause for concern. At present visitors to Clonmacnoise do not have an opportunity to learn about the Shannon meadows and none receive protection anywhere on the Shannon.

THE ROCKS OF CLORHANE

Limestone outcrop can be found in several places in the Heritage Zone.

1. At the Rocks of Clorhane and extending across the river, access via forestry track off the Shannonbridge road, 4km south of Clonmacnoise.
2. Below Bunthulla, the large esker directly to the north of Clonmacnoise.
3. South east of Fin Lough, the lake south of Mongan Bog.

It is interesting to note that fords across the Shannon were present at 1 and 2. These fords were excavated during the Shannon Navigation works in the last century.

Large areas of pavement with typical solution features can be seen at

Clorhane, clints, grykes, karren etc. As the beds have been tilted (30-40 degrees) some of the openings are wider than usual. The callow land bordering Clorhane has several small wet depressions, could they be swallow holes?

Quarries operated at Clorhane until the 1950's. That on the right of the track 200m from the road, had a turf driven water pump of which traces survive. The soils at Clorhane are developed on heavy textured deposits which are probably of alluvial origin. Most of the pavement (22ha) is covered in a dense hazel scrub, more than half of which was underplanted by the Forest and Wildlife Service in the late 1960's. As there is little native woodland in the region of the Zone the survival of this type is vital to protect the habitat of the wooland flora, invertebrates and birds. An unusual feature of the vegetation is the presence of yew growing on the limestone.

FWS now amalgamated with the Office of Public Works (owners of the National Monument) have declared their intention to manage the area as a nature reserve. The obvious conservation unit would include the quarry, bordering callow as well as the remaining hazel scrub.

FIN LOUGH

According to David Bellamy, the basin south of Mongan Bog contained the most impressive raised bog he had ever seen, with several drainage systems and huge hummocks of Sphagnum imbricatum. Its vast size led to BNM interest in the area and their H.Q. was set up on the southern margin of the bog in 1965. Two areas of open water remained in the basin, Lough Nanag ("lake of the yound birds") and Fin Lough ("bright lake" from the marly bottom). Their survival is something of an enigma. Is it due to the abundance of alkaline water seeping from springs on the eskers? Or are they connected to a groundwater source as both are near outcrops of limestone rock? If they are natural wetlands around the bog, do they correspond to a type of lagg?

The nature conservation interest of both is high, not just because lakes are rare in the region but as the lakes lie between esker and bog one can see a succession of communities side by side in a sequence which one associates with raised bog development, i.e. aquatic community, reedswamp, fen, acid bog. Therefore, the lakes and particularly Fin Lough are an invaluable outdoor laboratory in vegetation history.

At Fin Lough, the extent of open water had declined by about 80% since 1838. This decline resulted from drainage work initiated by farmers in the last century and in recent years drying out has been accelerated by BNM operations. Other changes include agricultural intensification in surrounding eskers which has resulted in higher nitrate levels in the lake water. Lough Nanag has almost disappeared as it lies nearer BNM drains. Research on hydrology is urgently required at this lake in order to make management decisions regarding its future.

ESKERS

Much of the better land in the Heritage Zone is found on the eskers, which are also sites for ancient settlements, fortifications and trackways. North of Mongan Bog the esker is called the Pilgrims Road and it reputably formed part of the Eiscir Riada which led to Clonmacnoise. On the esker northwest of Fin Lough is a constructed embankment called the "split hills", which formed part of the outer boundary of the monastery enclosure.

The eskers are complex structures and as there are numerous gravel pits the deposits can be seen in many places. The most interesting exposure is at Nally's pit which is on the esker south-east of Mongan Bog. Travelling east from Clonmacnoise, the entrance can be found on the right after passing the turn signposted to Clonfinlough Stone. This stone is lying in a field west of the Catholic Church and is a limestone erratic with supposedly human markings (see Jackson, 1967). Many more erratics can be found on the eastern shores of Fin Lough.

Many areas of the eskers support a shallow soil of rendzina type. The nature conservation interest of these areas is high as the steeper places have escaped ploughing, reseeding or fertilizing. These pastures now support a very species-rich flora with many native grass species, bryophytes and colourful herbs reminiscent of the Burren. They are threatened partly by farm management practices but also by quarrying which seems to concentrate on areas with shallow soil. Farmers are increasingly turning to silage in the Zone without making any provision for retention of silage effluent and disposal. This must give rise to concern on the shallow esker soils.

MONGAN BOG

Mongan is one of only six intact raised bogs remaining in the Midlands. While it is best viewed from the Pilgrims Road esker, access is only possible from the opposite side of the bog where one should follow any one of a number of turf cutters' tracks from the public road to the dome.

it is a very small wet bog (110 ha) which explains why it escaped exploitation in the 50's and 60's. Bord Na Mona had started to drain it in the 70's when a decision was made to swop it for Ahascragh Bog which was owned by An Taisce. An Taisce have been the owners designate of Mongan since 1981 but due to legal problems, they still do not have title to the bog.

The bog has suffered from marginal turf-cutting etc. on the west and south but most of the dome remains intact. Compared to other equally "intact" bogs, Mongan is very wet and has an abundance of unusually large pools in the central area. The surface has well-defined hummock and hollow pattern, and the vegetation is dominated by Sphagnum species, including Sphagnum imbricatum. Possibly as a result of the wetness, Mongan has suffered less from fires than most bogs which might explain the well developed hummock and hollow pattern as well as the exceptionally rich epiphytic lichen flora on old heather plants.

Grouse have been hunted out but Greenland white-fronted geese still frequent the bog. Research has been continuing at Mongan since 1981 on vegetation history, vegetation dynamics and decay processes as well as hydrology and management. An account of its development is given by Bradshaw (1987). The principal management problems concern the effect of marginal drainage and the impact of research. While a management plan has been prepared for the site, lack of funds may make implementation impossible.

CONCLUSIONS

As the Heritage Zone contains examples of all the landscape units associated with the Midlands it is an ideal area for a conservation area such as that proposed. While the assessment of conservation value is biased in favour of species and habitats, the geological/geomorphological interest has been noted. The sixth sense of biologists which guides them to interesting habitats is generally a feeling for landscape. There are many more problems in assessing sites of geomorphological interest. How does one identify an esker of conservation interest? How can one educate people to regard the Midlands as an interesting landscape in a cultural climate which values dramatic scenery?

(MT)

SITE 11: CLARA

THE CLARA ESKER

The journey from Clonmacnoise to Clara (N 257 325) through Ballycumber follows the line of Eiscir Riada. Between Doon and Ballycumber the road travels along the top of the esker. A clear appreciation can be gained of the importance of eskers as routeways through the bogs of the Midlands as well as a good impression of the morphology of the esker systems (Fig. 20). The integrity and extent of this esker system, which can be traced westward beyond Ballinasloe and eastwards at least as far as Tyrellspass indicates that deglaciation proceeded westwards towards the head of Galway Bay without any significant readvance or change in direction of movement.

Approaching Clara from Ballycumber a right turn after the railway bridge (about 2.5km from Clara) followed by a sharp turn left takes us on a short drive along one of the two esker ridge crests that go to make up this feature at this point and gives a fine view of on almost untouched esker landscape. The deep inter-esker hollow between the two ridges must have been occupied by a large block of dead ice while the ridges were being built up. A pit in the esker where the road to Rahan crosses it shows many of the type of features seen at Tullamore. Another pit further east where the road to Tullamore crosses the esker shows large foreset gravel beds indicating deposition in a pro-glacial lake. The foresets at this point dip north, but this is as would be expected at the northern edge of the delta. Galway granite erratics were found at this site and they can be found in greater numbers further west along the Eiscir Riada complex indicating an ice source to the west of Galway. This esker converges with the Ballyduff esker about 16km to the northeast at Tyrellspass.

(WPW)

CLARA BOG

Clara Bog (N 2630) is about 650 ha in extent and is situated about 1km south of Clara. It is classed as an Area of Scientific Interest of International Importance. It has now been acquired for conservation by the Office of Public Works. Drains, opened previously by Bord Na Móna, are now being infilled with the assistance of the Irish Wildlife Federation.

The extract below from the Seventh International Peat Congress Tour Booklet (1984) describes the main features of the bog.

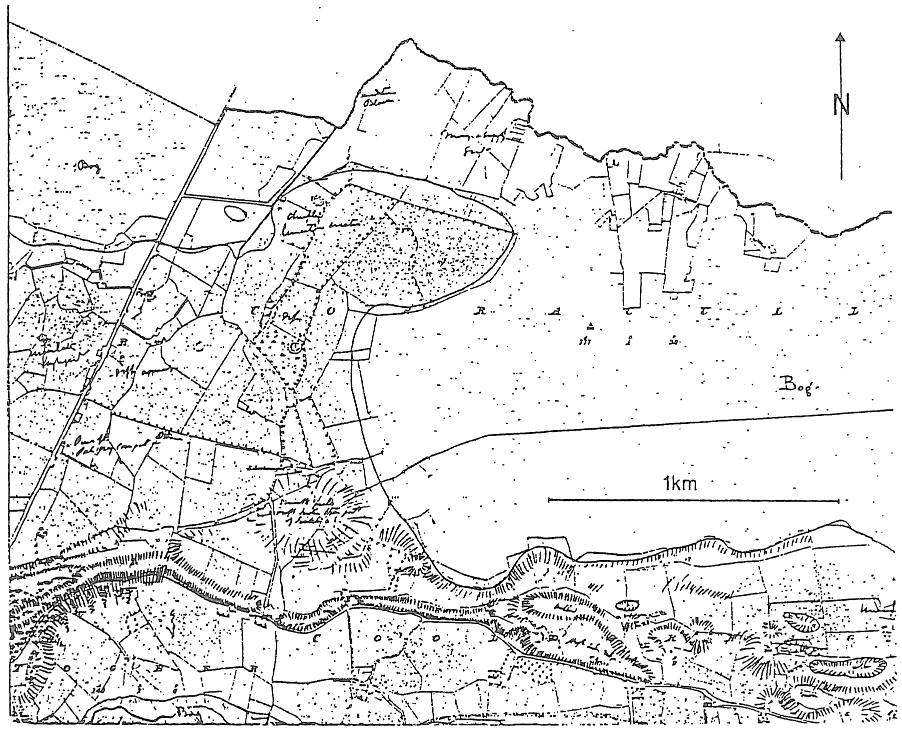


Fig. 20 Part of the road from Clonmacnoise to Clara (Near Togher) as it follows the line of Eiscir Riada (from Geological Survey of Ireland ms. map)

"This is the only Midland raised bog known to possess a well developed soak (internal drainage) system. Such systems were a characteristic feature of the larger Midland bogs most of which have by now been developed for peat production.
The vegetation and fauna of the soaks are indicative of minerotrophic rather than oligotrophic conditions. The source of the eutric plant nutrients is thought to be spring water seeping up through the peat. The vegetation of the soaks is quite varied, ranging from open water fringed by Carex rostrat and Juncus effusus at the source of the soak, to Sphagnum cuspidatum and S. recurvum lawns with Juncus bulbosus where water flows are strongest, to areas dominated by Eriophorum vaginatum tussocks and hummocks of Polytrichum juniperinum and Aulacomnium palustre with abundant Empetrum nigrum and Vaccinium oxycoccus and finally to Betula pubescens scrub woodland with Myrica gale, Molinia caerulea and occasionally Rubus fruticosus. The freshwater fauna consists of an unusual mixture of species some characteristic of acid environments while others are more characteristic of eutrophic ponds and rivers.
The ombrotrophic vegetation is similar to, but more developed than, that at Raheenmore and includes areas with well developed hummock-hollow patterns - the main hummock formers being Sphagnum rubellum and S. imbricatum with S. cuspidatum in the wettest hollows".

The "soak" system and the associated flora are the main reasons for conservation. However, as yet there has been little research on the source of the "soak", on the hydrology of the bog and its relationship with the surrounding area. It is possible that the source of water to the "soak" system is groundwater in the esker gravels that are present north of the bog. Consequently groundwater development or a lowering of the water table in the gravels by drainage north of the eskers could reduce the flow of hard base-rich groundwater to the bog and could affect the "soak" system. Therefore it is essential that a comprehensive geological, hydrological and hydrogeological investigation should be carried out in the near future.

(DD)

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APPENDIX 1

IRISH LAKE MARLS

Carbonate Depositional Processes

The solubility of calcium carbonate ($CaCO_3$) is related to ambient carbon dioxide levels. If water saturated with $CaCO_3$ in equilibrium with carbon dioxide levels greater than atmospheric (due to passage through the soil) comes into contact with the atmosphere, CO_2 diffuses out, causing the water to become supersaturated with $CaCO_3$, and deposition may result. Supersaturation can also be brought about by an increase in temperature, or by an increase in concentration resulting from evaporation. In addition to purely physico-chemical methods, supersaturation may result from biological influences on the equilibrium reactions. Photosynthesising phytoplankton or higher plants in water bodies remove CO_2 from solution, thereby upsetting the equilibrium in the same way as loss of CO_2 to the atmosphere. Some plants can utilize biocarbonate ions (HCO_3) for photosynthesis, and uptake of HCO_3 is by active transport, resulting directly in the precipitation of calcite (Wetzel, 1983); an example of this is the stonewort alga, **Chara**, which becomes totally encursted with calcite.

The relative importance of physico-chemical and biological factors in lacustrine $CaCO_3$ precipitation has been much debated in the literature. Several authors (e.g. Golubic, 1973) suggests that a substantial part of the $CaCO_3$ precipitation in lakes is biogenically induced by the phytoplankton and this is probably the case where a lake is on the lower course of a river which is already in equilibrium with atmospheric CO_2, and has precipitated any excess $CaCO_3$. However, lakes may also be fed by springs in equilibrium with high CO_2 levels, containing high concentrations of $CaCO_3$ in solution, or by streams which have lost some CO_2 but are still super- saturated with $CaCO_3$, and in such situations, physico-chemical processes resulting in deposition are likely to occur. A study of carbonate depositional processes in turloughs in the Ballinrobe area, Co. Mayo (Coxon, 1986; Coxon, in prep.) found evidence from chemical observations that in these groundwater-fed temporary lakes, $CaCO_3$ deposition is due predominantly to loss of CO_2 to the atmosphere, resulting in supersaturation with calcite.

Marl deposits

Whitish deposits consisting of at least 90% $CaCO_3$, often referred to as marl, have long been known to occur in parts of the Irish midlands, and have been used in the past for agricultural liming because of their great purity, but they have received relatively little academic attention. The term marl requires some clarification. In the geological literature, marl is usually defined as an impure, calcareous clay deposit (e.g Holmes, 1920). However, some geologists and many limnologists use the term marl to describe purer carbonate deposits, e.g. definition No. 3 from Howell (1962): "a soft, earthy material, usually buff to white in colour, composed largely of calcium carbonate (commonly 80 to 95%), that is found as a fresh-water deposit in lake basins, bogs, marshes and low areas once covered with water", and this is the usage here. An alternative name is lacustrine chalk: Kelts and Hsu (1978) define this as containing more than 60% carbon- ate, and marl as containing less than 60%. The deposits are found beneath many raised bogs, fens, turloughs and river callows in the Central Lowland, implying that lakes were much more numerous and extensive here in the past. Mitchell (1986, Fig. 4.2) indicates that lakes in the Shannon and Erne basins were formerly more extensive, while Delaney (1987) uses marl deposits to delimit the former extent of Lough Corrib.

A survey of the deposits present in ninety turloughs (Coxon, 1987) found that marl occurred in approximately half of the sites. White or cream pure marl (Munsell colour 10YR 7-8/1-3) was found to contain more than 90% $CaCO_3$, while grey or light brown impure marl (Munsell colour 10YR5-6/2-4) contained less than 90% $CaCO_3$ but generally more than 60%. A gradation was recognised from pure marl to peaty marl to marly peat, involving increasing organic content, from 1-3% to 15-30%, generally accompanied by an increase in non-calcareous inorganic content, from c.5% to up to 50%. A similar gradation has been noted by Daly (1981) in Pollardstown Fen. The pure marls frequently contained shell fragments, but were largely composed of inorganic calcite crystals. Recognisable fragments of Chara were rare, suggesting that this was not a major source of $CaCO_3$. Similar inorganic marls of lacustrine origin have been described in the literature, e.g. Terlecky (1974). It is unclear how typical these turlough marls are of Irish marls in general: in some, fragments of Chara form a more important component.

The stratigraphy of two turloughs containing marl in the Ballinrobe area was studied in detail, and the pollen record was examined by P. Coxon.

Broad pollen assemblage biozones were recognised, and biostratigraphically correlated with radio-carbon-dated pollen zones from elsewhere, enabling the deposits to be tentatively dated. The basal deposits of silty clay containing 70% carbonate date from 12,500-12,000 B.P., while deposition of pure white marl appears to have started at both sites at approximately 10,000-9,500 B.P. The correspondence of the initiation of pure white marl deposition to the warming up of climate in Holocene times may be due to increasing rates of photosynthesis causing CO_2 depletion in the water body. Alternatively, deposition may have been predominantly physico-chemical in nature (as the present day), and the increase in purity may be due to decreasing solifluction inputs of non-calcareous matter following slope stabilization, combined with increasing $CaCO_3$ content of the inflowing water due to increased soil CO_2 production. At one site, marl continues to the surface, and the uppermost pollen assemblage, at 1.5-2.0m, is though to date from c.9000 B.P., while at the other site the marl deposition was followed by a period of accumulation of pollen-bearing fen peat, making it possible to assign a date to the cessation of marl deposition, of approximately 9000 B.P.

The duration of marl deposition in these turloughs appears to be fairly typical. For example, fen peat directly above marl in Mongan Bog, Co. Offaly, was radiocarbon dated to 9200 B.P. (H. Parkes, pers. comm). The causes of the cessation of marl deposition may be several. At some sites an actual drop in water level seems to have occurred, while at other sites the transition can be accounted for in purely ecological terms, by the over-growing of the lake margins, initially by fen peat and then by Sphagnum peat.

While a sequence of peat overlain by marl is the most common, some turloughs show an alternating sequence of marl and peat deposits, suggesting a series of transitions from open water to marshy conditions and back to open water. Alternations of this sort are also seen at Pollardstown Fen (Daly, 1981): it is possible that they reflect changing hydrologic conditions in the fen due to variations in the quantity of groundwater feeding it, presumably related to climatic fluctuations.

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