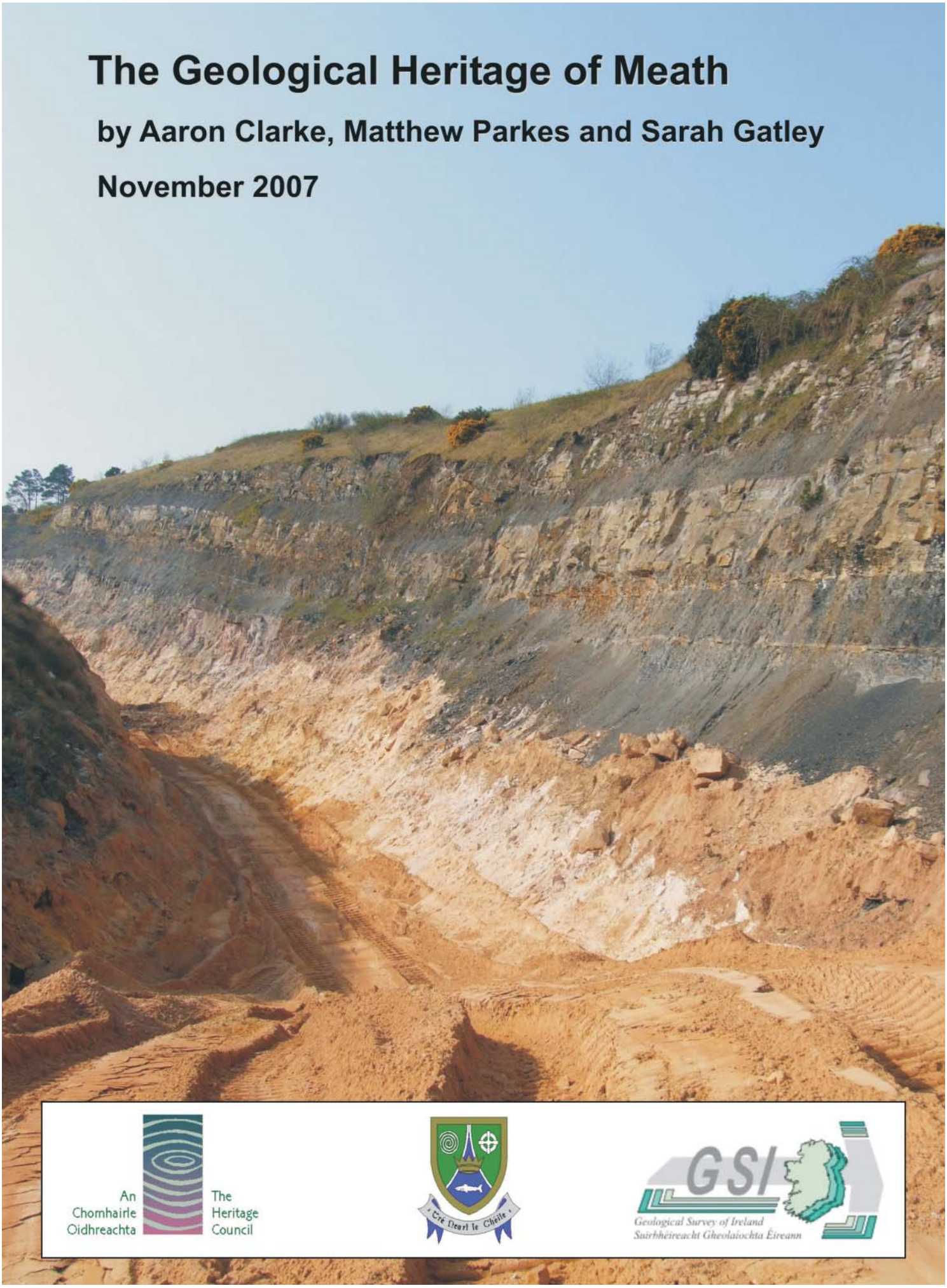
The Geological Heritage of Meath

by Aaron Clarke, Matthew Parkes and Sarah Gatley

November 2007



An Chomhairle Oidhreachta
The Heritage Council

Cré Dearl le Chéile

GSI
Geological Survey of Ireland
Suirbhéireacht Gheolaíochta Éireann

The Geological Heritage of Meath

An audit of County Geological Sites in Meath

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November 2007

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'Cré Neart le Chéile'

An action of the County Meath Heritage Plan 2007 - 2011

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Report Summary
(County Geological Sites in the Planning Process)

County Meath is a place with a subtle but distinctive landscape. The bedrock foundation, with hundreds of millions of years in the formation and shaping, and the more recent history of geomorphological processes involving river channels and glaciers are what has created an underlying geological diversity or geodiversity for short. Geological understanding and interpretation is best done on the ground at sites where the rocks and landforms are displayed. County Meath has a range of such natural and man-made sites.

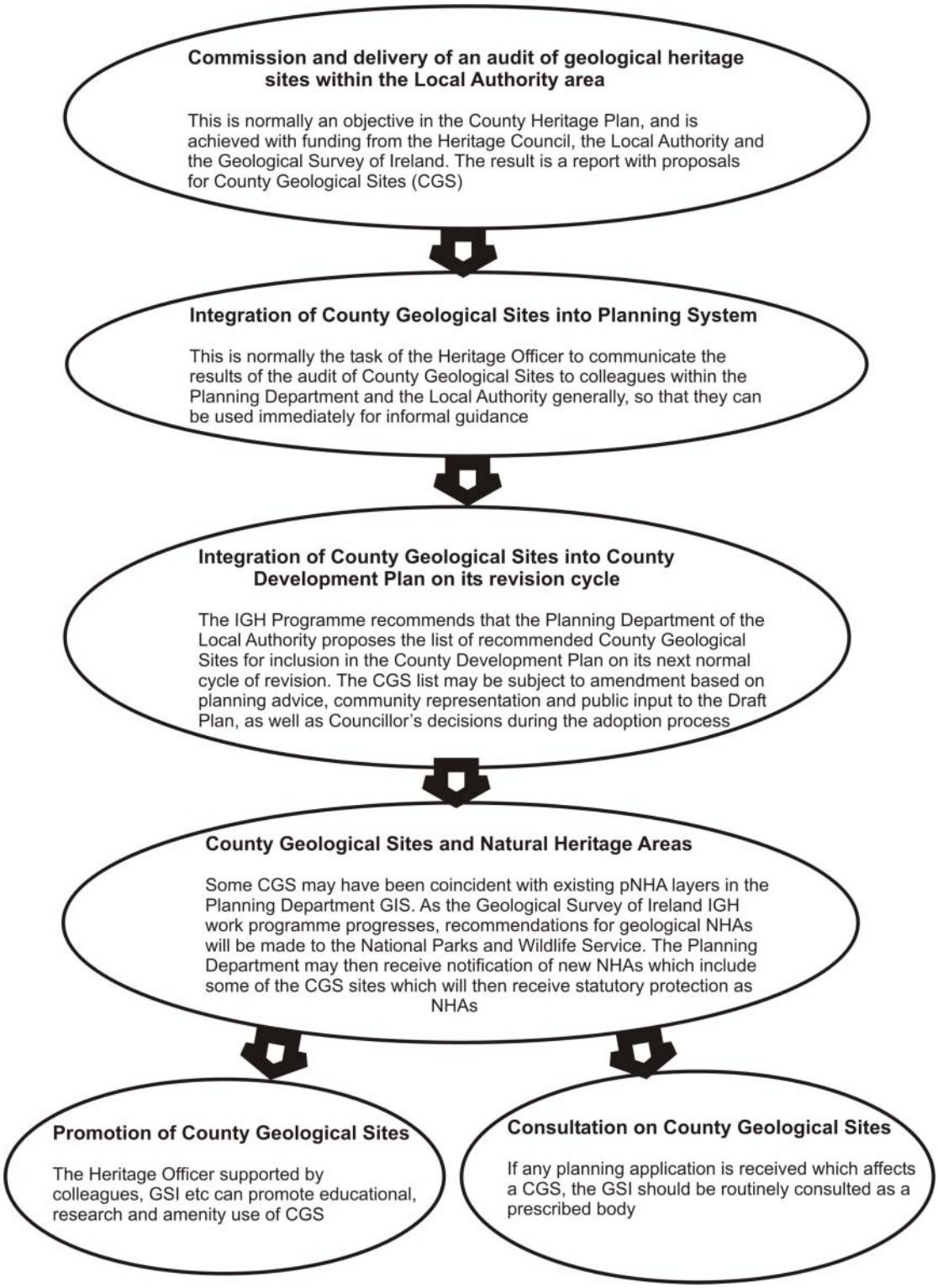
This report documents what are currently understood to be the most important geological sites within Meath by the Irish Geological Heritage Programme of the Geological Survey of Ireland. It proposes them as County Geological Sites, for inclusion within the Meath County Development Plan. County Geological Sites do not receive statutory protection like Natural Heritage Areas (NHA) but receive an effective protection from their inclusion in the planning system. The flow chart below summarises the process. In brief, the sites listed in the report can be used for immediate guidance by the Planning Department, and incorporated as a layer in planning GIS systems. When the next County Development Plan is formulated, the IGH programme recommends that these sites be formally adopted as County Geological Sites and that they receive appropriate protection in the planning process.

However, some of the sites described in this report are considered to be of national importance as best representative examples of particular geological formations or features. They either have been, or will be, formally proposed by the Geological Survey of Ireland, for designation as NHAs by the National Parks and Wildlife Service after due survey and consultation with landowners. However, some of these sites fall within existing NHAs and SACs where the ecological interest is founded upon the underlying geodiversity.

The report also documents a wide variety of geological data sources providing information about Meath. It includes a simple geological history of the county, with maps, charts and a glossary that make the information accessible to those who have not had any formal geological training.

This report is written in non-technical language (with a glossary for unavoidable geological terminology) and structured as a working document for use by the Heritage Officer and the Planning department of Meath County Council. It is not primarily intended for publication for the people of Meath in its existing form. A chapter of the report includes recommendations on how to best present and promote the geological heritage of Meath to the people of Meath. However the preliminary sections, summary geological history and accompanying map, timescale and stratigraphical column may be used as they stand to preface a booklet or as website information in the development of this work and for information.

County Geological Sites - a step by step guide



Meath in the context of Irish Geological Heritage

To date, Meath is one of only a handful of counties which has commissioned an audit of geological heritage sites within the scope of the County Heritage Plan. It will hopefully act as a model and an inspiration for other councils to follow. It will hopefully act as a model and an inspiration for other counties to follow. It represents a significant commitment on the part of the Local Authority to fulfil its obligations to incorporate geology into the spectrum of responsibilities under the Planning and Development Act 2000, Planning and Development Regulations 2001, Wildlife (Amendment) Act 2000, Heritage Act 1995 and the National Heritage Plan (2002). The Geological Survey of Ireland views partnerships with the local authorities, such as through this report, as a very important element of its strategy on geological heritage.

Geology in Local Authority planning

Geology is now recognised as an intrinsic component of natural heritage in three separate pieces of legislation or regulations, which empower and require various branches of Government, and statutory agencies, to consult and take due regard for conservation of geological heritage features: Planning and Development Act 2000 [e.g. Sections 212 (1)f; Part IV, 6; First Schedule Condition 21], Planning and Development Regulations 2001, Wildlife (Amendment) Act 2000 (enabling Natural Heritage Areas) and the Heritage Act 1995. The Planning and Development Act and the Planning Regulations in particular, place responsibility upon Local Authorities to ensure that geological heritage is protected. Implementation of the Heritage Act 1995, through Heritage Officers and Heritage Plans, and the National Heritage Plan 2002, allow County Geological Sites to be integrated into County Development Plans.

The Irish Geological Heritage Programme (IGH) in the Geological Survey of Ireland (GSI) complements other nature conservation efforts of the last two decades, by assessing Ireland's geodiversity. This geodiversity is the foundation of the biodiversity addressed under European Directives on habitats and species by the designation of Special Areas of Conservation (SAC), and more recently on a national scale by the designation of Natural Heritage Areas (NHA). This national nature conservation process is enacted through the Wildlife (Amendment) Act 2000. As a targeted conservation measure to protect the very best of Irish geology and geomorphology, NHA designation fills a void which has existed since the abandonment of the Areas of Scientific Interest (ASI) scheme, listed by An Foras Forbartha in 1981.

The IGH Programme does this by identifying and selecting the most nationally important geological sites for designation as NHAs. It looks at the whole of Irish geology and geomorphology under 16 different themes. The fundamental approach is that only the minimum number of sites necessary to demonstrate

a particular geological theme is selected. This means that our first criterion is to identify the best national representative example of each feature or major sequence, and secondly any unique or exceptional sites. The third criterion, of selecting any sites of International importance, is nearly always covered by the other two.

IGH THEMES

1. **Karst**
2. **Precambrian to Devonian Palaeontology**
3. **Carboniferous to Pliocene Palaeontology**
4. **Cambrian-Silurian**
5. **Precambrian**
6. **Mineralogy**
7. **Quaternary**
8. **Lower Carboniferous**
9. **Upper Carboniferous and Permian**
10. **Devonian**
11. **Igneous intrusions**
12. **Mesozoic and Cenozoic**
13. **Coastal geomorphology**
14. **Fluvial and lacustrine geomorphology**
15. **Economic geology**
16. **Hydrogeology**

Designation of geological NHAs is undertaken by our partners in the Programme, the National Parks and Wildlife Service (NPWS – formerly a part of Dúchas) in the Department of Environment, Heritage and Local Government. Once designated, any geological NHAs will be subject to normal statutory process within the Meath Planning Department and other relevant divisions. However, management issues for geological sites are generally fewer, and are different from many ecological designations. A later chapter considers these issues.

As a result of extensive comparison of similar sites to establish which is the best, we have a good overview of many other sites, which although not the selected best example, may still be of National importance. Others may be of more local importance or of particular value as an educational site or as a public amenity. These other sites are proposed here for CGS listing in the County Development Plan, along with the clear NHA selections.

At the time of writing this report, candidate sites for Ireland have been established by Expert Panels for all the 16 themes, and the indicative site lists have been finalised. For three themes, the entire process has been essentially completed and detailed site reports and boundary surveys have been included along with a Theme Report. A small number of the sites documented here are already selected and proposed for NHA designation, but due to various factors, they have not been formally designated yet. Members of the Expert Panels for each theme are too numerous to list here but the information is available in GSI's Annual Report for 2003 and on the Heritage Programme's pages on the website (www.gsi.ie).

The procedure for identifying and assessing sites has developed as the whole Irish Geological Heritage Programme has become established. Early thematic reports on Karst, Precambrian to Devonian Palaeontology and Carboniferous to Pliocene Palaeontology (IGH1, IGH2 and IGH3) were done in their entirety, by contractors or by Matthew Parkes. The Expert Panels met to decide which sites should be assessed and prioritised, followed by site reports and fieldwork to allow a basis for selection of the most important for NHA designation.

However, due to lessons learnt in establishing the methodology, and because of urgent demands for information on sites from many quarters, a different approach has evolved. All Expert Panels have concluded their preliminary selection of candidate sites so that we now have a picture of the full range of sites to be examined nationally as candidate NHAs or as County Geological Sites. This is also valuable because sites which have scientific importance under more than one theme can be properly defined in an integrated way. It is hoped that these indicative site lists and location maps will be publicly available on the GSI website in the near future.

Commissioned desk study site reports from members of the Expert Panels for a particular Theme are then followed by field site reporting by IGH Programme staff, including boundary surveys if the sites are suitable. After this stage the Expert Panels review sites to make the final selection for NHA status. Any suitable site may be promoted with a local authority as a County Geological Site, whether or not it goes forward as an NHA at a later stage after full assessment.

The sites proposed here as County Geological Sites (CGS) have been visited and assessed specifically for this project, and represent our current state of knowledge. It does not exclude other sites being identified later as the work of the GSI on the IGH Programme progresses. The project also does not exclude sites which may be directly promoted by Meath Council itself, or by local communities wishing to draw attention to important sites with an intrinsic geological interest for amenity or educational purposes.

Geological conservation issues and site management

The Earth sustains all human society. Soils provide the food we grow and all our material goods are derived from Earth resources extracted from the ground. The Earth also offers hazards and risks with earthquakes, volcanic eruptions, landslides, flooding, tsunami and storms. Understanding the Earth System and our impact upon it is vital to the sustainability of human culture, let alone the viability of all the rest of the enormous biodiversity sharing our planet. Geological heritage is a significant component of understanding the Earth, in that it identifies key places which demonstrate important earth science information. Identification of such places allows strategies to safeguard and promote them for future education and interpretation.

Since **geodiversity is the often forgotten foundation for much of the biodiversity** which has been identified for conservation through SAC or NHA designation, it is unsurprising that many of the most important geological sites are actually the same areas. In these areas, the geological case enhances and cements the value of these sites for nature conservation, but requires no additional designation of actual land areas. In Meath, the Boyne Valley and Blackwater Valley are such cases.

There tend to be two broad types of site identified by the IGH Programme. Most geological sites tend to be small and discrete. They may be old quarries, natural exposures on hilly ground, river sections, or other natural exposures. They usually have a specific interest such as fossils, minerals or are a representative section of a particular stratigraphical sequence of rocks. **The other type of site tends to encompass larger areas that represent a geomorphological interest – landscapes that illustrate processes which formed them**. In Meath, much of the landscape is dominated by landforms of glacial origin and several large areas such as Murrens and Summerhill present issues on how to best address the geomorphological interest.

It is also important from a geological conservation perspective that Planning Authorities understand the landscape importance of geomorphological features which may not in themselves warrant any formal site designation, but which are an integral part of the character of Meath. A lack of awareness in the past, has led to the loss of important geological sites and local character, throughout the country.

There are big contrasts in the management requirements for geological sites in contrast to biological sites. Most geological sites are actually quite robust and generally few restrictions are required in order to protect the scientific interest. In some cases, paradoxically, the geological interest may even be served better by a development exposing more rock. **The important thing is for the sites to be known about in the planning department, and more generally, that consultation can take place if some development or change in land use is proposed for a site**. Through this means, geologists may also get the opportunity to learn more about a site or area. They can record and sample temporary exposures. Early geological consultation may

influence the design of the development so that access to exposures of rock is maintained for the future. Equally, a strong geological heritage case might occasionally prevent completely inappropriate developments being permitted.

In Meath, as in some other counties, working quarries may be considered as CGS or NHAs simply because they are the best representative sections available of entire sequences, in areas where exposure is otherwise poor. No restriction would be sought on the legitimate operation of these quarries. However, in such cases, for hard rock quarries, maintenance of exposure after quarry closure would be sought with the operator and planning authority. In sand and gravel pits, faces tend to degrade and vegetate once abandoned, but active management of a site can maintain access to the scientific interest once the pit has stopped working, if the site merits it.

One specific area where there are significant difficulties in creating a meaningful geological heritage site is in relation to mine sites. Meath hosts Tara Mine, which along with Lisheen Mine in Tipperary and Galmoy Mine in Co. Kilkenny make Ireland the largest producer of zinc in Europe. However, the IGH Programme has determined that with most major mines in Ireland it is impractical to select them as either a CGS or an NHA. That includes Tara Mine. There are specific issues with the NHA legislation of the Wildlife (Amendment) Act 2000 such that they could only be selected for their mineralisation, and not for any industrial heritage representation. More importantly the practical difficulties outweigh selection as CGS, since modern mining techniques involve total or maximised extraction of the ore with backfilling of waste rock so there is normally nothing to access after mine closure. There are also numerous safety, insurance, permission and legal issues. It is the aspiration of the IGH Programme to negotiate with mine owners and operators for the long term maintenance of small representative sections of geological heritage interest where feasible.

Specific sites may require restrictions and a typical case might be at an important fossil locality or a rare mineral locality, where a permit system may be required for genuine research, but the general opportunity for collecting may need to be stopped. However, Meath's palaeontological sites are not likely to require such an approach, being slow to yield their fauna without very hard work by a palaeontologist.

The previous paragraphs provide some discussion of generic management issues but it is important to note that any proposed development affecting a CGS should lead to early consultation with the IGH Programme on a case-by-case basis. Different developments may generate different issues relating to the geological heritage interest.

In terms of landowner interests, the inclusion of their land within a County Geological Site does not automatically imply severe restrictions on development, but flags the geological importance so that consultation may take place. As noted before, some developments may be positively beneficial in exposing more of the geological character.

New exposures in development
One less obvious area where the Local Authority or the National Roads Authority can play a key role in the promotion and protection of geology is in the case of new roadways. **Wherever new carriageways are built**, or in other major infrastructural work, it should be a policy within the Planning Department that **newly created rock exposures are left open and exposed** unless geotechnical safety issues occur (such as bedding dips prone to rock failure). The grading and grassing over of slopes in cuttings is largely a civil engineering convenience and a mindset which is hard to change. However, it leads to sterile and uninteresting roads which look the same throughout the country. By leaving the rock exposures intersected along the routeway, there is an improvement in character and interest, reflecting the geology and landscape of an area. Sympathetic tree or shrub planting can still be carried out, but leaving bare rocks, especially where they show interesting features, not only assists the geological profession, but creates new local landmarks, to replace those removed in the construction of the roadway. It can also potentially save money on the construction.

Geoparks
An extremely interesting development in geological heritage, not just in Europe, but internationally, has been the rapid recent growth and adoption of the Geopark concept. From an initial European Geoparks Network, there is now a Global Geoparks programme, fully endorsed by UNESCO. A **Geopark is a territory** with a well defined management structure in place (such as Local Authority support), **where the geological heritage is used to develop sustainable tourism opportunities**. A fundamental basis of the Geopark is that it is driven from the bottom up – the communities in the Geopark, are the drivers of the project and are the main beneficiaries. It therefore provides protection of the geological heritage resource so that the community can benefit from it.

In Ireland there are already two members of the European Geopark Network (the Copper Coast in Waterford and Cuilcagh-Marble Arch in Fermanagh), but there are several active proposals in development from Kerry, to the Burren, through the esker landscapes of Offaly and Westmeath to Carlingford in County Louth and the Mourne Mountains. Applications usually need to demonstrate some existing promotion of geological heritage. **It is the opinion of the authors that Meath does not have any areas likely to conform to the quite stringent requirements of an application to the Geoparks Network.**

World Heritage Site status
Previous UNESCO criteria for defining a World Heritage Site allowed only two classifications: either a natural site or a cultural site. This meant that globally, the majority of sites were of cultural heritage. In Ireland, Newgrange and the Boyne Valley archaeological sites (Brú na Bóinne), and the monastic site of Skellig Michael in Kerry were our only World Heritage Sites. In Northern Ireland, the Giants' Causeway is a World Heritage Site of prime geological importance as a natural site.

However, the criteria have been modified recently to reflect a more holistic approach, and to realise that many sites have a natural component and a history of cultural modification which results in unique landscapes. The Burren in County Clare is perhaps the strongest case Ireland has for another World Heritage Site. **It is the opinion of the authors that Meath does not possess any geological sites likely to be suitable as candidate World Heritage Sites.** Notwithstanding this and recent excellent publications such as Geraldine Stout's *Newgrange and the Bend of the Boyne* study, as the Boyne Valley is renowned for its archaeology, much more should also be made of its superb glacial and fluvial geomorphology within the provision of educational and tourist interpretation.

Proposals and ideas for promotion of geological heritage in Meath

Meath is significantly advanced compared to most counties in having geological heritage addressed within both the Heritage Plan and the County Development Plan. This report is part of that progress and the following section discusses how these elements interact and offers some suggestions.

The clear and significant inclusion of geological heritage in the County Development Plan 2007-2013 for County Meath is a most welcome and positive step, for a topic that is often undervalued and poorly known in the wider community. Listed below are the main directly relevant policies in the plan, to which this report relates.

> **Her Pol 19** – Further to the designation of sites of geological and geomorphological interest within the County, it is the policy of the Council to protect and conserve such sites from inappropriate development that would detract from their heritage value and interpretation.
> **Her Pol 20** – To ensure that where development is permitted, its effect on future designated sites of geological and geomorphological interest is minimised through appropriate conditions and retention of a buffer zone.
> **Her Pol 21** – To require applications to have regard to the Irish Geological Institute EIS guidelines.
> **Her Pol 22** – To consult with the Geological Survey of Ireland in advance of proposals where deemed appropriate.

Of course, aside from these specific policies relating to geological heritage in the County Development Plan (CDP), there are many other policies in Chapter 8 of the Plan, covering natural heritage and landscape protection, where geological heritage may feature as an integrated facet of the topic. In particular those relating to the protection of designated sites such as NHAs and SACs and to peatlands, have geological components.

At the next cycle of formulating a new CDP some modifications to these policies are recommended in order to make the status of County Geological Sites more explicit. It is recommended that either as an addition to Heritage Policy 19 or as an extra new policy, it is stated:

It is the policy of the Council to protect and conserve the County Geological Sites listed (see below or as appendix X) from inappropriate development that would detract from their heritage value and interpretation.

It is also advised that the promotion of 'retention of a buffer zone' in Her Pol 20 is not deemed realistic or best practice for geological site conservation and should be replaced by 'and early consultation with geological conservation authorities'.

N.B It would also be advisable to substitute the correct title for the IGI in Policy 21 – the Institute of Geologists of Ireland.

The Heritage Plan for 2007-2011 itself includes a number of actions specific to geological heritage, which this report partially addresses.

> **Theme 1 – Awareness and Education**
> **Action 12** – Hold an annual geological event as part of Heritage Week
>
> **Theme 2 – Baseline data and Information**
> **Action 45** – Undertake an audit of geological heritage sites in the county in association with the Geological Survey of Ireland, and conserve important sites in the County Development Plan
> **Action 54** – Publish an explanatory booklet on the geology of the county

Of course, aside from these specific actions relating to geological heritage, there are many other actions in the Heritage Plan, where geological heritage may feature as an integrated facet of the topic. More obvious areas include:

- Geodiversity provides the habitats for much of the biodiversity which it is hoped to conserve.
- Archaeological and architectural monuments, vernacular buildings and features are often influenced by geodiversity, and this should be kept in mind in achieving any of the specific actions related to these parts of Meath's heritage.
- If the Council do own any of the geological heritage sites included here it will be easier to achieve positive results for both protection and promotion of those sites, and this may provide a basis for prioritising future actions.
- As a repository of the National Archives, the GSI holds various records relating to County Meath's geology. Efforts to publicise archives in Meath may need to report such external archives too.

Landscape Character Assessment is a tool which fundamentally defines differences in geology as the basis for land-use and cultural modifications, and the resultant landscapes. However it is clear from the County Development Plan, that this underlying basis is recognised.

Specific ideas for projects

Guides

There is one excellent guidebook to the Quaternary geomorphology of Meath (Meehan and Warren 1999), aimed at a general audience. There is certainly scope for others, and especially for guides at different levels of detail and accessibility to non-specialists. A range of leaflets, booklets, books and other media are all feasible, but the research and production of appropriate text and images is a difficult task to do well without appropriate experience, and adequate time and resources. **However, with appropriate resources, a**

simple, highly illustrated booklet on the geological heritage of Meath could be compiled for a wide general audience, based on the substance of this report.

Signboards
Simple explanatory or interpretive signboards may be advisable at some geological heritage locations, but if these are considered, their locations and individual siting should be very selective, since a proliferation of different interest groups may provoke a 'rash' of panels all over the county. A signage strategy could be developed, and its implementation would be subject to consultation with relevant landowners and the Planning Authority, as appropriate. Panels, with their text and graphics require a particular expertise to produce successfully, and the IGH Programme can offer input if signs are desired and planned for key visitor localities. However, given the nature of the majority of sites described in this report, which are either on private farmland, or have no suitable parking lay-bys to get an overview, it is difficult to suggest a suitable site that would benefit from a panel, with the possible exception of the Boyne Valley site.

Museum exhibitions
As a result of the work to produce this report, the material for a panel based exhibition has been largely compiled. With some extra resources an interesting exhibition can be put together for display in the Council offices, Libraries etc. A good model is that produced for Carlow, Kildare or for Dun Laoghaire Rathdown [see www.gsi.ie/Programmes/Heritage/Exhibitions].

Geoparks
As stated above, it is not considered that any areas are suitable candidates for Geopark status, based on the European and Global Geoparks Network criteria.

World Heritage Site bid
It is not considered that any areas are suitable from a geological or geomorphological perspective as candidate World Heritage Sites. It is understood that the National Parks and Wildlife Service and the Department of Environment, Heritage and Local Government are the recognised body for such a bid from Ireland. There is however, no site in Meath on the tentative list of candidate sites for Ireland on the World Heritage Site Organisation website. If there were any new heritage sites under consideration from a wider perspective, then the GSI should be consulted in relation to including a geological assessment in the work, even if it is only a small element, such as sources of building stone etc.

Summary stories of the Geology of County Meath

1) Simple summary:

The varied landscapes in County Meath formed over hundreds of millions of years by various geological processes. The oldest underlying bedrock geology stems from a time when Ireland was made up of two main 'halves'. Bellewstown and Grangegeeth areas have volcanic rocks erupted as oceanic islands as two plates of the Earth's crust came together and closed the Iapetus ocean, 500 to 400 million years ago. Associated with them are Silurian aged sandstones which formed in the shallowing sea as the ocean finally closed. The majority of the bedrock underlying the county consists of Lower Carboniferous aged rocks, which are mainly limestone. These formed on the continental shelf of a tropical sea around 340 million years ago. There were both deep marine basins and shallow water environments across Meath. A period of shallow seas with excessive evaporation left gypsum and mudstone deposits in the Kingscourt (Cavan) area in a downwarped basin. The southern end of the faulted depression is in Meath. Some of the last sediments to be deposited in Meath occurred during the Quaternary period (1.6 million years ago to present) when a series of large ice sheets moved over Ireland, and down the Irish Sea area, depositing glacial till (clay, sand and gravel) and scouring the underlying bedrock giving Meath much of its present day geomorphological character.

2) Main summary

The varied landscapes in County Meath formed over hundreds of millions of years by various geological processes, each one leaving its mark in the rock record. Careful examination of the rocks in the region can help unravel the story of their formation and thus shed light on the evolution of the Meath terrain.

Rocks can be divided into three main groups, **sedimentary**, **igneous** and **metamorphic**. Sedimentary rocks are laid down as particles of material such as sand or mud and then hardened by compaction and **lithification** into **sandstones**, **siltstones**, **mudstones** and **limestones**. **Fossils**, often preserved in these rocks, can give us an idea of when the rock formed and what the climate and environment were like at that time. **Igneous** rocks crystallise from **magma** originating deep beneath the Earth's surface and may be **extrusive** (i.e. **lava** flows at the Earth's surface) or **intrusive** (emplaced within the Earth's **crust**, below the surface). **Metamorphic** rocks are sedimentary or igneous rocks that have been altered by changes in temperature and/or pressure. New minerals grow in response to these changes and their composition depends on the composition of the original rock, and the temperatures and pressures that affect it.

The predominant rock types in Meath are sedimentary rocks, limestone of Carboniferous age in particular. These sedimentary rocks have only been

mildly affected by **folding** and retain many of their original sedimentary and depositional structures.

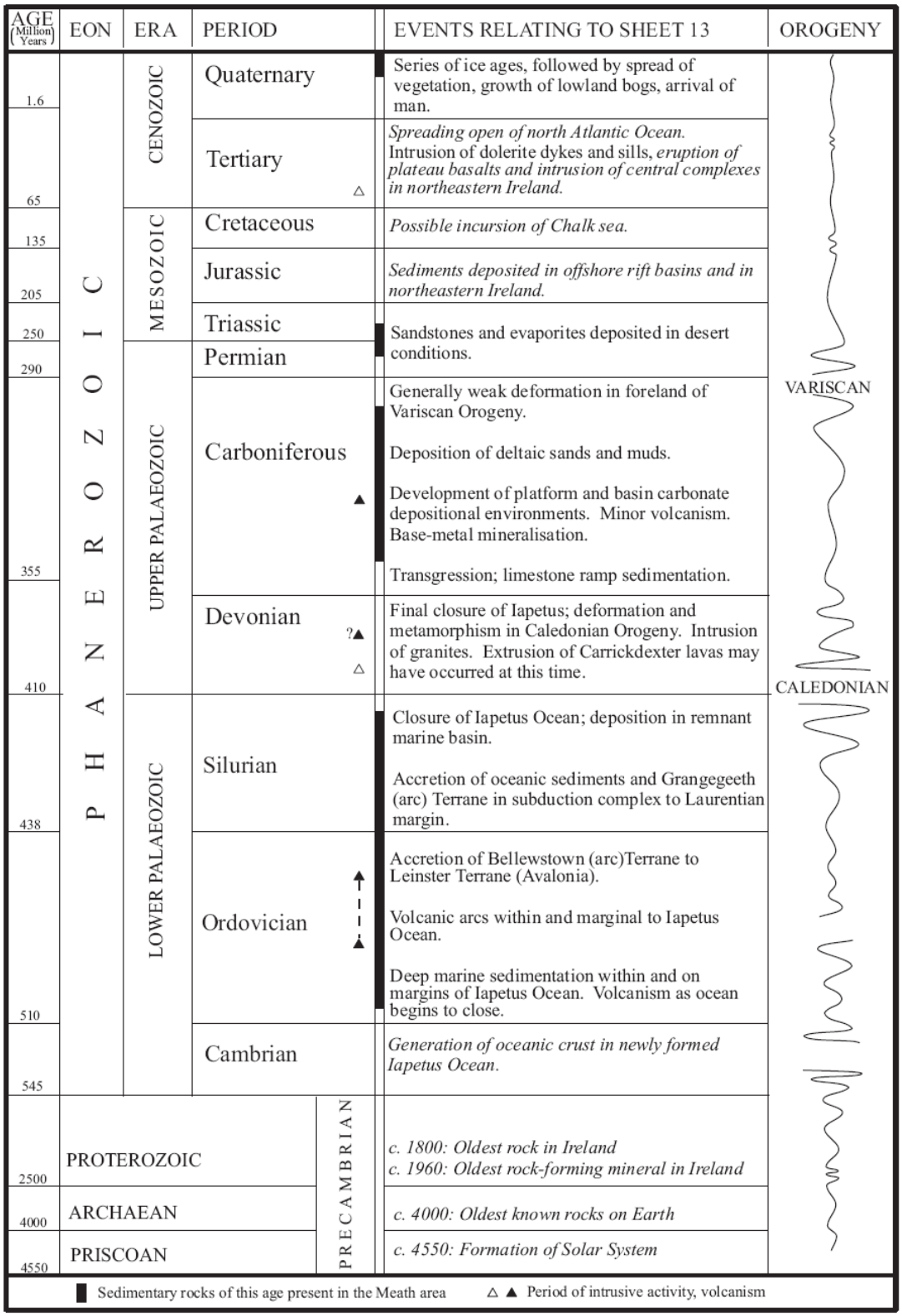
At any one locality there is usually more than one rock type, or **lithology** and they are generally inter-layered. Ranges of lithologies over a small area are largely consistent and sequences of rock often share common characteristics allowing them to be grouped together as packages or geological units. The most important of these 'units' is the **Formation**, which is defined as a sequence of related rock types differing significantly from adjacent sequences.

These formations are mapped as a sequence or succession of units in a **stratigraphical** order, with younger rocks overlying older rocks unless they have been strongly **faulted** or folded. By compiling the formations into a column with oldest at the bottom and youngest at the top we can represent the geological history of an area, with international names for the time periods. The following description of the main events and the rocks they formed in Meath should be read with reference to the map, stratigraphical column and geological timescale. The simplified map of Meath's geology outlines the main units by age. For more detail of the individual formations described it would be necessary to examine the GSI's 1:500,000 scale map and the 1:100,000 scale map of the area - Sheet 13.

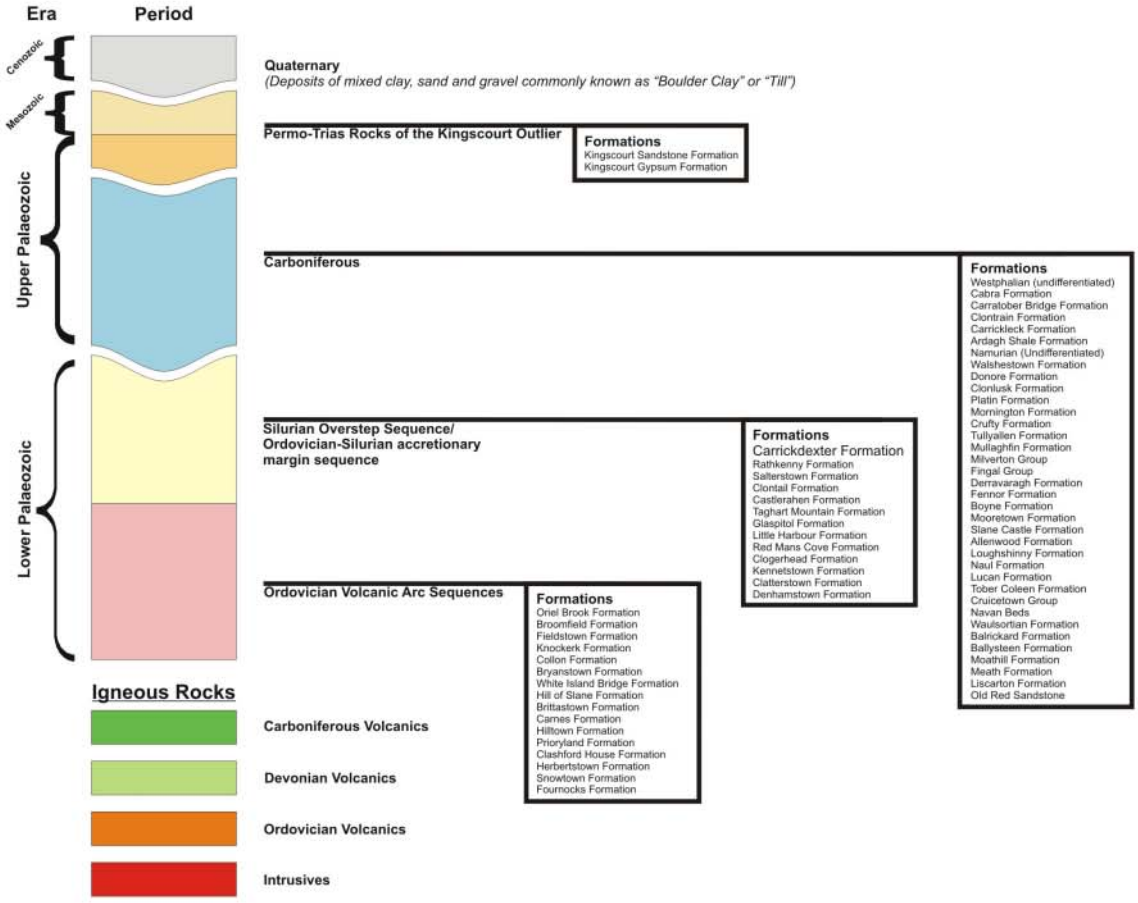
Geological timescale for Meath

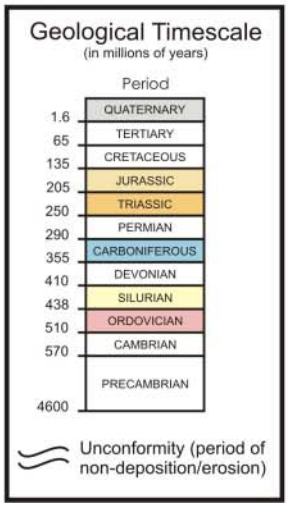
(Age in Millions of Years)

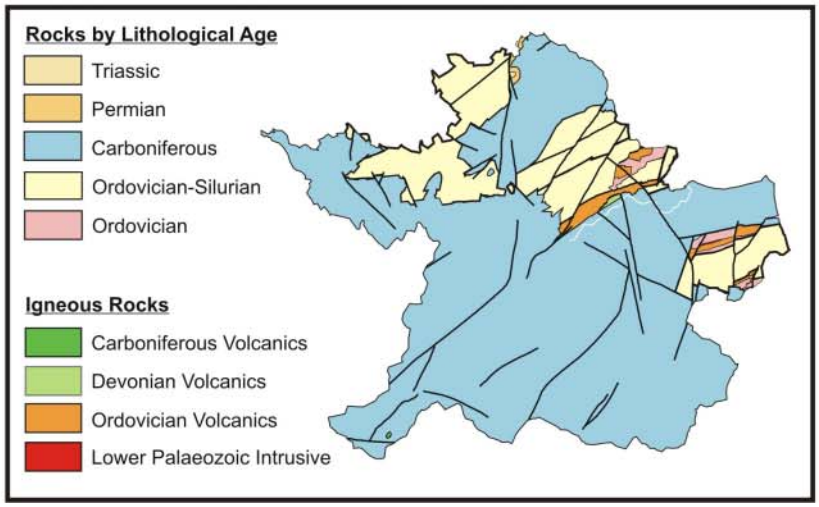
***(Italics* refer to geological events not preserved but inferred from elsewhere)**



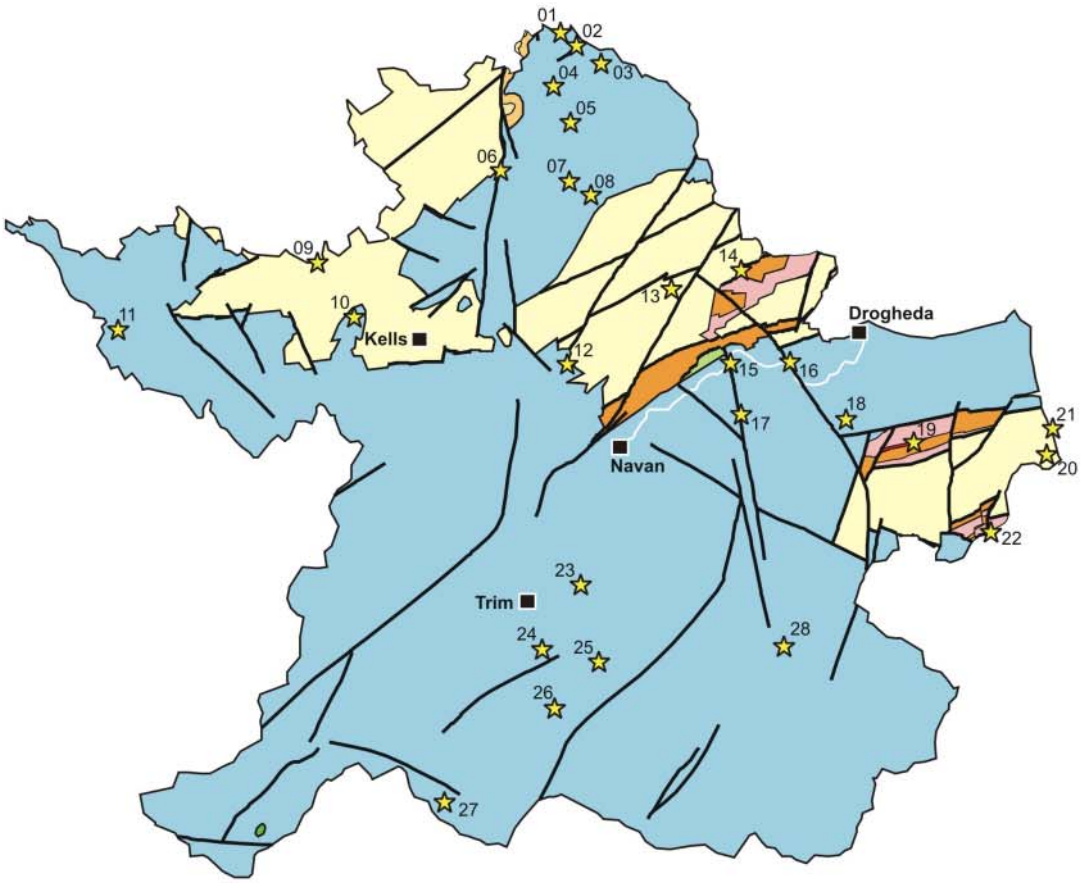
Schematic stratigraphic column summarising the rock sequence in Meath







Summary Geological Map of Meath
Including Site Locations



Geological Legend

Rocks by Lithological Age

- Triassic
- Permian
- Carboniferous
- Ordovician-Silurian
- Ordovician

Igneous Rocks

- Carboniferous Volcanics
- Devonian Volcanics
- Ordovician Volcanics
- Lower Palaeozoic Intrusive

- Town
- Site Boundary
- Lithological Boundary
- Fault Line
- River Boyne

N
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S

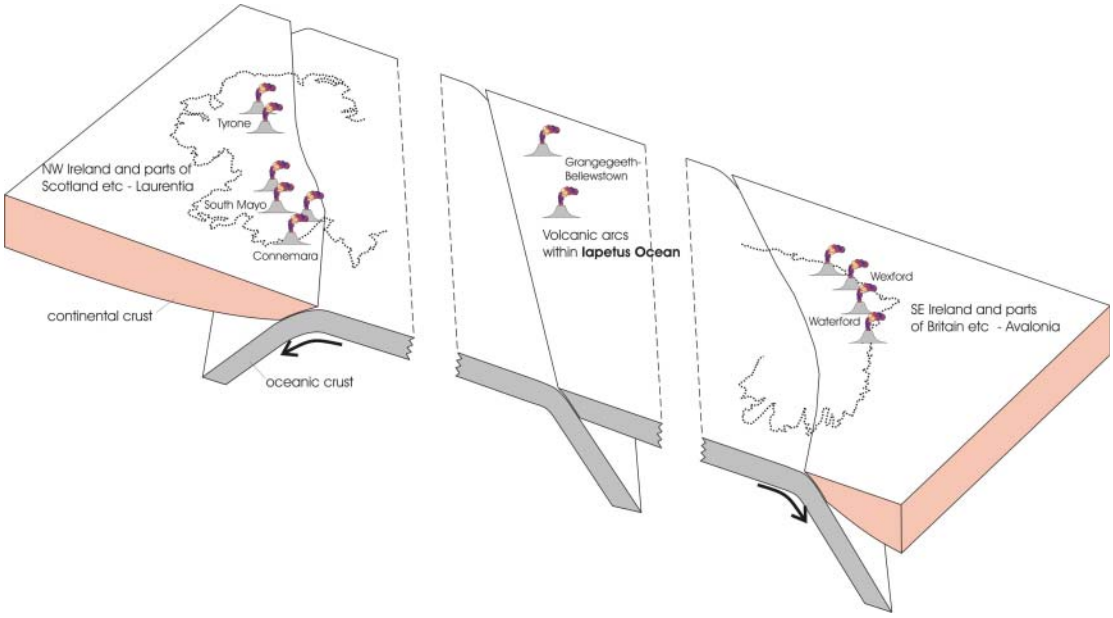
10 Km

Site Index

01. Poulmore Scarp
02. Barley Hill Quarry
03. Mullaghmore
04. Carrickleck Quarry
05. Cregg
06. Altmush Stream
07. Nobber
08. Kilbride Quarry
09. Blackwater Valley
10. St. Keeran's Well
11. Murrens
12. Gibstown Castle
13. Rathkenny
14. Grangegeeth
15. Rockwood Cliffs
16. Boyne Valley
17. Painestown Quarry
18. Duleek Quarry
19. Bellewstown
20. Benhead to Gormanston
21. Benhead
22. Naul
23. River Boyne, Trim
24. Bray Hill Quarry
25. Trim Esker
26. Summerhill
27. St. Gorman's Spring
28. Dunshaughlin

Lower Palaeozoic

It is now well understood that Ireland is made up of two 'halves', which were originally separated by an ocean that geologists call Iapetus. The northwestern half was on the margins of a North American continent, whilst the southeastern half was on the margins of the European continent. Plate **tectonic** movement throughout the Ordovician period saw this Iapetus Ocean close and the two halves converge and eventually combine in Silurian times. Meath's rocks tell part of this story, and need to be understood in the wider context.



The oldest rocks in Meath are fine-grained sedimentary rocks of early Ordovician age that outcrop over small areas between Balbriggan and Duleek. These rocks were formed from muds and silts deposited by **turbidity currents** in deep marine settings at the margins of, and within the ancient Iapetus ocean. The Precambrian rocks of Ireland's north-western and south-eastern extremities were widely separated by the ocean and most of the rocks at the surface today had yet to form. As Iapetus gradually closed during the Ordovician, by **subduction** of the ocean floor, **volcanic rocks** were erupted and intruded into the marine sedimentary sequences and built **volcanic arcs** (chains of islands) along the margins and within the ocean. Volcanic rocks occur in a belt between Navan and Collon (centred on Grangegeeth), and around Bellewstown. In the latter two areas, eruption was more explosive, producing **tuffs**. Shelly fossils from these volcanic sequences form distinct communities, indicating that the ocean was wide and a barrier to migration. Palaeomagnetic studies show that the Grangegeeth arc lay towards the northern margin, with the Bellewstown arc within the ocean. As northward subduction of the oceanic **plate** continued, the late Ordovician and early Silurian sediments deposited on the ocean floor were scraped off and accreted against the northern margin as a series of fault-bound slivers. Volcanism appears to have ceased by the end of the Ordovician, suggesting that subduction had stopped. The latest Ordovician black **shales** were

deposited over the Grangegeeth arc sequence, suggesting a relatively deep marine environment. By mid-Silurian times, the ocean had narrowed enough to no longer be a barrier to **benthic** migration, and deposition of greywackes by turbidity currents could span both sides. Silurian rocks are widespread, though generally not well exposed, in the Meath area.

Following deposition of the Lower Palaeozoic sequences, the continents on opposite sides of the Iapetus Ocean were brought together, squeezing the oceanic sediments and volcanic arcs in between. The collision crumpled the rocks and uplifted them to produce a range of mountains, in an event known as the Caledonian **Orogeny**. The axes of the folds, and the associated **cleavage**, are aligned generally northeast—southwest and give an idea of the orientation of the mountain range and the continental margins during collision. The base of the crust was pushed down under the weight of the mountains and the heat at depth caused it to partially melt, producing a large volume of magma. This rose into the upper crust and cooled slowly to form coarse-grained **granite**. The Kentstown and Drogheda granites are small occurrences at the present land surface of a much larger body of granite at depth, which can be "seen" by geophysical studies. The Caledonian mountain belt was an area of erosion rather than deposition during most of the Devonian period, and no sedimentary rocks of this age are present in Meath (though there may have been some volcanic activity). The prolonged erosion wore down the mountains, right down to the granite, so that the next stage of deposition followed a major **unconformity** in the rock succession.

Upper Palaeozoic

The Carboniferous

The eroded Caledonian mountains were patchily veneered by the earliest Carboniferous "Old Red Sandstone" arid-climate river deposits. In the Navan area there may have been remnant hills, formed of resistant Lower Palaeozoic rocks, the continued erosion of which produced coarse **alluvial fans**. The same red beds are overlain by estuarine and then marginal marine sedimentary deposits, representing a marine transgression across the area. As the transgression advanced northwards, during the early Carboniferous, a thick succession of progressively deeper water limestone sediments accumulated in slowly subsiding basins. Richly **fossiliferous** mounds of carbonate mud ("Waulsortian Limestones") are a particular feature of this phase (e.g. Bray Hill Quarry). Tectonic stretching then accentuated the earlier subsidence patterns, and introduced new ones, and resulted in the formation of a "block and basin" topography. The blocks, bounded by faults, moved up relative to the basins, and became areas of mainly shallow-water limestone sedimentation ("**platforms**"). The basins, meanwhile, accumulated fine-grained deep-water sediments, plus debris shed off the adjacent platforms, including boulders and large blocks from partial collapse of the "platform" margins. A general subsidence followed and the shallow "platforms" were buried by calcareous muds and sands. In the mid-Carboniferous, a southward advance across the area of a delta complex deposited sands and muds in progressively shallower environments over the limestone-dominant successions.

Stretching of the Earth's crust beneath Ireland during this period of limestone deposition permitted percolation of mineralised fluids up faults in the rocks. These fluids selectively altered the limestone into magnesium-enriched **dolomite** in a process known as **dolomitization**. Other minerals such as lead and zinc also percolated up through these faults forming economic deposits within the limestone. These valuable ore deposits are currently being extracted in places like Tara Mines at Navan.

A major compressive tectonic phase, the Variscan Orogeny, occurred towards the end of the Carboniferous. This folded, faulted and uplifted the Carboniferous rocks, commonly along earlier fault trends, and refolded and re-faulted the older Caledonian rocks. It is evident in the Kingscourt Outlier that much of the Carboniferous sequence was eroded off during this uplift, before the overlying Permian beds were deposited.

Permian – Triassic (and Jurassic, Cretaceous and Tertiary)
Ireland lay in the northern tropics during the Permo-Trias, and the sedimentary rocks from this time, preserved around Kingscourt in the counties of Cavan and Monaghan and on Meath's northern margin, record deposition of sediments in arid deserts and temporary seas that were periodically dried out to precipitate thick **evaporite** deposits of **gypsum**. The subsequent Jurassic, Cretaceous and Tertiary periods have largely left no trace as rocks preserved on land. It is inferred that Ireland was mostly a land area, subject to weathering and erosion, which supplied only offshore basins with sediment. During the Tertiary period Ireland probably suffered karstic weathering like the famous tower karst of Guilin in China.

Quaternary
The Quaternary Period covers the last 1.6 million years and includes the Pleistocene and Holocene Epochs. During the Pleistocene, which lasted from 1.6 million years to 10,000 years ago, alternating cold and warm stages (termed glacial and interglacial periods) led to the growth and decay of ice sheets which covered the country on a number of occasions. The Holocene, which is the current interglacial or postglacial period, dates from 10,000 years ago to the present day.

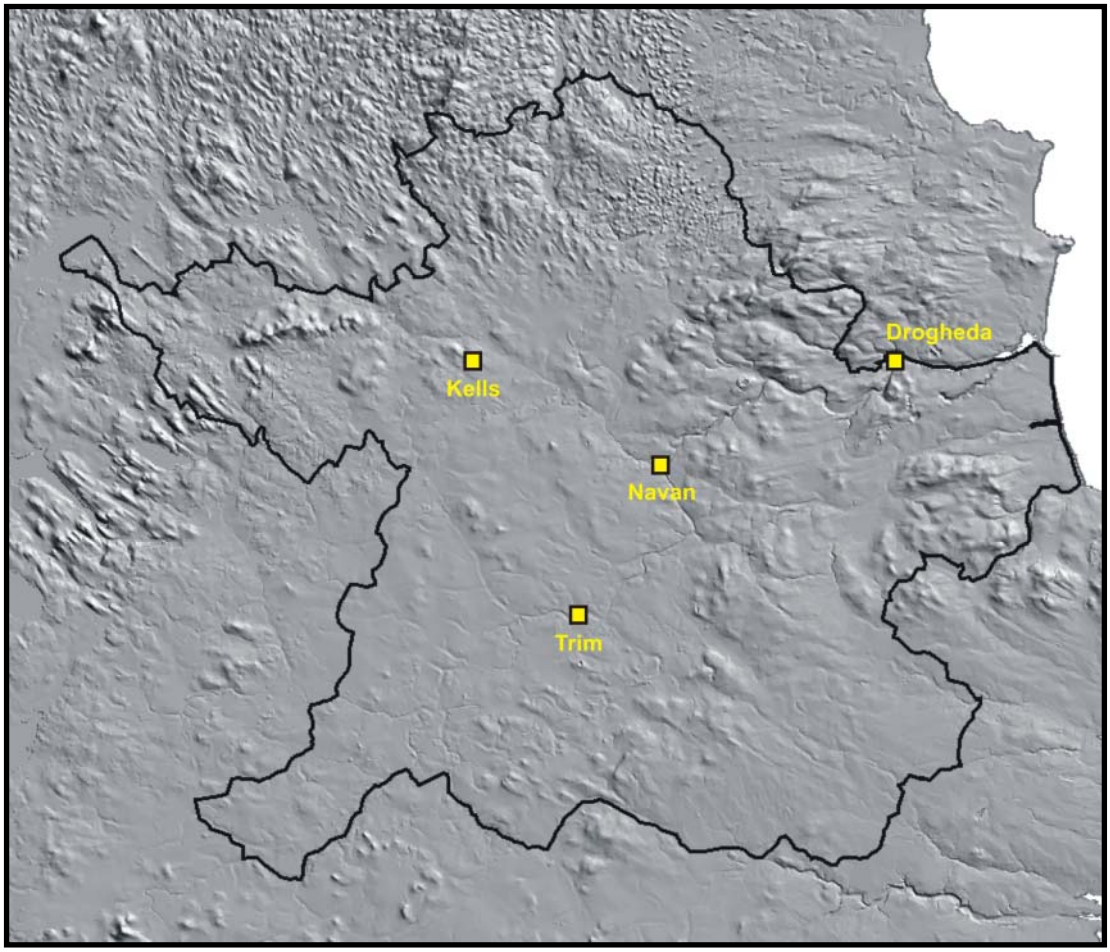
As ice moves over its substrate, pieces of rock are incorporated into its basal layers, making the ice very abrasive. It subsequently scours and erodes the bedrock over which it flows. The rock material eroded by and incorporated into the ice was eventually deposited, either directly by the ice as **till** (commonly known as boulder clay) or by meltwater as sorted gravel, sand, silt or clay. The glacial deposits are thin or absent on the upland areas, but on the lowlands till thicknesses of over 30m are common throughout Meath. In the north of Meath the till takes the form of drumlins which are streamlined hills generally composed of till deposited under a moving ice mass, with their long axes parallel to ice flow direction. Their characteristic shape gave the feature its name which is derived from the Irish droimnín (small, round-backed hill). Drumlins are widespread north of a line joining Dunany and Oldcastle and they are predominantly composed of clayey or silty till. These features

influence the local drainage pattern, resulting in poorly drained land in the inter-drumlin zones relative to the steeper drumlin slopes. In north county Meath lakes often occupy these badly drained, inter-drumlin areas. Other lakes also owe their origin to glacial action. Lough Ramor in Cavan (part of the Blackwater Valley site) is a result of ice erosion and deposition acting together.

As the ice sheet shrank towards the end of the glacial period, glacial debris was frequently deposited at the ice margin in the form of ridges called **moraines**. Many hummocky moraines occur south of Slieve na Calliagh. Large expanses of glaciofluvial sands and gravels deposited by meltwater streams flowing from a glacier are common in the area. The most striking examples of these occur in the Gormanstown and Summerhill areas and along the Boyne. An extensive system of **esker** gravels, which have been sorted and deposited as ridges subglacially by meltwaters, occurs around Trim and Summerhill. Delta sands and gravels are present in association with these eskers. Meltwater erosion has cut some spectacular meltwater channels in the area, notably the Boyne Channel itself, with its tributary channels.

Digital Elevation Model (DEM) for County Meath

(This image has been artificially illuminated from the northeast from a 45° angle to highlight Meath's topographic features)



The above image is a processed digital elevation model (DEM), which has been illuminated from the northeast, at a 45 degree angle to highlight landforms in the Meath area and aid understanding of the dominantly glacial terrain of the county. Not all possible features show up but many large scale glacial erosional and depositional features are apparent. This image illustrates how Meath is dominated by a broad, smooth surface taking up much of the southern and central parts of the county. These smooth areas represent large expanses of a till plain. One of the most striking features of this glacial landscape occurs in the area between Benhead and Gormanston where a large flat **outwash plain** of sand and gravel has been deposited. Other examples of meltwater deposited features include the esker at Murrens and the delta fan formation at Rathkenny. The high relief, bumpy topography around Ardagh to the north, exposes a glacially streamlined landscape. This area is a classic example of a large scale drumlin field.

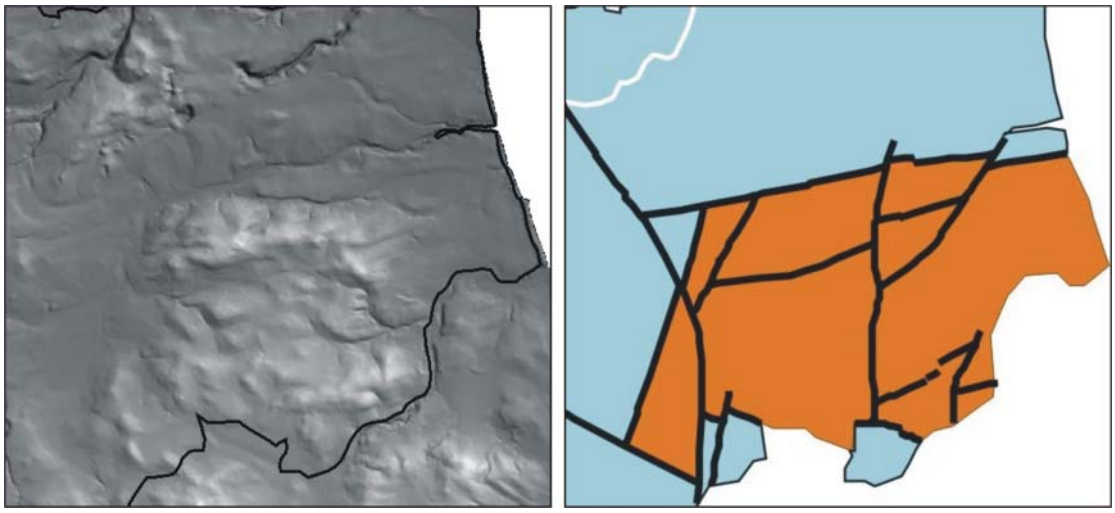
The military aerodrome just south of Benhead takes full advantage of the unusually flat surface generated by a glacial outwash plain. The underlying stratum is composed of glacial sands and gravel forming a feature known as a Sandur.

A number of very pronounced gorges cutting into Meath's landscape are clearly illustrated in this DEM image. These represent modern fluvial systems that occur within pre-existing glacial channels. The Boyne Valley is the best example of this, seen here as a dark linear feature running from the east of the county near Drogheda to beyond Navan in central Meath. This large channel was gouged out by the erosive power of glacial meltwater that once flowed through the landscape.

As the ice moved across Meath's landscape it produced a range of linear features including drumlins, crag and tails and glacial flutes. The landforms depicted in the digital elevation model of Meath display the general northwest-southeast direction in which the ice was moving. Whilst they are important, their scale is too big to promote as County Geological Sites.

A large terrace left behind by an ancient meandering river channel seen here on the southern slopes of the Boyne Valley. These reflect high water levels, owing to the release of vast amounts of glacial meltwater during the last Ice Age.

There are a number of prominent upland areas within this image. These are predominantly composed of igneous rocks that were able to resist the erosive power of passing glaciers during the last Ice Age. The Silurian greywacke and Ordovician volcanic rocks around Bellewstown were more resistant to the ice as they can be seen in the south east portion of this image as an area of high topographic relief. In contrast the softer Carboniferous limestone and shale that surrounds these formations has been eroded down to almost sea level.



The DEM image (of part of east Meath) to the left and geological map on the right complement each other very well. Areas of high relief (white) on the DEM represent the resistant Ordovician and Silurian rocks (shown by the orange area) and the low lying areas (grey) represent the more easily eroded Carboniferous rocks (shown by the blue area).

Glossary

Alluvial Fan	a fan-shaped deposit formed where a fast flowing river levels out and slows, typically from the mountain foot onto the plain.
Bedrock	a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
Benthic	referring to marine and/or fresh water animals that live on or are attached to the seabed or lake floor.
Cleavage	a flat plane of breakage caused by compressive deformation of rocks. e.g. the splitting of slate.
Crag and tail	a steep resistant rock mass (crag), with sloping softer sediments (tail) protected from glacial erosion or deposited as glacial debris on the crag's 'downstream' side.
Crust	the outermost, solid, layer of the Earth.
Dolomite	calcium and magnesium-bearing carbonate mineral; also a rock, usually forming when magnesium replaces some of the calcium in limestone after burial.
Dolomitization	a chemical process in which magnesium rich fluids replaces calcium within limestone to produce dolomite.
Esker	an elongated ridge of stratified sand and gravel which was deposited in a subglacial channel by meltwaters. Eskers are frequently several kilometers in length.
Evaporite	a chemical sediment that forms in layers through the evaporation of seawater (or lakes) in arid climates.
Extrusive	an igneous body emplaced (erupted) at the Earth's surface as lava.
Fault	planar fracture in rocks across which there has been some displacement.
Flute (glacial)	smooth gutter-like channels or furrows made by the abrasive underside of a glacier moving across a rock face.
Fold(ing)	flexure in layered rocks caused by compression.
Formation	a sequence of related rock types differing significantly from adjacent sequences.
Fossiliferous	pertaining to a rock with a high concentration of fossils.
Fossils	any remains, trace or imprint of a plant or animal that has been preserved in the Earth's crust since some past geological or prehistoric time.
Glacial	of or relating to the presence and activities of ice or glaciers.
Granite	a coarsely crystalline intrusive igneous rock composed mostly of quartz and feldspar.
Gypsum	a soft evaporite mineral found in clays and limestones, sometimes associated with sulphur.
Igneous	a rock or mineral that solidified from molten or partially molten material i.e. from a magma.
Intrusive	an igneous rock emplaced within the Earth's crust, not extruded like lava.

Lava	magma extruded onto the Earth's surface, or the rock solidified from it.
Limestone	a sedimentary rock consisting chiefly of calcium carbonate ($CaCO_3$), primarily in the form of the mineral calcite. It is mostly formed by the accumulation of calcareous shells, cemented by calcium carbonate precipitated from solution.
Lithification	the process of rock formation from unconsolidated sediment.
Lithology	the description of rocks on the basis of such characteristics as colour, composition and grain size.
Magma	molten rock, which cools to form igneous rocks.
Metamorphic	referring to the process of metamorphism or to the resulting metamorphic rock, transformed by heat and pressure from an originally igneous or sedimentary rock.
Moraine	any glacially formed accumulation of unconsolidated debris, in glaciated regions, such as during an ice age.
Mudstone	a very fine grained sedimentary rock, containing quartz and clay minerals. Similar to shale, but not as easily split along the plane of bedding.
Orogeny	the creation of a mountain belt by tectonic activity.
Outwash Plain	an area of meltwater deposition produced at the leading edge of a glacier.
Plate Tectonics	a dynamic process driving the interaction between a series of interlocking crustal plates along their plate boundaries, e.g. by subduction.
Platform	a continental area of relatively flat or gently sloping, mostly sedimentary strata, overlying a basement of consolidated igneous or metamorphic rocks.
Sandstone	a fine to coarse sedimentary rock, deposited by water or wind, and composed of fragments of sand (quartz grains), cemented together by quartz or other minerals.
Sedimentary	a rock formed by the deposition of sediment, or pertaining to the process of sedimentation.
Shale	a very fine-grained mudstone, containing quartz and clay minerals, that splits easily along the plane of bedding.
Siltstone	is similar to mudstone but with a predominance of silt-sized (slightly coarser) particles.
Subduction	the sinking of one crustal plate beneath the edge of another through the process of plate tectonics.
Till	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock such as sand, silt or clay.
Tuff(aceous)	consolidated rock formed from the ash ejected from a volcano.
Turbidity Currents	underwater density currents carrying suspended sediment at high speed down a subaqueous slope. The resulting deposit is called a turbidite.

Unconformity	a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.
Volcanic Arc	a linear belt of volcanoes formed on the overlying plate at a subduction zone, resulting from subduction of the underlying plate.
Volcanic Rock	any rock produced from volcanic material, e.g. ash, lava.
Volcanism	the process by which magma and its associated gasses rise into the crust and are extruded onto the Earth's surface and into the atmosphere.
Volcano	a vent in the surface of the Earth through which magma and associated gasses and ash erupt.

Data sources on the geology of County Meath

This section is a brief summary of relevant GSI datasets, to assist any enquiry concerning geology to target possible information easily. The GSI has very many datasets, accumulated since it began mapping Ireland's geology in 1845. A recent project has established a Document Management System into which about half a million documents and maps have been scanned. This means that any user can visit the GSI Customer Centre themselves and search on screen for data of relevance to them. High quality colour and black and white prints can be made or data supplied on CD. Data is now supplied free but a small service charge may apply.
Key datasets include:

1:100,000 Map Report Series

All historical, modern and other mapping has been compiled into very useful maps and reports that describe the geology of the entire country. Sheet 13 covers Meath. In addition digital mapping from the 1:100,000 series is now available on a seamless national basis and customised output can be produced for specific areas.

19th century 6 inch to the mile fieldsheets

These provide an important historical and current resource, with very detailed observations of the geology of the entire country. These are also now available seamlessly on line through the GSI website www.gsi.ie. The Archives of the GSI also include a set of first edition Ordnance Survey six inch to the mile maps, which generally predate the geologically coloured fieldsheets. For historical study they can be useful in showing changes through time.

19th century one inch maps and Memoirs

Information from the detailed 19th century mapping was distilled into one inch to the mile maps, of which Sheets 80, 81, 82, 90, 91, 92, 100, 101 and 102 cover County Meath. Each sheet or several sheets were accompanied by a Memoir which described the geology in some detail. These still provide valuable records of observations even though interpretations may have changed with better geological understanding.

MinLocs Data

The MinLocs Database records all known mineral occurrences, however small, from GSI records, such as 19th century fieldsheets and Open File data. These include economic deposits such as sand and gravel pits, brick clays, building stones as well as metallic and non-metallic minerals.

Historic Mine Records

Abandonment plans and varied other material exists for the various mining and exploratory ventures in the county, at places like the copper mines at Beauparc and Brownstown.

Quaternary Mapping
Since a Groundwater Protection Scheme has been completed for County Meath by GSI, a modern mapping of the Quaternary sediments exists as well as bedrock mapping. This provides a significant resource in general terms as well as for groundwater protection. Customised output is possible.

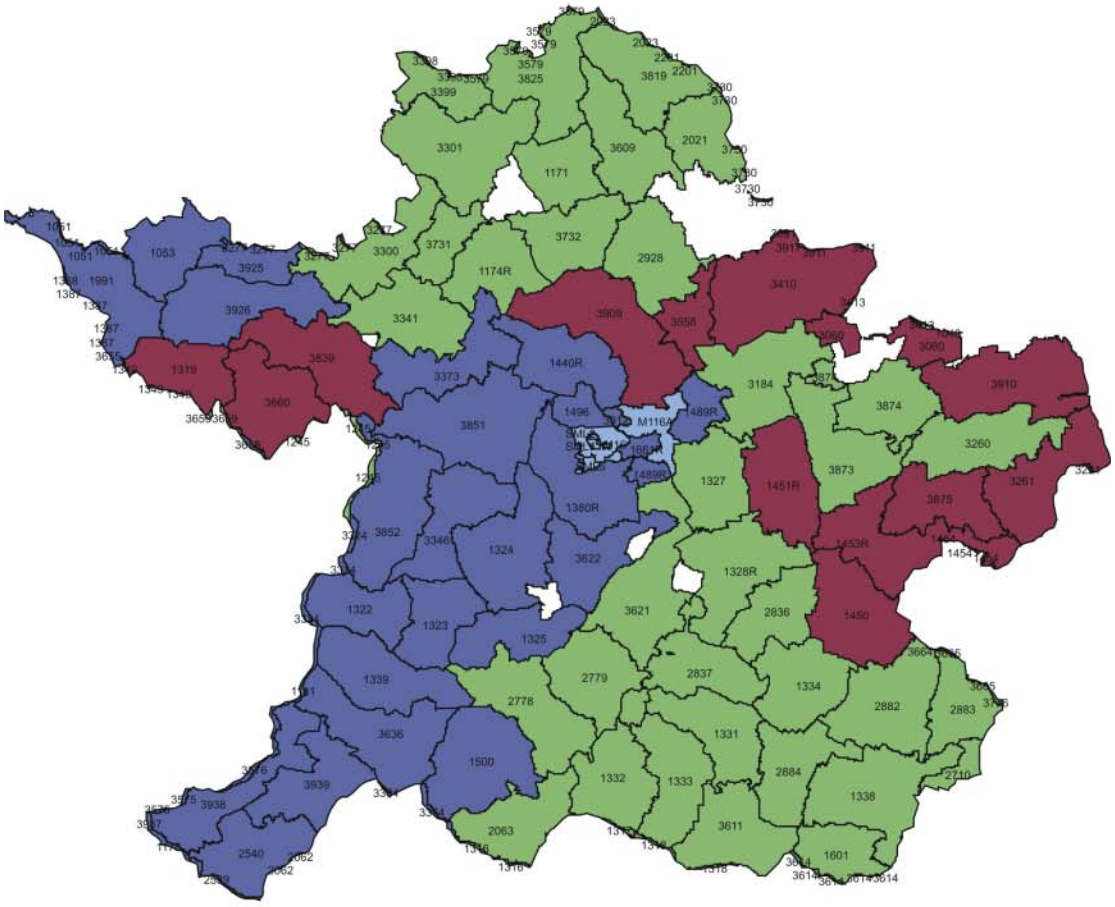
Aerial Photography
The GSI has almost full coverage of the country in 1973 black and white Air Corps vertical aerial photography, which together with a stereoscope can be very useful in interpreting geological and geomorphological features. Partial coverage of 1954 photography is also available. All are available for public consultation, with a stereoscope in the Customer Centre of GSI.

In addition the GSI network has more recent digital ortho photography and colour aerial photography from about 2000 and 2004 which can be consulted for particular purposes on request, but OSi copyright applies.

Open File Data
Each Mineral Prospecting Licence issued by the Exploration and Mining Division of the Department of Communications, Energy and Natural Resources (currently, but formerly the Department of Communications, Marine and Natural Resources) carries an obligation on the exploration company to lodge records of the work undertaken, for the common good. These records are held by the Geological Survey and are available as Open File Data, once a period of time has expired. They may include geological interpretations, borehole logs, geophysical and geochemical surveys and so on. Exploration is based on areas known as Prospecting Licences (PL) which allow someone the right to search and investigate for minerals under the ground within the PL or a block of PLs. The PLs covering Meath and their current status are shown below.

Prospecting Licence Designation Supplied By Exploration and Mining Division (EMD)

Department of Communications, Marine and Natural Resources
Roinn Cumarsaide, Mara agus Acmhainni Nadurtha



Prospecting Licence Designation

- Held
- Mining Lease
- Open
- Open - Exploration Incentives
- 3636 Licence Number

N
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Shortlist of Key Geological References

This reference list includes a few key papers, books and articles that are recommended as access points to Meath's geological heritage. A full reference list of papers relating to the geology of County Meath is contained in Appendix 2, including all references cited in the individual site reports.

****

Introduction to geology in general

DUNNING, F.W., ADAMS, P.J., THACKRAY, J.C., van ROSE, S., MERCER, I.F. and ROBERTS, R.H. 1981. *The story of the Earth*. (2nd edition). Geological Museum, H.M.S.O., 36pp.

EDMONDS, E. 1983. *The geological map: an anatomy of the landscape*. Geological Museum, H.M.S.O., 36pp.

HOLMES, A. 1978. *Principles of Physical Geology*. (3rd edition revised by D. Holmes), Thomas Nelson, 730pp.

THACKRAY, J. 1980. *The age of the Earth.* Geological Museum, H.M.S.O., 36pp.

Introduction to the geology of Ireland

AALEN, F.H.A., WHELAN, K. and STOUT, M. (eds) 1997. *Atlas of the Irish rural landscape.* Cork University Press, Cork.

FEEHAN, J. and O'DONOVAN, G. 1996. *The Bogs of Ireland. An Introduction to the Natural, Cultural and Industrial Heritage of Irish Peatlands*. *University College Dublin. The Environmental Institute.*

HOLLAND, C.H. (ed.). 2001. *The Geology of Ireland*. Dunedin Academic Press, Edinburgh.

HOLLAND, C.H. 2003. The Irish Landscape. A scenery to celebrate. Dunedin Academic Press, Edinburgh. 180 pp.

KENNAN, P. *Written in Stone*. Geological Survey of Ireland, 50pp. [*Also DVD/VCR of TV Series*]

MITCHELL, F. and RYAN, M. 1997. *Reading the Irish Landscape*. Town House. Dublin. 392 pages.

SLEEMAN, A.G., McCONNELL, B. and GATLEY, S. 2004. *Understanding Earth Processes, Rocks and the Geological History of Ireland*. Geological Survey of Ireland, Dublin. 120 pp, including map and CD.

STILLMAN, C. and SEVASTOPULO, G. 2005. Leinster. Classic Geology in Europe 6, Terra Publishing, Harpenden, Herts. 192 pp.

WHITTOW, J.B. 1974. *Geology and Scenery in Ireland.* Pelican Books, 301pp.

WILLIAMS, D.M. and HARPER, D. 1999. *The Making of Ireland*. Landscapes in Geology. Immel Publishing, London. 98 pp.

Introduction to geology of Meath (and adjoining areas) in particular

McCONNELL, B., PHILCOX, M, E. and GERAGHTY, M. 2001. *Geology Of Meath. A Geological Description To Accompany The Bedrock Geology 1:100,000 Scale Map Sheet 13, Meath.* Geological Survey of Ireland.

MEEHAN, R.T. and WARREN, W.P. 1999. *The Boyne Valley in the Ice Age: A field guide to some of the valley's most important glacial geological features*. Meath County Council and the Geological Survey of Ireland. 84 pages.

STOUT, G. 2002. *Newgrange and the Bend of the Boyne*. Irish Rural Landscapes: Volume 1, Cork University Press, Cork.

WYSE JACKSON, P., STONE, J., PARKES, M. and SANDERS, I. 1993. *Field Guide to the Geology of some localities in County Dublin*. Department of Geology, Trinity College Dublin and ENFO, Dublin.

Further sources of information and contacts
The Geological Survey of Ireland, and the Head of the Irish Geological Heritage Programme, Sarah Gatley can be contacted in relation to any aspect of this report. Loreto Guinan, the Heritage Officer of Meath County Council, is the primary local contact for further information in relation to this report. Other contacts are the Conservation Rangers of the National Parks and Wildlife Service, of the Department of Environment, Heritage and Local Government. The names and phone numbers of current staff may be found in the phone book.

Web sites of interest
www.gsi.ie - for general geological resources
http://www.habitas.org.uk/es2k/index.html - for general geological information of wide interest
http://www.tcd.ie/Geography/IQUA/Index.htm - for information, fieldtrips, lectures etc in relation to Ireland's Ice Age history
http://www.sgu.se/hotell/progeo/index.html - for information about ProGEO the European Association for the Conservation of Geological Heritage

Acknowledgements

The authors would like to gratefully acknowledge the assistance of Loreto Guinan, Heritage Officer for Meath County Council in the development of this project. The members of Meath Heritage Forum are kindly thanked for their support and input. We also acknowledge the many members of the IGH Programme Expert Panels who helped define the sites which were considered for County Geological Site status. Colleagues in the GSI are thanked, in particular Brian McConnell and Padraig Connaughton. We also thank consultant geologist Robbie Meehan for much advice and input. The quarries and quarry managers are especially thanked for their help and cooperation during this audit.

County Geological Site Reports – General Points

The following site reports are brief non-technical summaries of the proposed County Geological Sites for Meath. These have been specially prepared for this Report in order to make the information accessible to planners and other staff without geological training. For most sites more detailed reports and information files are held in the IGH Section in the Geological Survey of Ireland. These are available for consultation if required. Further sites may become relevant as IGH Programme work develops.

Each site report has primary location information, a mention of the main rock types and their age, and a short description of the key aspects of scientific interest. A section outlining any particular management or other issues specific to the site is included, along with one or two low resolution photographs exemplifying the site. CDs accompanying this report include further pictures of most sites at higher resolution. Grid references are given normally for a central point in the site, or two extreme points at opposite ends of the site.

GIS shapefiles with associated attribute tables have been provided with an outline of the site boundaries. It is important to note that no legal or definitive basis should be based on these boundaries. They are indicative only of the limits of exposure or of geological interest, and not based on detailed field surveys, which were outside the scope of this contract.

For sites that have been proposed (pNHA) or will be proposed for NHA designation, detailed site boundary maps will become available to the Local Authority, through NPWS as the designation process is undertaken. **In terms of any geological heritage site designation as an NHA, due process of site reporting, boundary survey and very importantly, consultation with landowners where they can be readily identified, will take place before GSI makes recommendations to NPWS on the sites to be designated.**

Any landowner within areas or sites identified in this report with concerns over any aspect of this project is encouraged to contact Sarah Gatley at the Irish Geological Heritage Programme, in the Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4.
Phone 01-6782837. Email: sarah.gatley@gsi.ie

Map/Photo Scales

In the following section each site has a segment of 1:50,000 Ordnance Survey of Ireland map, and/or a segment of 1:10,560 (six inch to the mile) OSi map and/or a colour aerial photograph (2000 or 2004). The displayed scale is variable, i.e. they have been zoomed in or out to best show the limits of the site in the page space available. They are therefore indicative only and should not be used with assumption that they are all at the same or standard scale. Dates of publication on maps vary considerably.

Section 2

Site Reports

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Gibstown Castle**		
Other names used for site			
IGH THEME:	IGH 1 (Karst)		
TOWNLAND(S)	Milestown, Gibstown		
NEAREST TOWN	Navan		
SIX INCH MAP NUMBER	17, 18		
NATIONAL GRID REFERENCE	283100 273100 = N 831 731		
1:50,000 O.S. SHEET NUMBER	42	**1/2 inch Sheet No.**	13

Outline Site Description
Natural rock outcrop and spring.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Courceyan) limestone of the Ballysteen Formation.

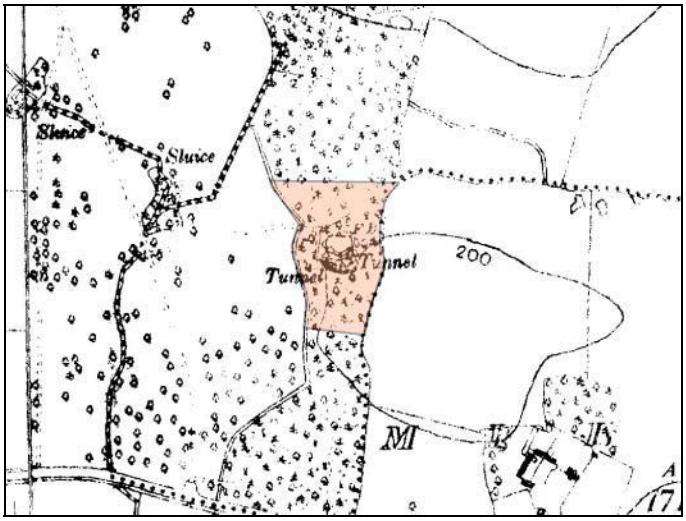
Main Geological or Geomorphological Interest
Situated 5km north of Navan, south of Gibstown Castle are exposed outcrops of limestone, which display solution features associated with karst weathering. This area was once used as part of a garden walk for the inhabitants of the castle. A number of tunnels have been carved out of the stone as well as a narrow passage winding through the limestone. Within this area is a natural spring, which may be feature associated with the karstification of the surrounding limestone.

Site Importance
There are very few naturally exposed karst features seen within the limestone of Meath and therefore this site is recommended as a County Geological Site.

Management/promotion issues
This site can only be accessed by crossing agricultural land, mainly used for cattle grazing. This site itself appears to be used by cattle, possibly using the spring as a drinking source. Public access is therefore not suitable and the site is not recommended for public promotion.

Left: Manmade tunnel cut into the limestone at Gibstown Castle.
Right: Exposed limestone just outside of the main wooded area that makes up most of this site.

Gibstown Castle



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**St. Keeran's Well**		
Other names used for site			
IGH THEME:	IGH 1 (Karst)		
TOWNLAND(S)	Castlekeeran		
NEAREST TOWN	Carnaross		
SIX INCH MAP NUMBER	16		
NATIONAL GRID REFERENCE	268760 277070 = N 6876 7707		
1:50,000 O.S. SHEET NUMBER	42	**1/2 inch Sheet No.**	13

Outline Site Description
Natural rock outcrop and springs.

Geological System/Age and Primary Rock Type
Carboniferous limestone, with surface karst weathering features.

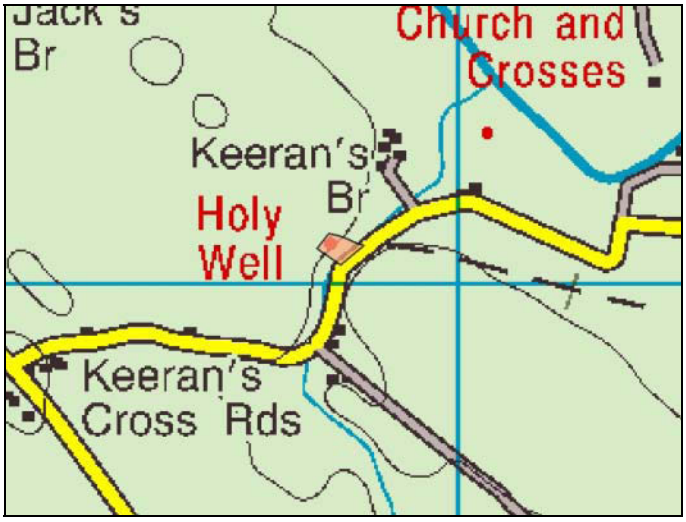
Main Geological or Geomorphological Interest
This small collection of outcrops, situated 1.5km south of Carnacross, displays smooth, undulating channels cut into the limestone. These are karst weathering features known as karren, and were produced by solution of the limestone. This is a chemical process by which dilute acid within water (naturally occurring in rainwater) dissolves the calcium carbonate within the limestone, leaving the features we see today. A small natural spring is found within the same limestone outcrop, where groundwater appears at the surface.

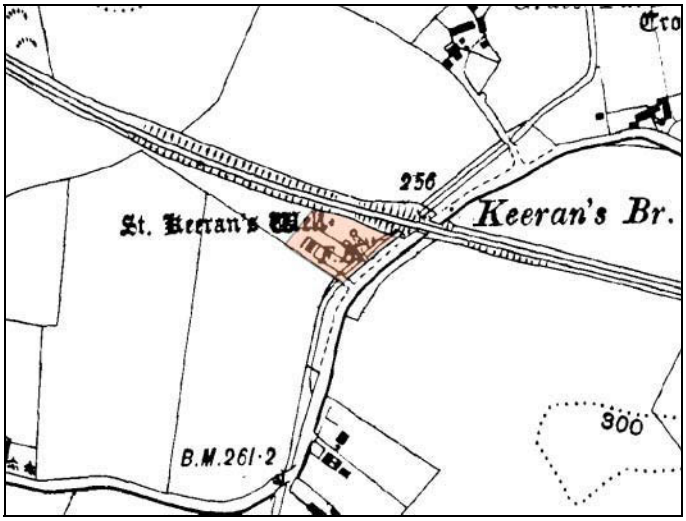
Site Importance
There are very few naturally exposed karst features seen within the limestones of Meath and therefore this site is recommended as a County Geological Site.

Management/promotion issues
Access to this small site is just off a quiet third class road. This is a public area and a religious site, also commonly used by passers by as a picnic spot. The area is well maintained but its ownership is unknown and it is unclear who manages this site.

Left: Limestone outcrops displaying karst weathering features. A shrine to the Virgin Mary is observed in the background.
Right: Natural spring occurring within the limestone at St. Keeran's Well.

St. Keeran's Well





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Bellewstown**
Other names used for site	
IGH THEME:	IGH 2 (Precambrian to Devonian Palaeontology)
TOWNLAND(S)	Bellewstown
NEAREST TOWN	Duleek
SIX INCH MAP NUMBER	27
NATIONAL GRID REFERENCE	307870 267130 = O07870 67130
1:50,000 O.S. SHEET NUMBER	43 **1/2 inch Sheet No.** 13

Outline Site Description
Working quarry and natural exposures in agricultural fields with rock close to surface beneath soil.

Geological System/Age and Primary Rock Type
Ordovician volcanic and sedimentary rocks.

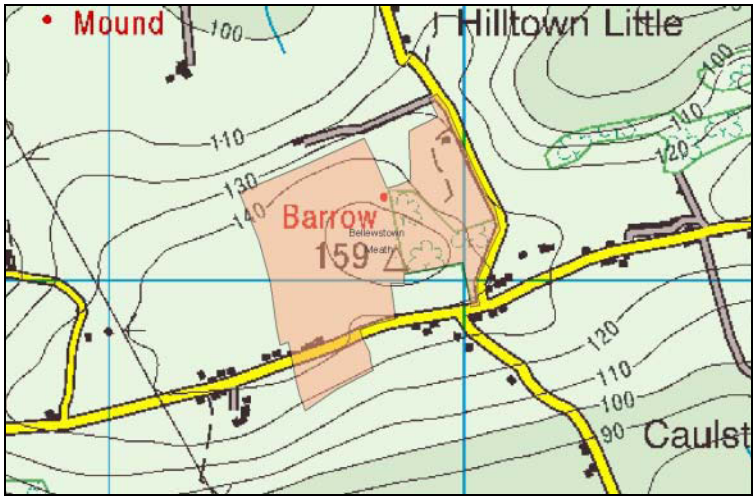
Main Geological or Geomorphological Interest
This site exhibits a few exposures but has significant rocks below the soil surface of the Bellewstown site. This geological terrane represents volcanic and sedimentary rocks that existed as a volcanic island in the middle of an ancient ocean called Iapetus during the Ordovician Period about 460 million years ago. Brachiopod fossils within the sedimentary rocks are similar to other island faunas – part of a so called 'Celtic' brachiopod province. There is also a younger, thin limestone deposit which may represent a very long time period, perhaps ten million years. Even younger shales include fossils showing plate tectonics had moved the island closer to adjacent continents. The biogeographical and stratigraphical information of these fossiliferous rocks is important in understanding how Ireland has moved throughout geological time.

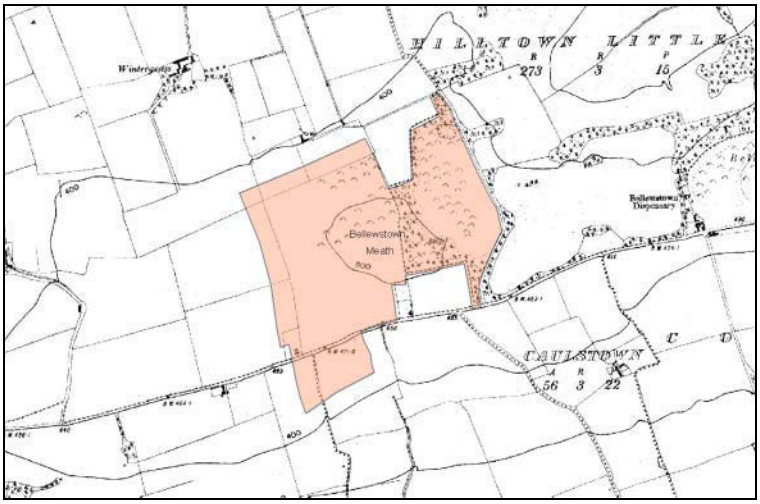
Site Importance
The ongoing quarry extension provides a new opportunity for significant improvement in knowledge of the detailed geology and stratigraphy of the Bellewstown Inlier. The additional exposures may yield a clearer picture of the relationships of different geological formations, enabling a more accurate interpretation of events during Ireland's geological past. This will be recommended as an NHA.

Management/promotion issues
The site is a Kilsaran Concrete working quarry, with part of it extending into some privately owned adjacent farmland. A formal proposal for access by a geological research team for fossil collecting and research has been given positive response by Kilsaran Concrete, and is anticipated to provide a model of best practice for industry operators of extraction sites of geological heritage importance. The model may also include the future provision of interpretation panels and viewing areas to further promote geological heritage to the public, particularly within the context of active quarrying.

Left: Exposures of Hilltown Formation yielding 'Celtic' brachiopod fauna, with planned future excavations (late 2008).
Right: Looking northwards across quarry exposures of the Bellewstown Inlier volcanic sequence (late 2008).

Bellewstown





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Grangegeeth**		
Other names used for site			
IGH THEME:	IGH 2 (Precambrian to Devonian Palaeontology)		
TOWNLAND(S)	Grangegeeth		
NEAREST TOWN	Slane		
SIX INCH MAP NUMBER	14		
NATIONAL GRID REFERENCE	295420 279350 = N 9542 7935		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
An overgrown depression which may have been quarried or may be a natural head of stream gully and waterfall.

Geological System/Age and Primary Rock Type
Ordovician fossiliferous sandstones.

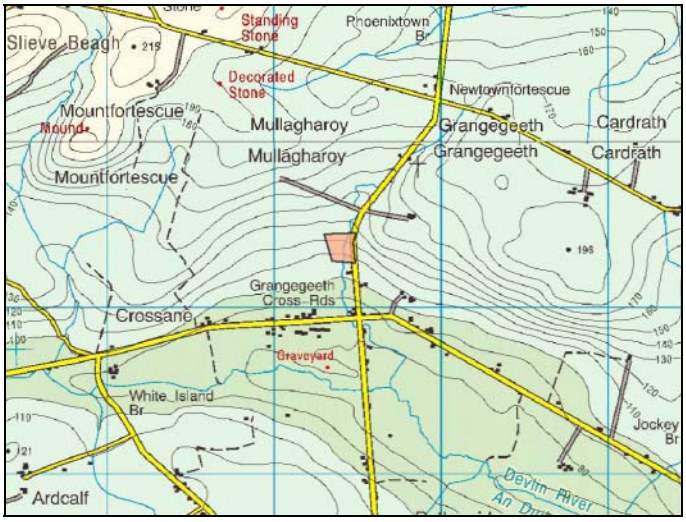
Main Geological or Geomorphological Interest
Small rock exposures in a stream gully, that may once have been quarried, have a rich assemblage of marine fossil brachiopods (shellfish) and trilobites (arthropods) and other invertebrates. These are of Ordovician age, and are a key piece of evidence in understanding the geological development of the rocks in the Grangegeeth area. The Grangegeeth inlier (older rocks entirely surrounded by younger rocks) is thought to be the remnants of a volcanic island formed in the Iapetus Ocean, which once separated the two halves of Ireland. The biogeographical affinities of the faunas at Grangegeeth match those of the Scoto-Appalachian (i.e. American) side of the ocean. They contrast significantly with faunas of the adjacent Bellewstown inlier, which have Anglo-Welsh provincial affinities.

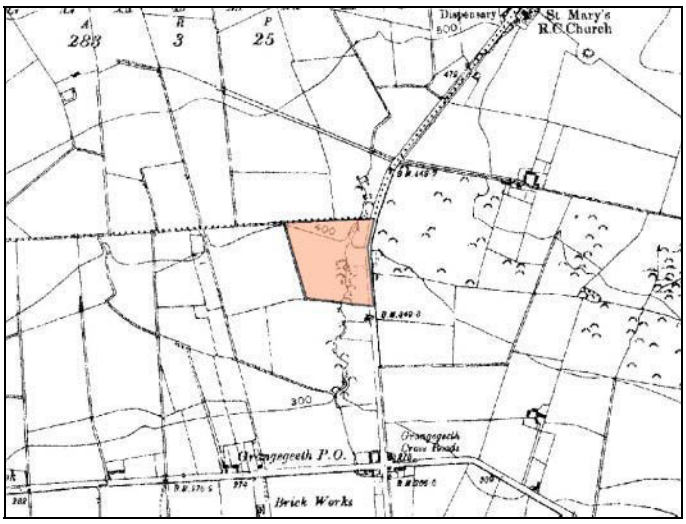
Site Importance
The fossils found here are important and the site has therefore been proposed as an NHA, as well for County Geological Site status in this report.

Management/promotion issues
This site is privately owned and is in agricultural usage. Any proposed changes to the site, including vegetation clearance or removal, should involve a palaeontologist (through the GSI).

A view from the west into the upper part of the old quarry. Brachiopod fossil moulds occur on bedding surfaces in the centre.

Grangegeeth





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Barley Hill Quarry**
Other names used for site	Ardagh Quarry
IGH THEME:	IGH 3, 8, 9 (Carboniferous to Pliocene Palaeontology, Lower Carboniferous, Upper Carboniferous)
TOWNLAND(S)	Ardagh
NEAREST TOWN	Kingscourt
SIX INCH MAP NUMBER	3
NATIONAL GRID REFERENCE	283500 295500 = N 835 955
1:50,000 O.S. SHEET NUMBER	35 **1/2 inch Sheet No.** 13

Outline Site Description
A working quarry.

Geological System/Age and Primary Rock Type
Lower to Upper Carboniferous limestone, locally fossiliferous.

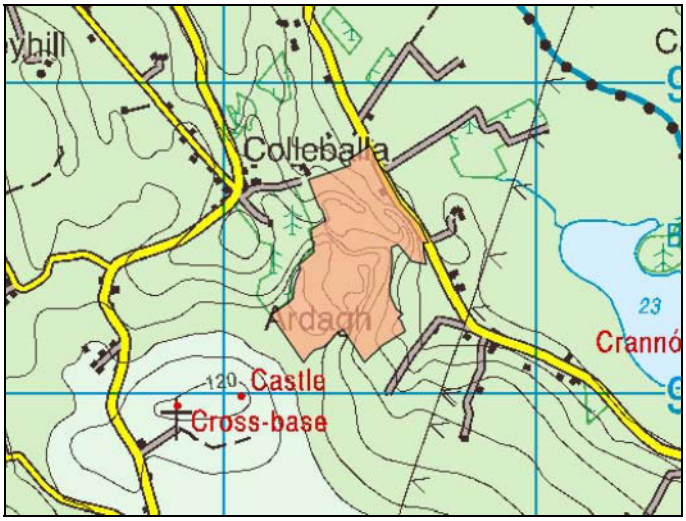
Main Geological or Geomorphological Interest
This relatively large Roadstone quarry, situated just east of Kingscourt, shows good exposures of locally fossiliferous limestone (used for aggregates). The quarry contains a reef limestone mud-mound, which is home to a variety of fossil species, including examples of brachiopods, bivalves, gastropods, corals and algae, and others. Many of the faces within this quarry, some up to 50m high, are highly weathered, with only a few fresh faces exposed. Fossils are best viewed within these fresh faces.

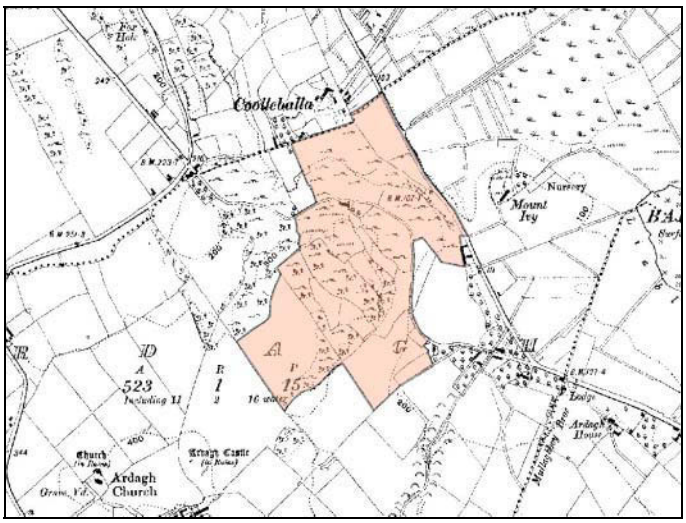
Site Importance
The rare assemblages of some of the fossils within this quarry, including species of coral and algae are grounds for designation of this site as a NHA.

Management/promotion issues
As a working quarry this is a potentially hazardous environment and would not be suitable for general promotion without appropriate access arrangements being made with Roadstone.

Left: Brachiopod fossil found within Barley Hill Quarry (many of the species observed were found within debris that had fallen away from the quarry faces.
Right: Quarrying for aggregate in operation at Barley Hill Quarry

Barley Hill Quarry





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Cregg**		
Other names used for site			
IGH THEME:	IGH 3 (Carboniferous to Pliocene Palaeontology)		
TOWNLAND(S)	Cregg		
NEAREST TOWN	Nobber		
SIX INCH MAP NUMBER	6		
NATIONAL GRID REFERENCE	283000 289300 = N830 893		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

Outline Site Description
Natural rock outcrops.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan) fossiliferous limestone of the Milverton Group.

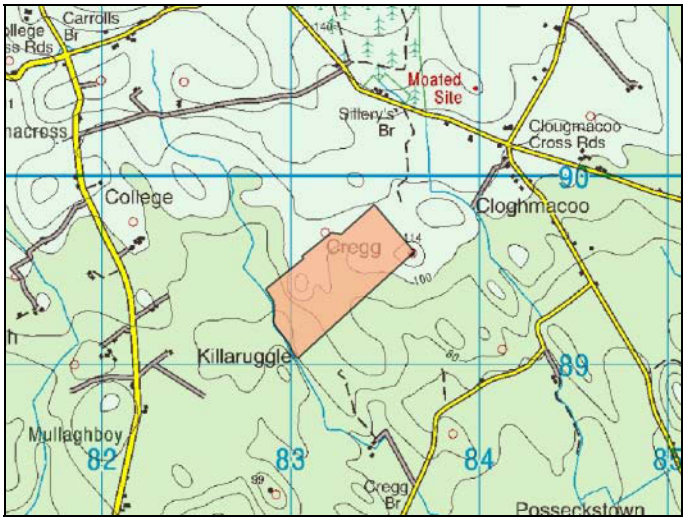
Main Geological or Geomorphological Interest
This large mound of heavily fossilised limestone, found at Cregg, represents a time in geological history when the Irish landmass was submerged in relatively shallow, tropical waters. The animals that lived in this marine environment thrived and their numbers and diversity can be seen within rocks that were formed during this period.

Site Importance
This site has yielded a unique and scientifically important collection of Lower Carboniferous marine fossils ranging from microscopic algae to larger marine invertebrate animals like cephalopods. It is therefore recommended that this site should become a County Geological Site.

Management/promotion issues
The site at Cregg is used for cattle grazing and a number of young bulls were observed. Public access is therefore not suitable and this site is not recommended for public promotion even though the fossils here are easily observed. It is possible that this area may be utilised for academic research in the future, subject to landowners permission.

Top Left: General appearance of the weathered limestone outcrops at Cregg.
Top Right: Cephalopod fossil.
Bottom: Gastropod fossil.

Cregg


Carrolls Br
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Sillery's Br
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Cregg
Killaruggle
Mullaghboy
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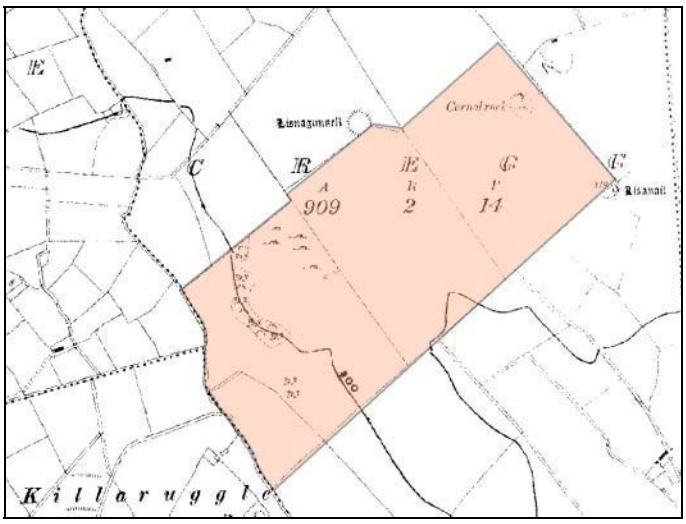
Cregg Br
Possecksfown


Lisnagunnell
Killaruggle

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Poulmore Scarp**
Other names used for site	South of Barley Hill House
IGH THEME:	IGH 3, 8 (Carboniferous to Pliocene Palaeontology, Lower Carboniferous)
TOWNLAND(S)	
NEAREST TOWN	Kingscourt
SIX INCH MAP NUMBER	2, 3
NATIONAL GRID REFERENCE	282450 295850 = N 8245 9585
1:50,000 O.S. SHEET NUMBER	35 **1/2 inch Sheet No.** 13

Outline Site Description
Swallow hole and cliff section, which may also be a disused quarry.

Geological System/Age and Primary Rock Type
Carboniferous limestone and sandstones.

Main Geological or Geomorphological Interest
Poulmore Scarp is an 11m section at the top of the Deer Park Formation in a swallow-hole just south of Barley Hill House. It exposes the Viséan-Namurian junction – that is what geologists classify as the boundary between Lower and Upper Carboniferous rocks. The section shows massive micaceous sandstones which overlie thickly bedded recrystallized limestones. The limestones have yielded abundant fossil corals (known as *Caninia cornucopiae*) and crinoid ossicles. Somerville and Somerville (1999) have indicated that the scarp has yielded an exceptionally high number of microfossils (of a type known as conodonts), as well as a unique occurrence of a fossil green algae.

Site Importance
The occurrence of prolific conodonts and other fauna across the boundary of Lower and Upper Carboniferous rocks means that this site is proposed for NHA status (under the IGH3 Carboniferous to Pliocene Palaeontology theme). It should also be listed as a County Geological Site in Meath.

Management/promotion issues
This site is on privately owned farmland and is under no obvious threat. The swallow hole should not be filled in or modified without geological advice, through the GSI. It is not suitable for general promotion with the public.

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Laytown to Gormanston**		
Other names used for site	Ben Head Moraine and Outwash Spread		
IGH THEME:	IGH 7 (Quaternary)		
TOWNLAND(S)	Numerous, including Gormanston, Julianstown		
NEAREST TOWN	Balbriggan		
SIX INCH MAP NUMBER	28		
NATIONAL GRID REFERENCE	316500 269300 = O165 693		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
Coastal plain, including sea cliffs.

Geological System/Age and Primary Rock Type
Quaternary sediments composed mainly of sand and gravel.

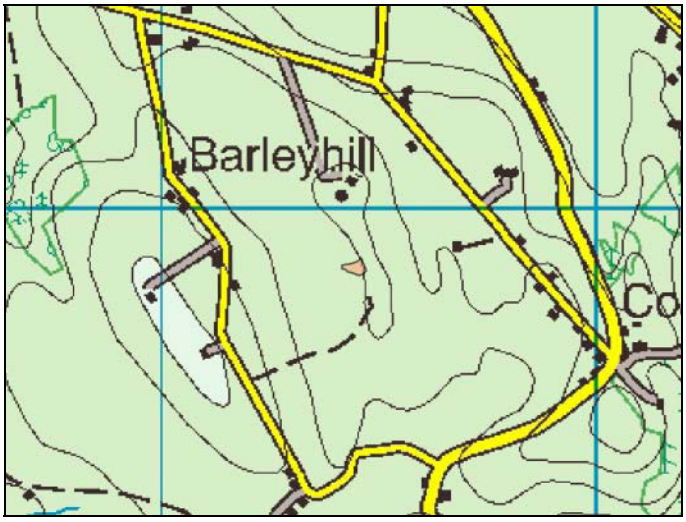
Main Geological or Geomorphological Interest
The Laytown to Gormanstown sandur is a flat to gently undulating glacial outwash plain, comprising glaciofluvial and glaciolacustrine sands and gravels deposited by outwash/meltwater flowing from the leading edge of a glacier. Approximately 5 kilometres east-west by 7 kilometres north-south, a sandur is commonly wider than it is long, as seen here. Sandpits to the south as well as numerous exposed cliff faces along the beach show good cross-sectional views of the internal structures within this sandur and a lower sequence of two separate facies of Irish Sea Tills.

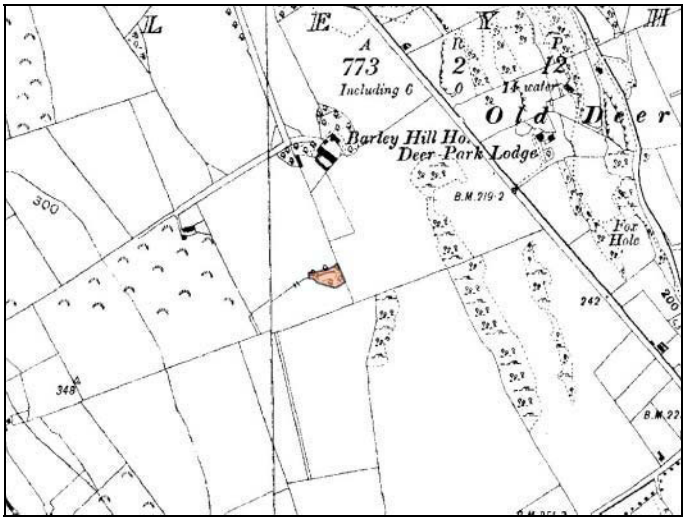
Site Importance
Glacial outwash plains are normally “hummocky”, meaning the terrain is bumpy. This example of an outwash plain is very flat, which makes it quite unusual and is therefore recommended as a County Geological Site.

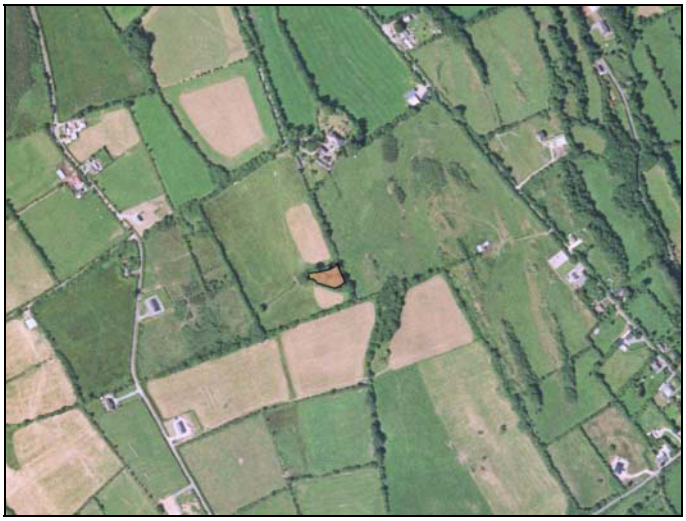
Management/promotion issues
Nearly all of the features between Laytown and Gormanston can be viewed from public roads or from the beach. The northern part of this locality is owned by the Department of Defence and is used as a military aerodrome and rifle range as it is very flat. Much of the rest of the site is agricultural with the exception of an old sand and gravel pit to the south, which is used as an off road motor track. Due to the nature of the landuse (especially military use) general promotion is not suitable without appropriate arrangements being made with the Camp Commandant and various landowners. Quarrying is a major threat to this feature and should not be permitted on the main gravel body.

Left: Abnormally flat terrain – the expansive outwash plain of sandur gravels at Gormanston.
Right: Coastal cliff sections allowing us to see the internal structure and composition of a sandur at Benhead.

Poulmore Scarp







Laytown to Gormanston


Laytown to Gormanston
Benhead

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Benhead**
Other names used for site	Ben Head moraine, Ben Head/Galtrim moraine
IGH THEME:	IGH 7 (Quaternary)
TOWNLAND(S)	Richardstown
NEAREST TOWN	Balbriggan
SIX INCH MAP NUMBER	28
NATIONAL GRID REFERENCE	317635 268570 = O 176 685
1:50,000 O.S. SHEET NUMBER	43 **1/2 inch Sheet No.** 13

Outline Site Description
A high coastal cliff face.

Geological System/Age and Primary Rock Type
Quaternary deposits of clay, sand, and gravel (boulder clay).

Main Geological or Geomorphological Interest
This small stretch of coastal cliff section at Benhead displays a cross sectional view of a recessional moraine. This was formed when Quaternary glaciers moving from north to south along the Irish coast deposited material at their leading edge as they began to melt. A recessional moraine represents a point where the ice front once existed but has later retreated due to melting. The moraine is composed of a dark grey to black, very stiff clay, containing gravel and occasional boulders At first glance it may be mistaken for a mudstone due to the stiffness and structure of the clay.

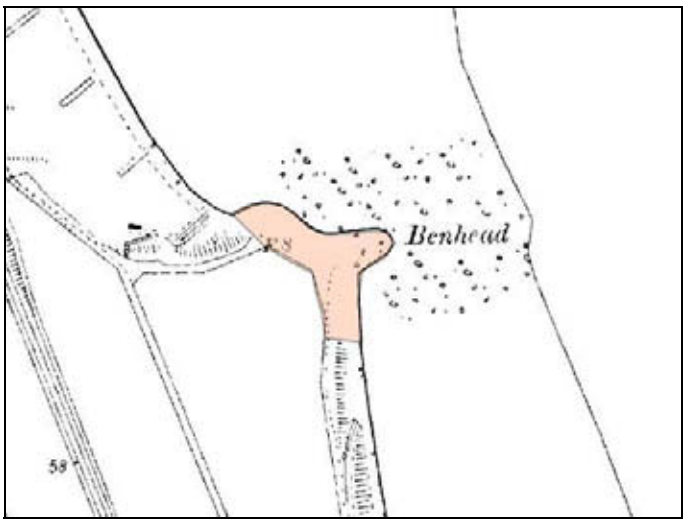
Site Importance
The Ben Head section is one of the type-sites for the 'Ben Head/Galtrim moraine' which was thought to demarcate the ice margin's retreat to the north. This 'moraine line' has been traced from Galtrim northeastwards to Benhead, although there is less evidence for the ridge and ice contact features at the latter locality. The feature at Benhead contains small and large scale structures that have allowed geologists to determine the direction of ice flow in this part of Ireland during the last Ice Age. This site is an excellent teaching locality and is recommended as a County Geological Site.

Management/promotion issues
The cliff face at Benhead can be accessed via the beach. Although this is a public beach it is beside a military base. Care should be taken when the red flags are flying, as they indicate live firing in operation. Coastal erosion is the major threat to this site and the quality of the exposure has deteriorated through the years.

Left: Cross sectional view of the recessional moraine at Benhead showing shear structures and slumping.
Right: Coastal cliff section exposing the feature at Benhead, viewed from the south.

Benhead


Mosney
aigh Muir
Military
Range
Benhead
17
18
Irishtown
25MP
Military
Aerodrome


Benhead

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Blackwater Valley**
Other names used for site	Blackwater Valley Sandur
IGH THEME:	IGH 7 (Quaternary)
TOWNLAND(S)	Numerous
NEAREST TOWN	Virginia, Carnaross
SIX INCH MAP NUMBER	10
NATIONAL GRID REFERENCE	267500 278700 = N 67 87 (near Carnaross)
1:50,000 O.S. SHEET NUMBER	35, 42 **1/2 inch Sheet No.** 13

Outline Site Description
Valley and outwash plain with Lough Ramor to the north.

Geological System/Age and Primary Rock Type
Quaternary deposits in the form of a pitted sandur (a glacial outwash plain).

Main Geological or Geomorphological Interest
The Blackwater Valley stretches from Castlekeeran in Meath to just north of Virginia in Cavan. This represents a large glacially derived valley, which is flooded to the north to form Lough Ramor. To the south of the lake is a glacial outwash feature known as a pitted sandur or pitted outwash plain. The valley catchment covers over 1,000 square kilometres, but the pitted sandur that forms a striking hummocky terrain at the base of the valley is only *c*. 20 square kilometres in area. A sandur forms when glacial meltwater flowing from a melting ice sheet deposits its load (silt, sand, gravel and boulders), creating a bumpy landscape. The term 'pitted' refers to the small to large depressions within the glacial sediment, created by solitary blocks of melting ice. These features are generally at such a large scale that they are difficult to recognise on the ground and may only be seen from satellite imagery or high resolution aerial photography. Unusually, in the Blackwater Valley, the hollows are visible on the ground. The full extent of the feature includes areas within County Cavan.

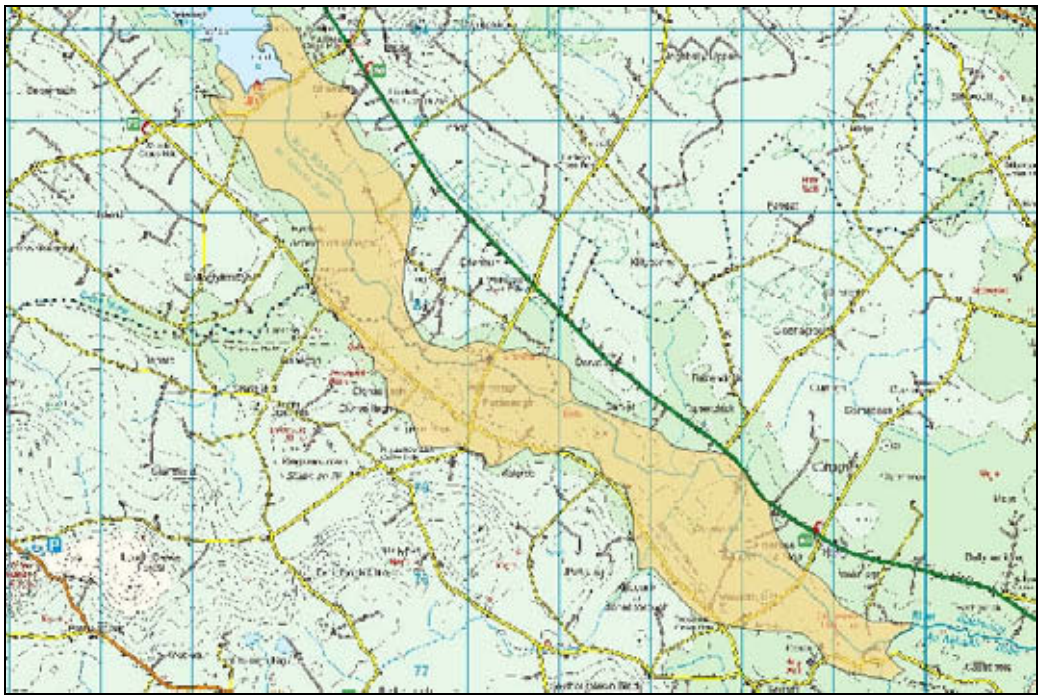
Site Importance
Most of this site lies within the River Boyne and River Blackwater SAC (Sitecode 02299). The Blackwater Valley sandur records the deglacial retreat of the ice sheet through north Meath and into Cavan at the end of the last glaciation. It is an excellent example of a series of proglacial outwash pitted sandurs, but is only recommended as a County Geological Site due to the size of the landforms.

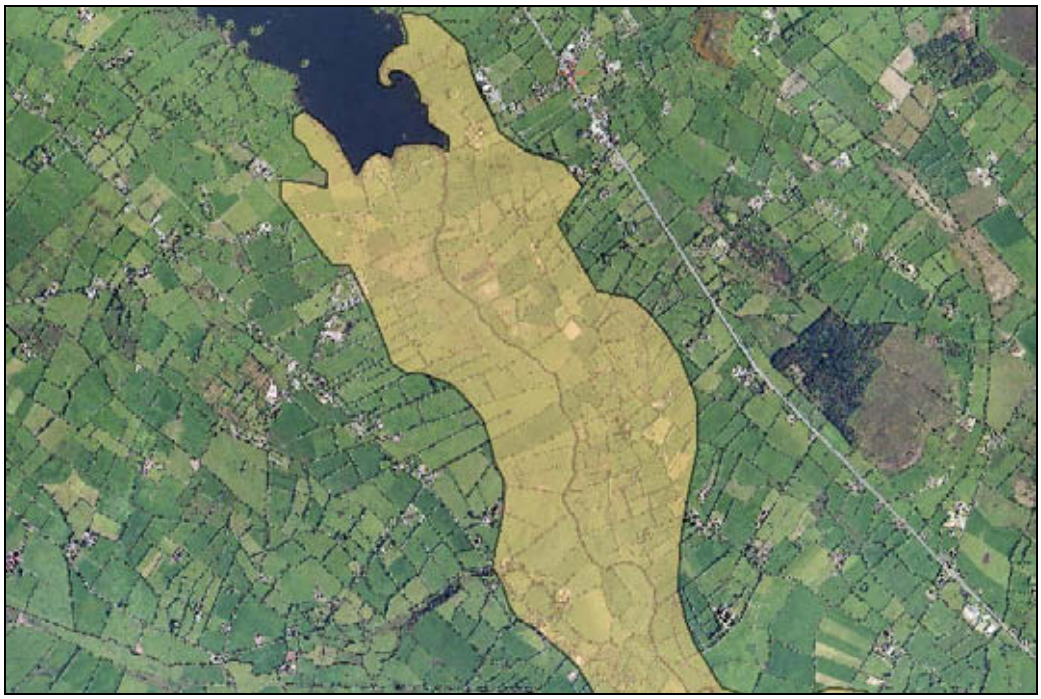
Management/promotion issues
Blackwater Valley is so large, that few threats would alter the overall geometry of the feature. However, individual gravel hummocks and ridges should be protected as best as possible, especially with regard to planning applications likely to alter their geomorphology. Some protection does exist for the SAC, but excavations and developments on the alluvial flat area or within the sands and gravels should be strictly monitored. This site is best observed from the roadside, as most of the land is privately owned agricultural land, and therefore not suitable for general promotion.

Above: A glacier carved out the broad and steep sided Blackwater Valley in which Lough Ramor lies today. All the deposits along the banks of this lake and along the Blackwater River to the south are glacially derived.

Above: Hummocky terrain of the pitted sandur at Pottlereagh, Carnaross.

Blackwater Valley





Blackwater Valley

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Boyne Valley**		
Other names used for site	Boyne Terraces		
IGH THEME:	IGH 7 (Quaternary)		
TOWNLAND(S)	Numerous		
NEAREST TOWN	Navan, Slane, Drogheda		
SIX INCH MAP NUMBER	18, 19, 20, 25, 26		
NATIONAL GRID REFERENCE	298000 273000 = N 98 73		
1:50,000 O.S. SHEET NUMBER	42, 43	**1/2 inch Sheet No.**	13

Outline Site Description
River valley.

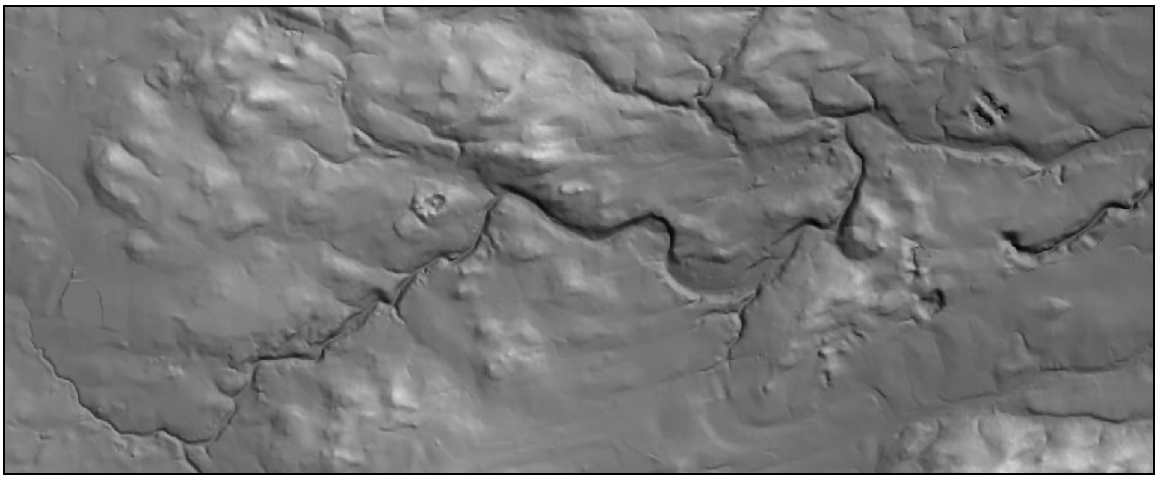
Geological System/Age and Primary Rock Type
Quaternary deposits, channels and terraces of a relict glaciofluvial system.

Main Geological or Geomorphological Interest
The Boyne Valley is a characteristic glacially modified lowland valley formed during the last Ice Age (before c. 10,000 years ago). It is characterised by hummocky topography and steep sided valley walls that have cut into the surrounding landscape. Features within the valley include suites of glaciofluvial and delta terraces. These are significant linear shelves generally subparallel to the meanders along the rock gorge. The terraces were formed by the meandering of the river after the channel had been deepened by large volumes of glacial meltwater. The Boyne Valley is complimented by many glacial meltwater channels, which feed into the Boyne system from either side.

Site Importance
This is a nationally important example of a glacially derived valley, with easily accessible features along both sides of the Boyne River. It is an excellent teaching locality and is commonly used by the public for recreational purposes (walking, canoeing, etc). Many of the important glacial features detailed above already lie within the Boyne Woods NHA (01592) and the River Boyne SAC (02299).

Management/promotion issues
This is a well maintained stretch of the River Boyne with many sites along its banks detailing significant sections of Ireland's history. The addition of signage would greatly enhance people's awareness of this area's equally significant geological history.

Above: The Boyne Valley, beside Slane. This broad, flat, steep sided glacial valley represents a period in Meath's geological history, when the land was dominated by massive, slow moving ice sheets and the large volume of erosive meltwater they generated.



Top: A delta terrace (terrace or slope left behind by an ancient meandering river channel).
Middle: The River Boyne with its steep sided wooded banks (commonly used for recreational sports such as kayaking).
Bottom: Digital elevation model (DEM) illustrating the pronounced glacially derived valley that is cut into the Meath landscape.

Boyne Valley

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Galtrim Moraine**
Other names used for site	Summerhill, Ben Head-Galtrim, Trim esker moraine
IGH THEME:	IGH 7 (Quaternary)
TOWNLAND(S)	Basketstown, Ballynamona, Monenstown, Galtrim,
NEAREST TOWN	Summerhill (village), Trim (town)
SIX INCH MAP NUMBER	42
NATIONAL GRID REFERENCE	286370 251850 = N 863 518
1:50,000 O.S. SHEET NUMBER	49 **1/2 inch Sheet No.** 13

Outline Site Description
Partially wooded, much quarried moraine ridge.

Geological System/Age and Primary Rock Type
Quaternary deposits predominantly of clay, sand and gravel.

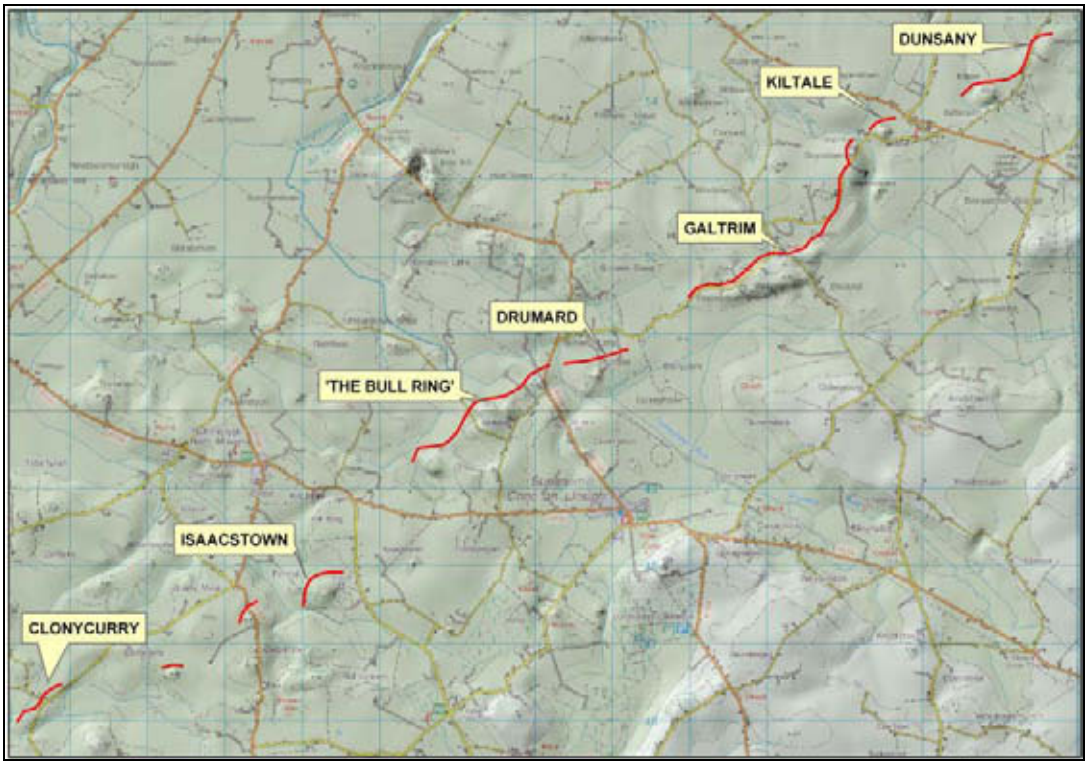
Main Geological or Geomorphological Interest
The Galtrim Moraine represents a large glacial depositional feature known as a recessional moraine which formed along the ice front of a melting glacier as it retreated across the north central Midlands at the end of the last glaciation. The morainic ridge is discontinuous but is at its most striking at Basketstown-Ballynamona-Galtrim-Martinstown, where it is up to 20m high and forms a NW-SW trending arcuate ridge 3 kilometres long. The ridges around Galtrim represent fan-like accumulations at the margins of the glacial lake at Summerhill. The northwest to southeast trending eskers (see Trim Esker) which join the northern ice contact face of the moraine represent the main subglacial feeder channels at the time of deglaciation around 17,000 BP.

Site Importance
Prior to its extensive quarrying in the 1960's, the Galtrim locality was the only place worldwide where an esker was seen to cross a moraine. Synge (1950) gave a detailed morpho-sedimentological description of the associated eskers around Trim that are contemporaneous with the Galtrim Moraine. His highly robust model has stood the test of time and this remains one of the most important areas in the historical evolution of the study of the Quaternary History of Ireland.
A small portion of the moraine in Formal Townland forms part of the Rathmoylan (sic.) esker NHA.

Management/promotion issues
Quarrying is a major threat to the moraine and has already destroyed much of its integrity. Future extraction should not be permitted without consultation with the GSI. This is not recommended as an NHA owing to the size of the landforms, but the national importance of the features should be highlighted.

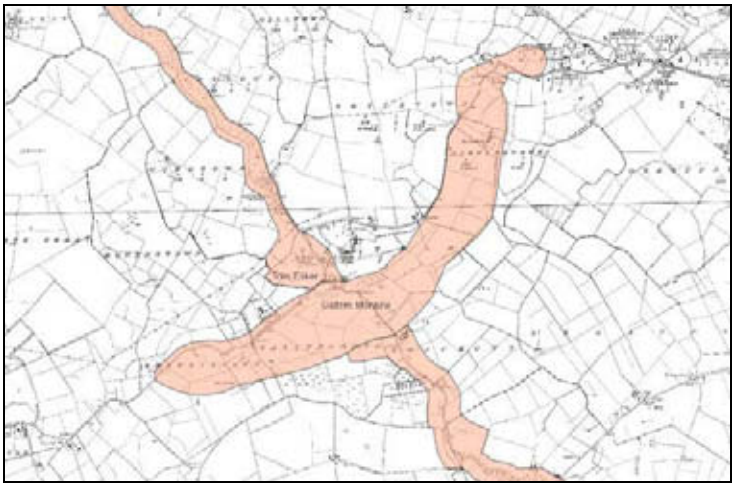
Left: A portion of the Galtrim moraine feature at Martinstown (R.Meehan 2007).

Galtrim moraine feature on DEM of area with the general ice limit marked in red (R.Meehan 2007).



Location of the ice contact faces along the Galtrim moraine feature as displayed on a DEM of the area, from Clonycurry in the southwest to Dunsany in the northeast. The interpreted general ice limit is marked in red (R.Meehan 2007).

Galtrim Moraine



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Mullaghmore**		
Other names used for site			
IGH THEME:	IGH 7 (Quaternary)		
TOWNLAND(S)	Mullaghmore, Ballyhoe		
NEAREST TOWN	Drumconrath		
SIX INCH MAP NUMBER	3		
NATIONAL GRID REFERENCE	285530 294163 = N 855 941		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

Outline Site Description
Gravel pits and agricultural land.

Geological System/Age and Primary Rock Type
Quaternary glacial deposits showing a thrust block moraine, with deformed sands and gravels.

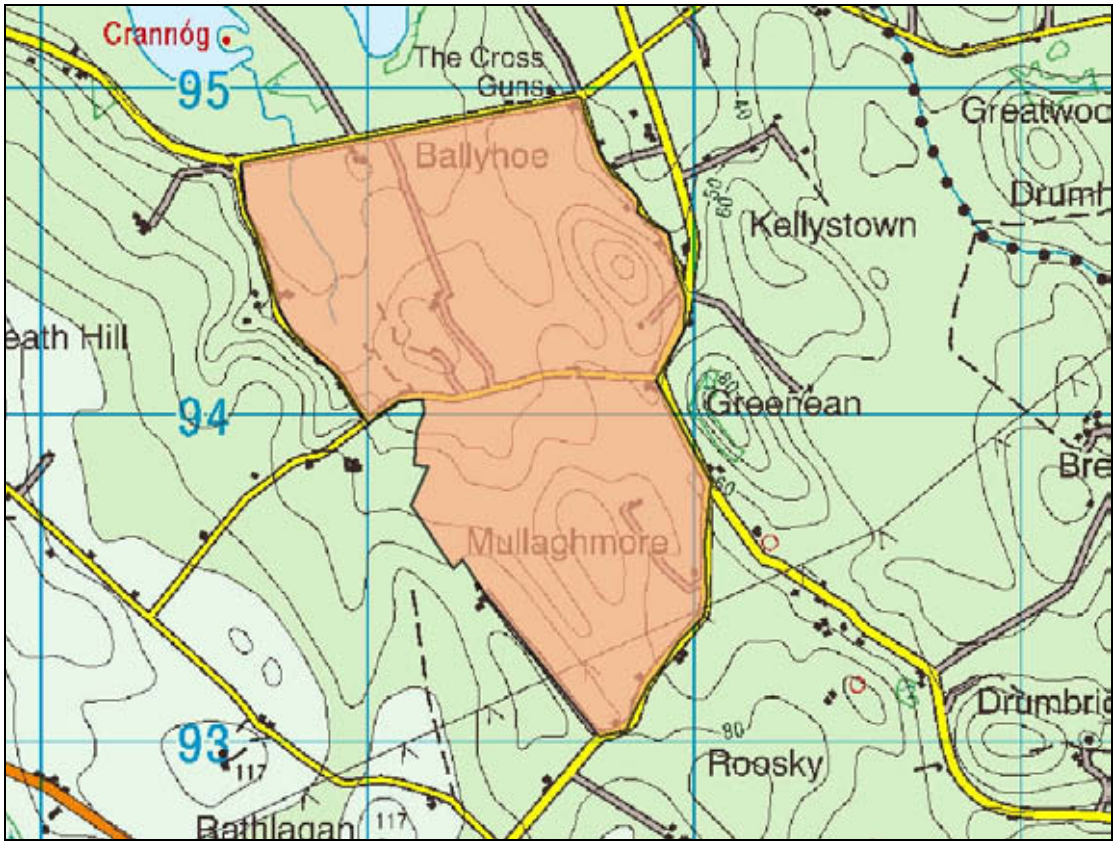
Main Geological or Geomorphological Interest
The site at Mullaghmore shows important glacial sediments with well exposed structural features. It is interpreted as a thrust block moraine, formed by localised ice oscillations. It records the push and deformation of a proglacial gravel feature during overriding by ice. The main section in the Mullaghmore disused aggregate quarry shows a series of overfolds around gravel 'cores' with fine deformational structures. The thrust block moraine is well exposed along three faces, giving a 3-dimensional view of the internal structure.

Site Importance
The site illustrates spectacular ice-thrust structures and marks a critical ice limit, which demonstrates that continual ice oscillations characterised the retreat of the ice sheet of the last glaciation, rather than regional ice movements. The feature will therefore be recommended as an NHA.

Management/promotion issues
The gravel pit is partially overgrown and the faces are continually collapsing, with the result that the section will slowly degrade. There is no dumping by local farmers at present. All of the features described lie on private agricultural land, mainly under pasture. Access to these areas is just off a third class road. Although all of the exposed pits within this locality need to be accessed through private land, most of the geomorphological landscape features are better seen from the roadside. It is recommended that general promotion is not suitable without first contacting the landowners.

Left: Exposed glacial material within the old Mullaghmore pit, showing 'cores' of boulders, gravels and thrust sediment at the top.
Right: Structures observed within one of the open pits, showing overfolded sands and gravels at the base of the section.

Mullaghmore



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Murrens**		
Other names used for site	Finnea-Murrens (Westmeath-Meath), Castletown Esker		
IGH THEME:	IGH 7 (Quaternary)		
TOWNLAND(S)	Murrens, numerous		
NEAREST TOWN	Oldcastle		
SIX INCH MAP NUMBER	14, 15		
NATIONAL GRID REFERENCE	252500 274800 = N 52 74		
1:50,000 O.S. SHEET NUMBER	34, 41, 42	**1/2 inch Sheet No.**	13

Outline Site Description
Wooded ridge – esker and hummocky ground including gravel pit.

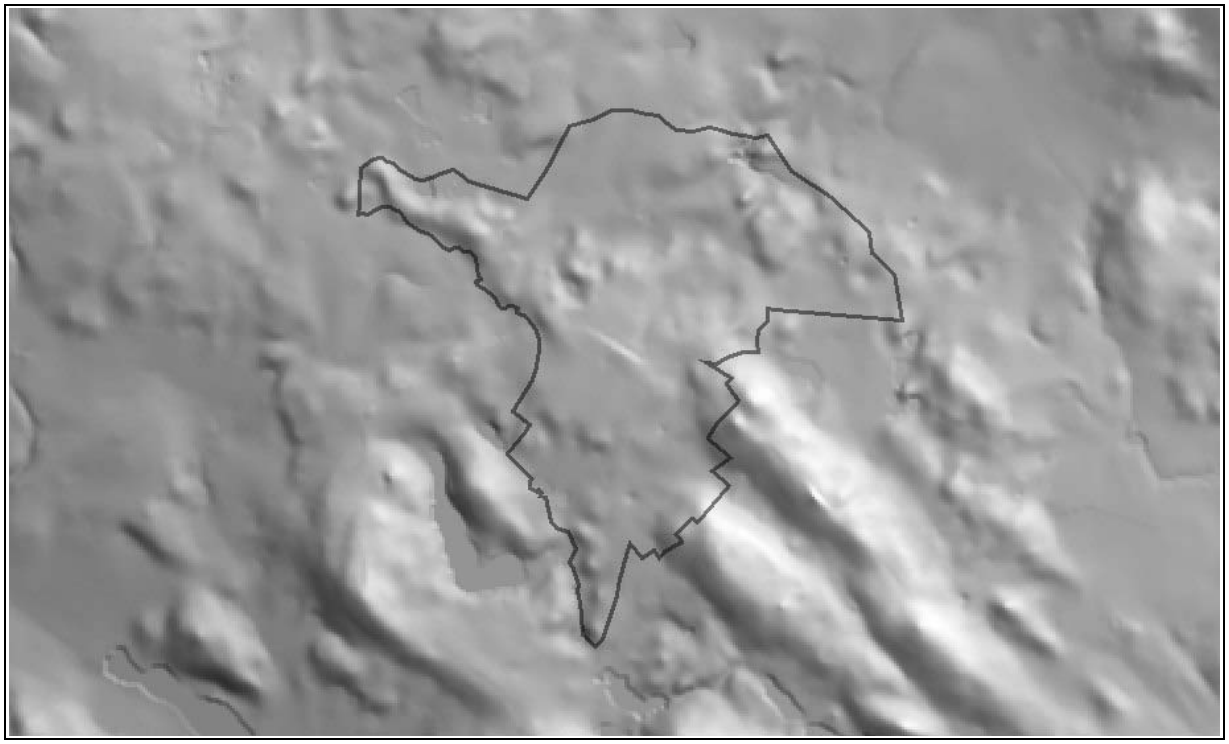
Geological System/Age and Primary Rock Type
Quaternary glacial deposits (esker, ice contact fan and delta system).

Main Geological or Geomorphological Interest
This is a long beaded esker system which feeds into a large, supraglacial delta complex, with flanking fans and kames. It extends into Westmeath (Finnea-Murrens Esker) over a distance of 15 km and comprising 11 segments in total. Murrens, which is situated 4km south of Oldcastle along the R195, is composed of a number of glacial depositional features. These include: an esker, formed by the deposition of sand and gravel by a subglacial river; and an ice contact fan and delta system, which is formed by the deposition of sand and gravel carried by glaciofluvial meltwater from a nearby ice sheet, creating hummocky terrain. A large sand and gravel quarry, called Murrens Quarry (owned by J.J. Flood and Sons) lies within this site.

Site Importance
This site is of very good quality, showing spectacular topography. Unique in Ireland and of international importance, the esker will be recommended for NHA designation.

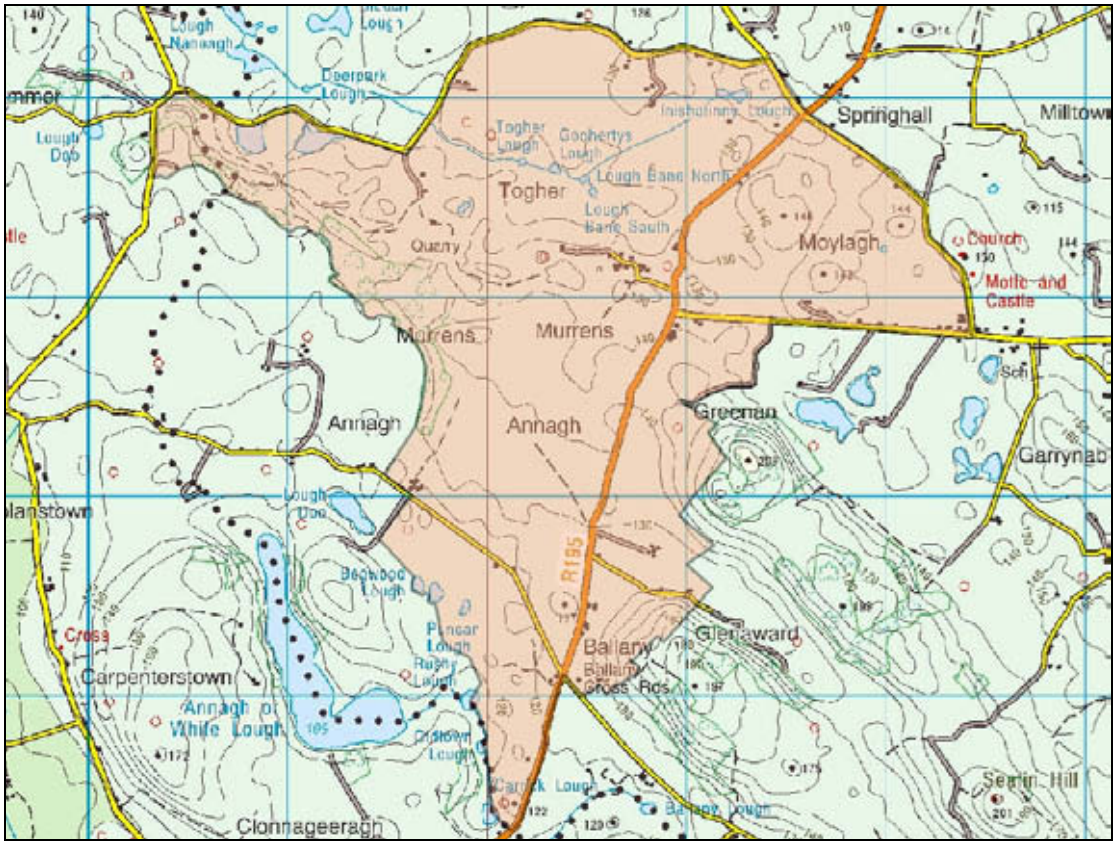
Management/promotion issues
No further quarrying should be permitted on this esker system. Illegal dumping has been noted on several occasions in old pits. It also has excellent educational potential, with a roadside cutting into the esker.

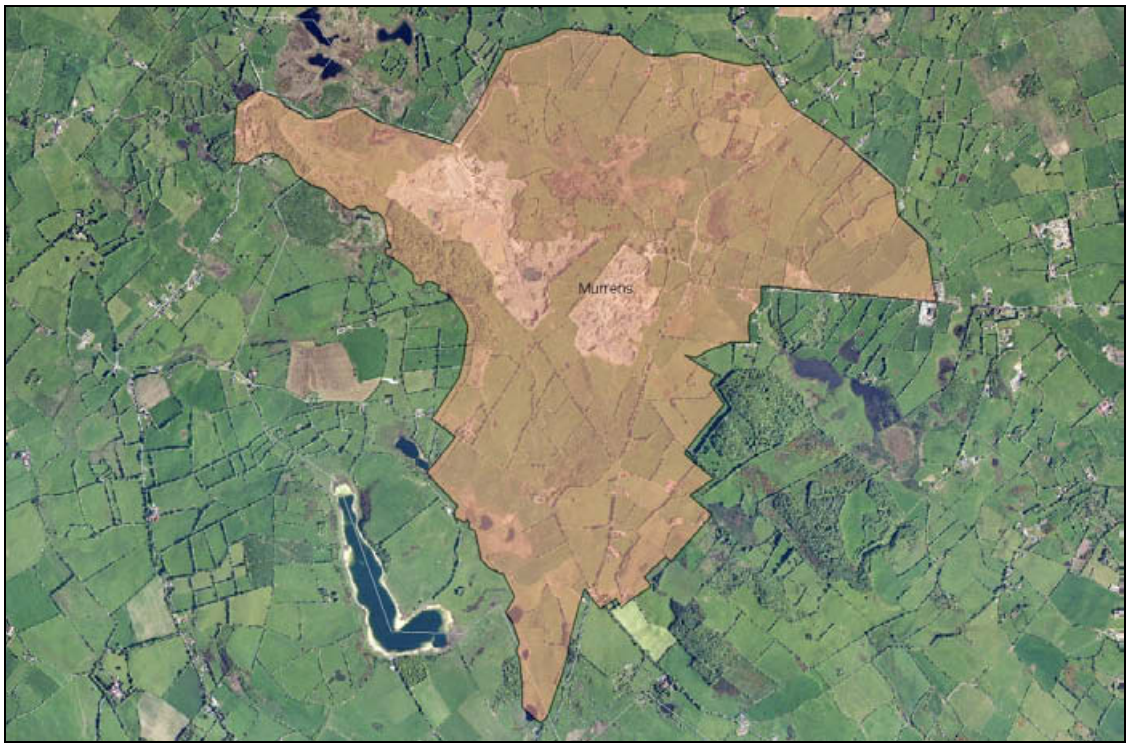
Above: A view from the north looking towards the esker at Murrens, seen here as a wooded ridge in the background.



Above: Digital elevation model (DEM) of Murrens clearly showing the esker as a ridge to the north west of the site. The low relief area directly to the south east of this ridge represents deposits of sand and gravel in a glacial outwash plain.
Below: Hummocky sands and gravels flanking the main esker ridge within the fan-shaped area (R.Meehan, 2007).

Murrens


Springhall
Milltown
Togher
Moylagh
Murrens
Murrens
Annagh
Annagh
Greenan
Garrynab
R185
Ballany
Glenaward
Carpenterstown
Clonnageeragh
Sean Hill


Murrens

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Rathkenny**		
Other names used for site	Rathkenny subaerial fan, Rathkenny sandur		
IGH THEME:	IGH 7 (Quaternary)		
TOWNLAND(S)	Rathkenny, Horistown, Tankardstown		
NEAREST TOWN	Slane		
SIX INCH MAP NUMBER	12		
NATIONAL GRID REFERENCE	289388 278600 = N 289 786 (fan)		
1:50,000 O.S. SHEET NUMBER	42	**1/2 inch Sheet No.**	13

Outline Site Description
Hummocky topography with gravel pit.

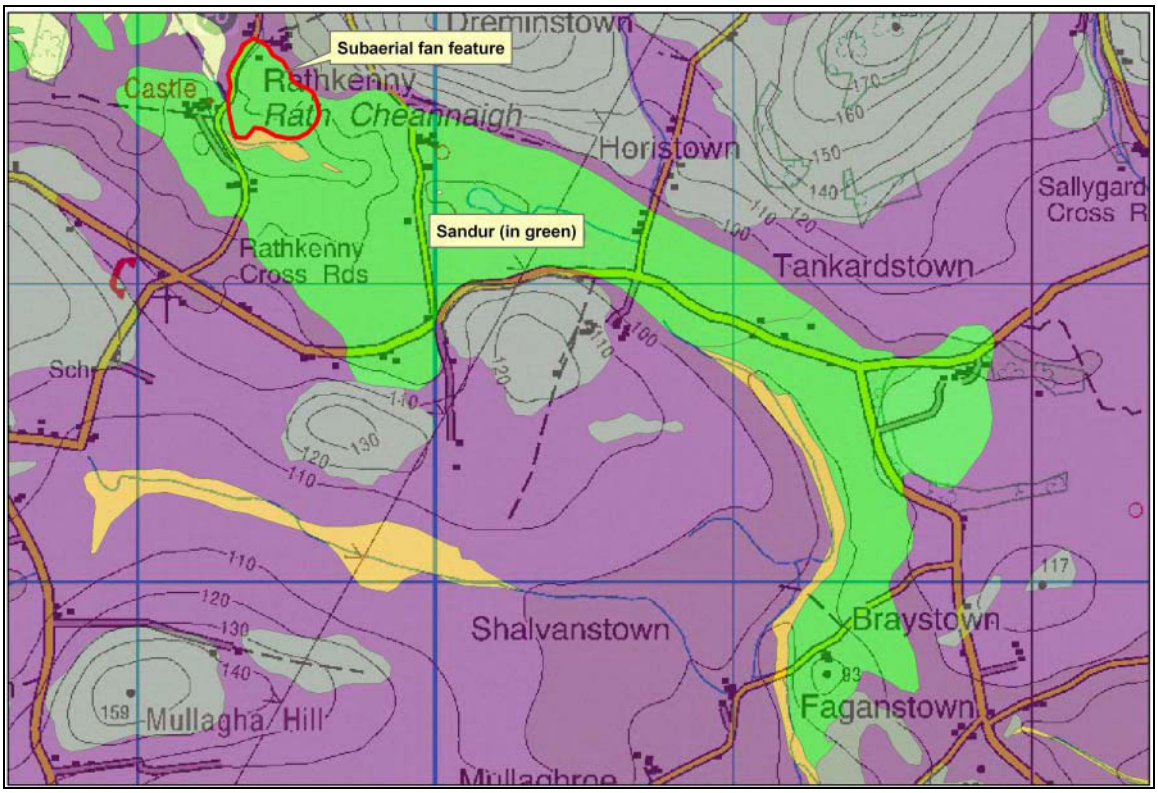
Geological System/Age and Primary Rock Type
Ice contact sub-aerial fan and glacial outwash deposits.

Main Geological or Geomorphological Interest
The site comprises a subaerial fan with a northwest ice contact face, deposited at the edge of a sandur feature that fills a deep glacial valley. This glacial feature is produced by the concentrated flow of meltwater from the edge of an ice sheet. The meltwater carries a variety of glacially derived material such as sand and gravel. As this water moves away from the glacier and into areas of relatively low gradient it slows and drops its material as a fan shaped deposit. The fan spreads out from its point of origin, away from the glacier. A disused sand and gravel pit (near where the ice front would have been) shows excellent cross sectional views of foreset sediments. The sandur itself extends out to the southeast from the fan, forming a feature almost 4 kilometres long and up to 800m wide. The sandur has a hummocky (bumpy) topography and is comprised of deep, well drained sands and gravels.

Site Importance
This is an excellent example of a subaerial fan deposited at an ice margin at the edge of a proglacial sandur feature and is recommended as a County Geological Site. It is one of the best examples countrywide of an exposed ice contact fan with associated foreset beds and collapse structures.

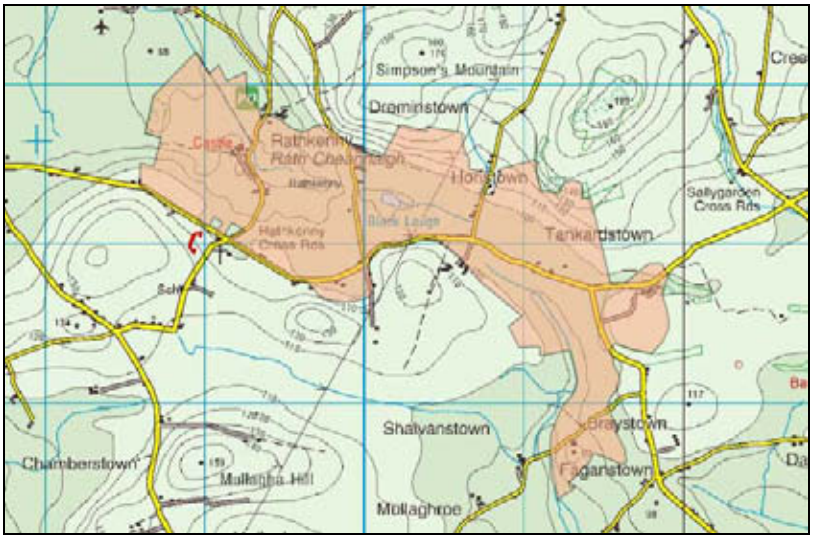
Management/promotion issues
This fine example of an exposed ice contact subaerial fan feature is particularly useful for teaching purposes, especially as the site is so close to an adjacent road. General promotion of the sand and gravel pit is not advised without first contacting the owners. Quarrying and infill form the major threat to the survival of this feature.

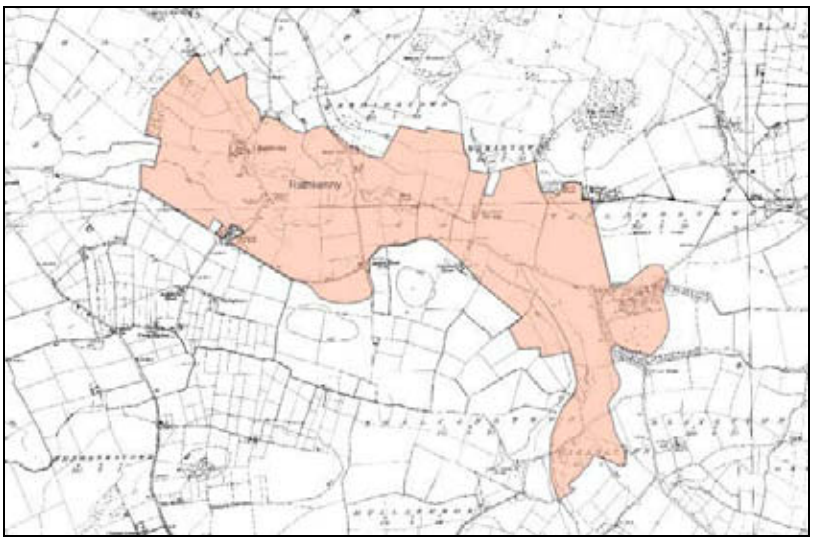
Left: Bedded layers of sand and gravel seen in the pit in the Rathkenny Fan. These layers represent different stages in meltwater flow.
Right: A boulder found within the same pit displaying striations (shown by white scrapes on the boulder surface) caused by glacial transportation and abrasion against other boulders at the base of the ice sheet.



Top: Subaerial fan and associated sandur at Rathkenny. The sandur (green, sands and gravels) fills a deep valley between ridges with rock outcrop on crests (grey) and a veneer of till derived from Lower Palaeozoic rocks (purple). Bottom: The morphology of the Rathkenny sandur, comprising flat-topped hillocks and hummocks.

Rathkenny


Simpson's Mountain
Drominstown
Rathkenny
Rath Cheannaigh
Castle
Hollystown
Sallygarden Cross Rds
Tankardstown
Rathkenny Cross Rds
Shalvanstown
Braystown
Chamberstown
Mullaghboy Hill
Fagarstown
Mullaghroe



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Rathmolyon Esker**
Other names used for site	Rathmolyan Esker (NPWS)
IGH THEME:	IGH 7 (Quaternary)
TOWNLAND(S)	Tromman, Cherryvalley, Rathmolyon, Glebe
NEAREST TOWN	Trim
SIX INCH MAP NUMBER	42
NATIONAL GRID REFERENCE	280060 249470 = N 800 470
1:50,000 O.S. SHEET NUMBER	49 **1/2 inch Sheet No.** 13

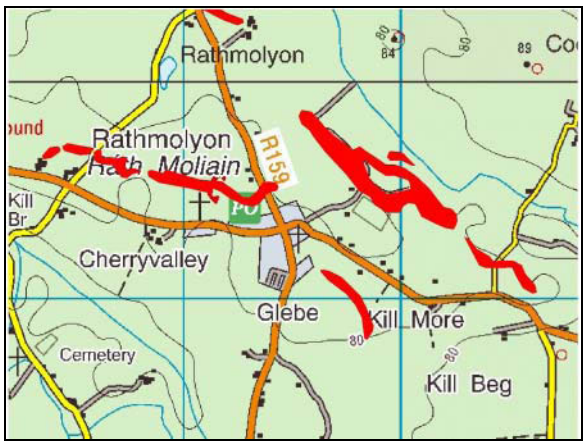
Outline Site Description
Remnant face in former sand & gravel quarry.

Geological System/Age and Primary Rock Type
Quaternary deposits predominantly of clay, sand and gravel.

Main Geological or Geomorphological Interest
The full Rathmolyon Esker, comprising 8 short beads, extending almost 2 km in length, was deposited in a tunnel feeding into the Summerhill (Galtrim) Delta Moraine. The portion of the esker considered here comprises one segment of a complex beaded esker, oriented northwest to southeast and bisected by a cul-de-sac roadway. Only the SE portion of the esker has been designated as a pNHA (Rathmoylan Esker - 0557). This wooded tip of the esker extends onto adjacent land.

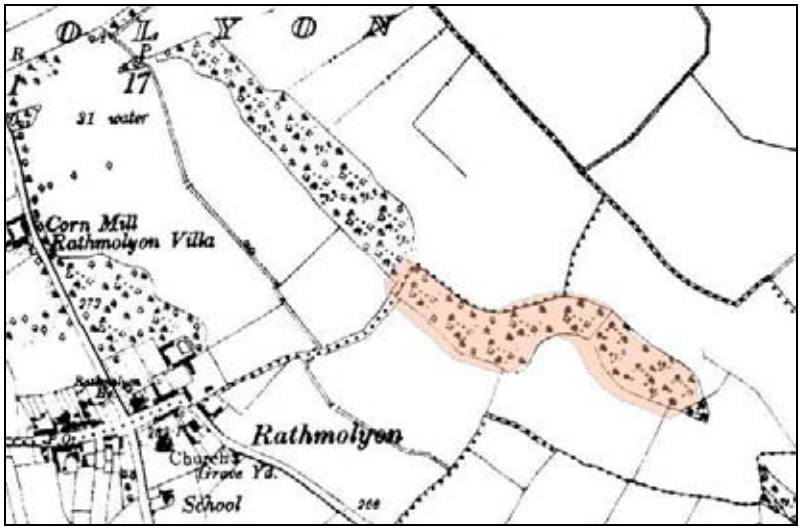
Site Importance
The Rathmolyon Esker was one of the type-sites for Francis Synge's theory of esker bead formation as fans. However, as most of the feature has been quarried out, leaving only the 3 faces topped by mature broadleaf woodland at the SE extreme, the status of the site has been downgraded from its original NHA recommendation under the IGH7 Quaternary Theme, to County Geological Site importance only. All eight segments are now deemed to be of CGS status only.

Management/promotion issues
Much of the major bead of the esker has been quarried away. The segments in Rathmolyon village are not currently under threat as houses have been built on them and these are well preserved. However, future quarrying on this feature should be prohibited. In the SE designated portion, three remaining faces along the final 80m of the pit provide a 3-dimensional section through the esker. Glynn Williams (WPE), on behalf of the quarry owner, has agreed with GSI (2009) a restoration and promotion plan to preserve the faces and help promote the esker locally. Only the part adjacent to the GAA pitch will be infilled with material. A nature walk from the gated access to the esker faces, fencing and bio/ geodiversity signage, will be provided. A stereoscope and aerial photos of the site should also be considered for access by schools in Trim Library.



Left: One of the esker faces to be preserved at the SE extreme of the esker pit. (Photo: R. Meehan, February 2009).
Right: Full extent of the Rathmolyon Esker. (R. Meehan, 2007)

Rathmolyon Esker



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Trim Esker**
Other names used for site	
IGH THEME:	IGH 7 (Quaternary)
TOWNLAND(S)	Numerous
NEAREST TOWN	Trim
SIX INCH MAP NUMBER	36, 37, 43
NATIONAL GRID REFERENCE	285500 253100 = N 855 531
1:50,000 O.S. SHEET NUMBER	42 **1/2 inch Sheet No.**

Outline Site Description
A 6km long section of a predominantly wooded esker ridge.

Geological System/Age and Primary Rock Type
Quaternary sand and gravel deposits.

Main Geological or Geomorphological Interest
Stretching along a 6km stretch of third class road between Trim and Arodstown is the heavily wooded glacial feature known as the Trim Esker. This beaded esker was formed by a river flowing beneath an ice sheet, which covered this area during the last Ice Age. This sub-glacial river deposited sand and gravel. When the ice finally retreated the deposited material remained to form a long linear ridge, which stands out from the surrounding landscape.

Site Importance
This beaded esker is part of the Galtrim meltwater complex, and demonstrates the importance of Irish eskers in world geological literature. It was here that Francis Synge observed the unique occurrence of an esker crossing a moraine, although the site of this intersection has been destroyed by quarrying. The Trim Esker, though itself not unique, as a beaded, feeder system and as one of the most studied and discussed eskers historically in the country, deserves designation as a County Geological Site.

Management/promotion issues
The total length of this feature is around 14.5km and comprises several segments, but many have been destroyed by quarrying. Only one segment, extending over 6km, is therefore recommended for designation in this report. A number of extraction companies are currently exploiting parts of this esker but future quarrying should be prohibited. Occasional dumping was observed along the roadside and needs to be addressed.

Left: Looking southwards along the Trim Esker from its shoulder (R.Meehan 2007).
Right: A number of areas along this esker have been used for illegal dumping which can adversely affect the feature.

Above: In many places along this esker are exposed sections of glaciofluvial material (mainly sand, rounded gravel and rounded cobbles). These sections allow geologists to better understand the processes involved in the generation of features like eskers.
Below: Northern section of the Trim Esker oriented northwest-southeast direction. This linear feature is easily identified by its vegetation growth (mainly wooded) and by the road that runs parallel to it (Aerial photo, OSi 2000).

Trim Esker


Ardbraccan or Wrightstown
Crumpstown or Marshallstown
Mountainstown or Batterhouse
Adamstown
Clonguffery
Walterstown
Branganstown
Killale
Freffans Little
Milltown
Mitchelstown
Batterjohn
Freffans Great
Foxtown
Boyerstown
Bray Hill
Readstown
Windtown
Derrypatrick Grange
Monerstown
Trim Esker
Galtrim
Ginnets Great
Galtrim Moraine
Blackcut
Derrypatrick
Dangan
Ginnets Little
Pramard
Derryclare
Curraghtown
Clonymeath
Collegeland
Arodstown
Ballinlig
Clonmahon
52
53
54
55
50
51


Trim Esker
Galtrim Moraine

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Altmush Stream**		
Other names used for site			
IGH THEME:	IGH 8, 9 (Lower Carboniferous, Upper Carboniferous)		
TOWNLAND(S)	Altmush		
NEAREST TOWN	Nobber		
SIX INCH MAP NUMBER	5		
NATIONAL GRID REFERENCE	278770 286830 = N 7877 8683		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

Outline Site Description
Natural rock outcrops along the banks of a stream over a distance of 1.5km.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan) to Upper Carboniferous (Namurian) limestone and shale of the Fingal Group and Ardagh Shale Formation respectively.

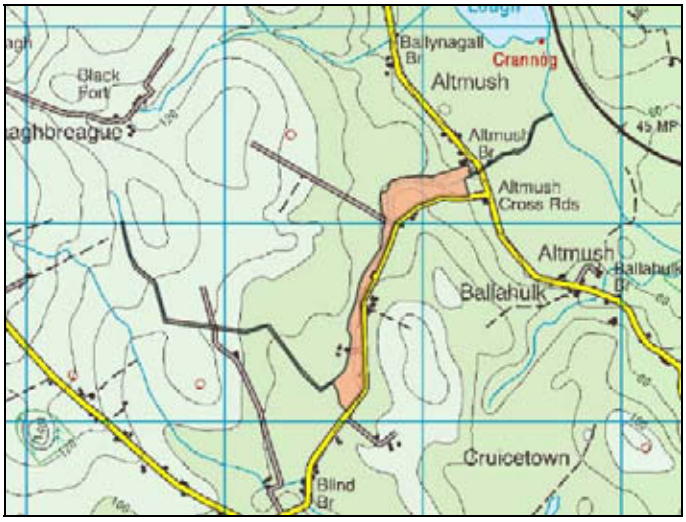
Main Geological or Geomorphological Interest
The small stream at Altmush has cut into the surrounding bedrock forming a steep sided channel and exposing long, continuous sections of dark grey limestone and black shale. The rocks here are generally thin to medium bedded and shallowly dipping at about 25°-30°. The limestone and shale, although mostly fresh, in places show several stages of mechanical weathering. Like most areas in County Meath the exposed rocks in this stream are heavily overlain by a blanket of glacial deposits.

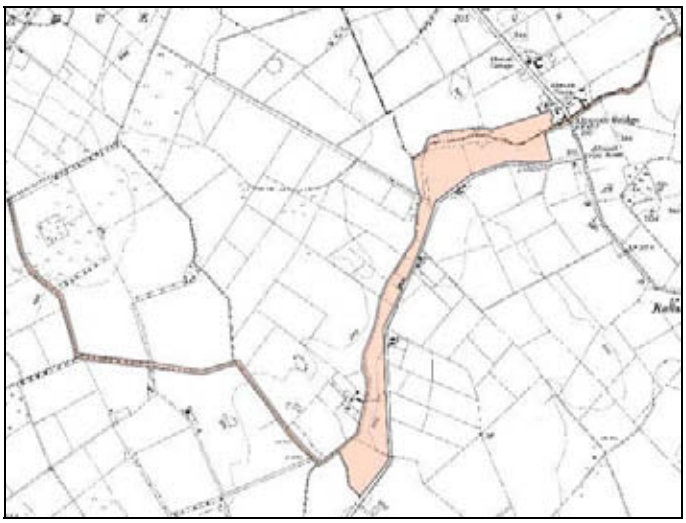
Site Importance
Natural well exposed outcrops such as this stream section are rare especially where they provide a continuous section. They should be considered important on a county level as they can be used by earth scientists as teaching localities and for mapping purposes.

Management/promotion issues
Access to this site is difficult as it mostly lies along steep banks and is in many places highly vegetated. The land is used for agricultural purposes (mainly cattle grazing) and therefore this site is not suitable for general promotion but may be used for further scientific research, with landowner permission.

Left: Thin bedded shallowly dipping black shale of the Fingal Group found within the stream at Altmush.
Right: A good representative image of the valley in which this stream and its outcrops lie.

Altmush Stream





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Bray Hill Quarry**		
Other names used for site	Roadstone – Trim Quarry		
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Stokestown		
NEAREST TOWN	Trim		
SIX INCH MAP NUMBER	36		
NATIONAL GRID REFERENCE	281500 253200 = N 815 532		
1:50,000 O.S. SHEET NUMBER	42	**1/2 inch Sheet No.**	13

Outline Site Description
A working quarry.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Waulsortian) limestone and Tertiary dolerite sill.

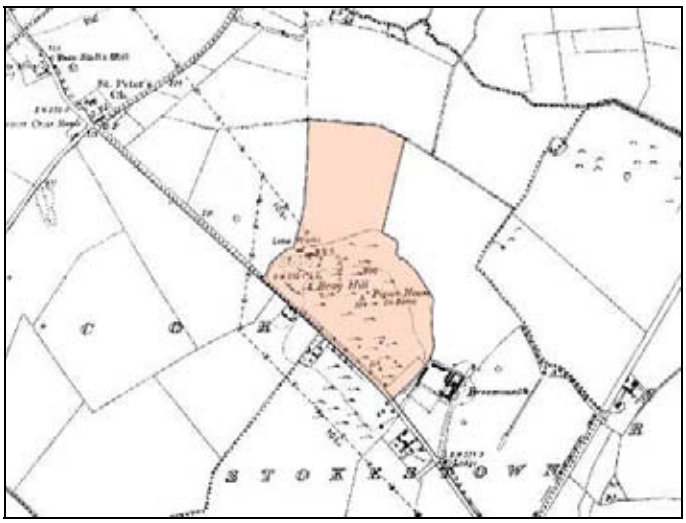
Main Geological or Geomorphological Interest
This large working quarry, operated by Roadstone, is found about 4km south of Trim along the R158. It is composed mainly of massive Waulsortian limestone with occasional shale in the upper levels, possibly of the Lucan Formation. Throughout this quarry are a number of good fossiliferous areas, mostly showing of crinoids and occasional corals. At the base of the quarry is an excellent example of an exposed sill, composed of dolerite. This dark coloured igneous intrusive rock was formed when magma pushed its way through the surrounding limestone beds and cooled to form a sill. The magma that forms these sills never reached the surface and was only uncovered here through the quarrying operation.

Site Importance
This is an excellent example of an easily accessible Tertiary sill within Waulsortian limestone and is recommended as a County Geological Site. This is also a good location for observing and collecting fossils and is an excellent teaching locality.

Management/promotion issues
As a large scale working quarry, operated by Roadstone, this is a potentially hazardous environment and is not suitable for general promotion without first contacting the owners.

Left: Gastropod fossil found within the Waulsortian Limestone at Bray Hill near where the sill is located.
Right: A number of crinoid stem fossils found in the Waulsortian Limestone in the upper areas of the quarry.
Middle: The Tertiary sill found within the lower levels of Trim Quarry. These sills are present along nearly all of the exposed faces at this level in the quarry pit. They are much darker than the surrounding light blue-grey limestone. The sills can be observed here running parallel to the beds of the surrounding limestone.

Bray Hill Quarry



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Duleek Quarry**		
Other names used for site	Duleek Roadstone		
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Longford		
NEAREST TOWN	Duleek		
SIX INCH MAP NUMBER	27		
NATIONAL GRID REFERENCE	303514 269522 = O 035 695		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
A working quarry.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan) limestone of the Clonlusk Formation.

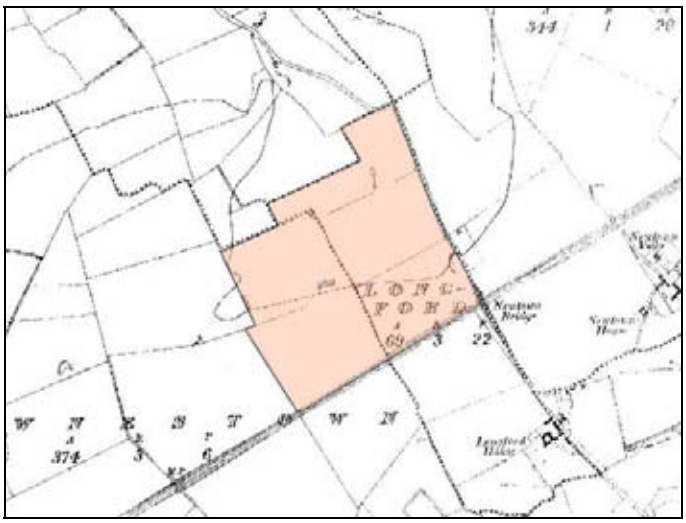
Main Geological or Geomorphological Interest
This site is situated 1km north of Duleek. The near vertical walls of this quarry expose large fresh sections of pale, thick bedded limestone. This limestone is bound by organic material. In this case the organic material is made up of peloids (dark pellet shaped grains) which gives this formation a sparkling appearance. A select number of fossil localities are found within this site.

Site Importance
This is a perfect location to observe Lower Carboniferous limestone. It also showcases how economic aggregates are extracted from modern quarries and is recommended for County Geological Site status.

Management/promotion issues
Although this is a small, relatively quiet working quarry it is still a potential hazardous environment and would not be suitable for general promotion without appropriate access arrangements being made with Roadstone.

Left: High vertical rock faces that make up this quarry.
Right: Quarrying for aggregate in Duleek Quarry.

Duleek Quarry



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Kilbride Quarry**		
Other names used for site			
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Kilbride		
NEAREST TOWN	Nobber		
SIX INCH MAP NUMBER	6		
NATIONAL GRID REFERENCE	284800 284770 = N 8480 8477		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

Outline Site Description
A disused quarry.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Courceyan) limestone of the Cruicetown Group.

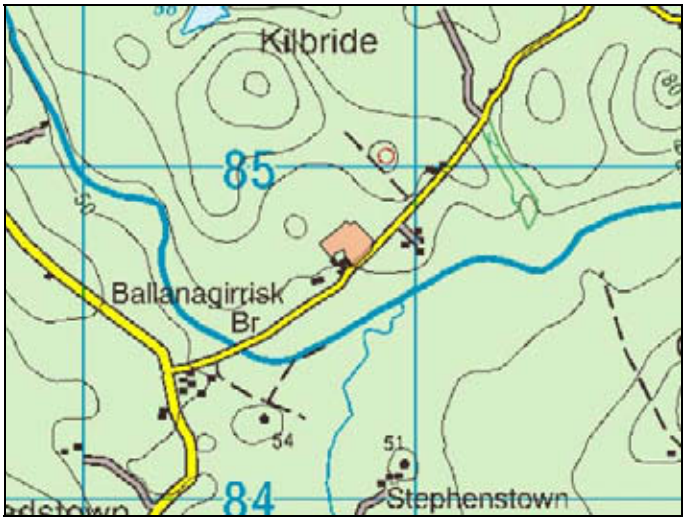
Main Geological or Geomorphological Interest
Found south of Nobber in the townland of Kilbride, this disused quarry displays exposed faces of medium bedded, crinoidal limestone and occasional ash beds. The remnants of this quarry lie within the north side of a farm yard and in a small outcrop in a field just east of the farmyard. Most of the quarry has been backfilled with the exception of these faces. The ash beds, which are found near the base of the quarry wall, are partially covered by silage.

Site Importance
This easily accessed site is a good fossil locality, which has been used in the past for scientific research. The partially covered ash beds can be used to date the surrounding Carboniferous rocks and it is therefore recommended that Kilbride Quarry becomes a County Geological Site.

Management/promotion issues
This site may be used for further research in the future, with permission from the landowner but is not suitable for general promotion due to the nature of the land surrounding this site. The silage clamps are not permanent obstructions and do not pose a significant long term threat.

Above Left: Exposed quarry face within the farmyard. Silage observed at its base.
Above Right: Medium bedded limestone beds found in the field adjacent to the farmyard.
Below: Crinoid fossils found in the field adjacent to the farmyard.

Kilbride Quarry



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Nobber**		
Other names used for site			
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Spiddal		
NEAREST TOWN	Nobber		
SIX INCH MAP NUMBER	5, 6		
NATIONAL GRID REFERENCE	283000 285800 = N 830 858		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

Outline Site Description
Natural rock outcrops along the banks of the River Dee over a distance of 360m.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan) limestone and shale of the Fingal Group.

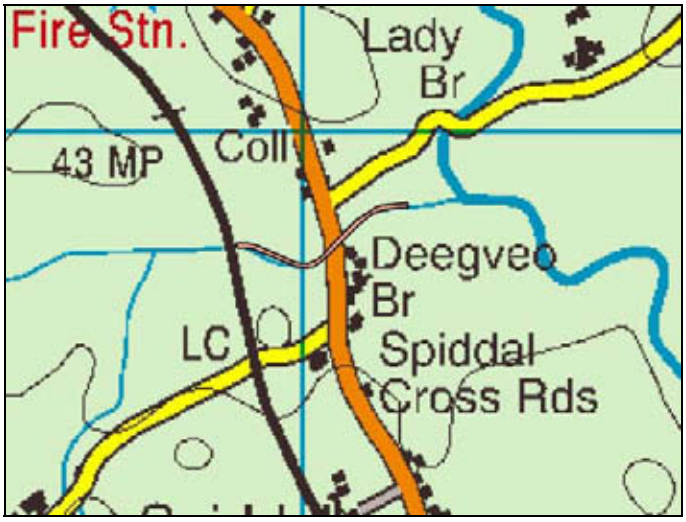
Main Geological or Geomorphological Interest
A small section of the River Dee, just south of Nobber, displays excellent exposures of dark limestone and shale. These thin to medium bedded, steeply dipping (45°) rocks are exposed on both sides of the river bank and are best exposed adjacent to the Deegveo Bridge. Along this section, the River Dee has cut into glacial till and underlying bedrock forming a deeply incised, steep sided river valley. It is also noted that the channel was deepened through the Dee Drainage Scheme – the original cut was not so deep.

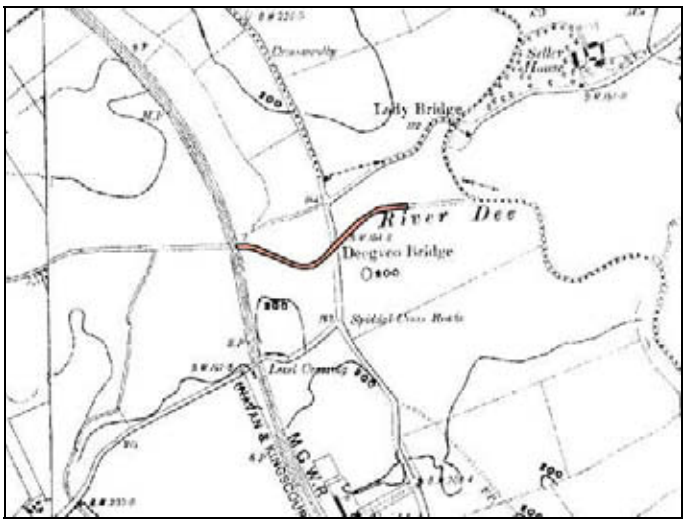
Site Importance
Natural well exposed outcrops such as this river section are rare and the site is recommended for County Geological Site designation. These rock outcrops could be used by earth scientists as teaching localities and for mapping purposes.

Management/promotion issues
This site lies on both the east and west side of the R162 and can be accessed at Deegveo Bridge. This site is on private agricultural land and is not suitable for general promotion without first contacting the landowner(s). A local angling club appears to have access rights to this site.

Left: Riverbank exposure of thin to medium bedded limestone and shale seen near Deegveo Bridge, just south of Nobber.
Right: A view of the deeply incised River Dee from Deegveo Bridge.

Nobber


Fire Stn.
Lady
Br
43 MP
Colly
Deegvee
Br
LC
Spiddal
Cross Rds


Lady Bridge
River Dee
Deegvee Bridge
M.G.W.R.

MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Painestown Quarry**		
Other names used for site			
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Painestown		
NEAREST TOWN	Slane		
SIX INCH MAP NUMBER	26		
NATIONAL GRID REFERENCE	295350 270000 = N 9535 7000		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
A disused quarry now heavily vegetated.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan) thin to medium bedded limestone and shale of the Loughshinny Formation.

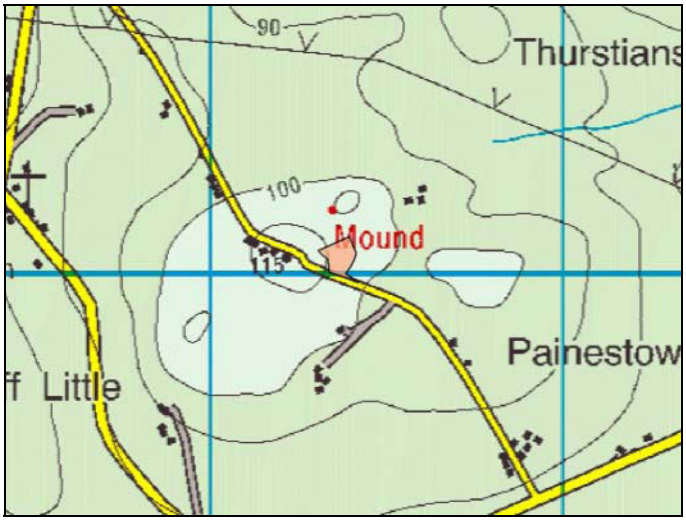
Main Geological or Geomorphological Interest
This disused quarry has cut into thinly bedded limestone and shale, which displays a series of angular, zig-zag folds called chevron folds. These occur when pressure is exerted on thinly bedded sequences of alternating rocks, where one rock type (limestone) is competent and the other (shale) is incompetent. These features are also found in the same rock formation along the coast at Loughshinny.

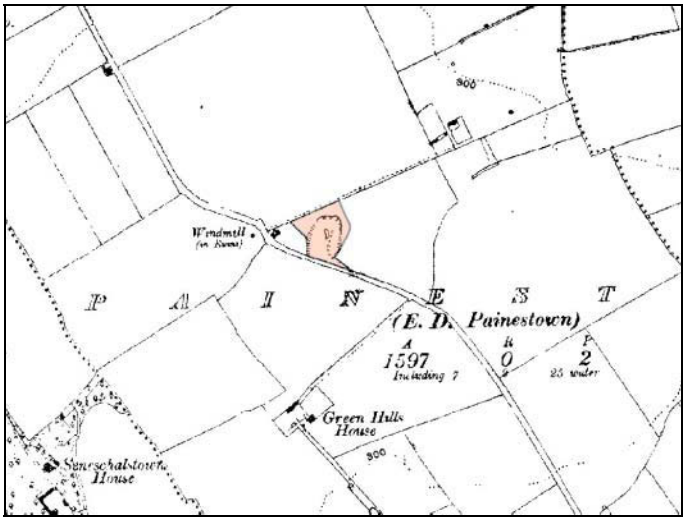
Site Importance
This is a spectacular and easily accessible example of chevron folds, which could make an excellent teaching locality. It complements the example of coastal geology at Loughshinny. It should become a County Geological Site.

Management/promotion issues
This site is found just off a third class road and is on private agricultural land, which is occasionally used for grazing cattle. Access to the site is through a farm gate along the road. This is not suitable for general promotion without suitable arrangements being made with the landowner. Only one exposed face still remains within the old quarry as the rest of the site has been filled in. It is important to keep this last face exposed and if possible, relatively free of vegetation cover.

Left: Exposed quarry face displaying excellent examples of chevron folding.
Right: A closer look at the zig-zag shaped folds. The limbs of the folds usually form at a 45°- 60° angle, as seen here at Painestown.

Painestown Quarry





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Rockwood Cliffs**		
Other names used for site	Boyne Walk		
IGH THEME:	IGH 8 (Lower Carboniferous)		
TOWNLAND(S)	Slane		
NEAREST TOWN	Slane		
SIX INCH MAP NUMBER	19		
NATIONAL GRID REFERENCE	294750 273200 = N 9475 7320		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
Cliff section along the River Boyne.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Viséan, Courceyan) limestone of the Boyne Formation (commonly known as 'Calp') and Waulsortian Limestone.

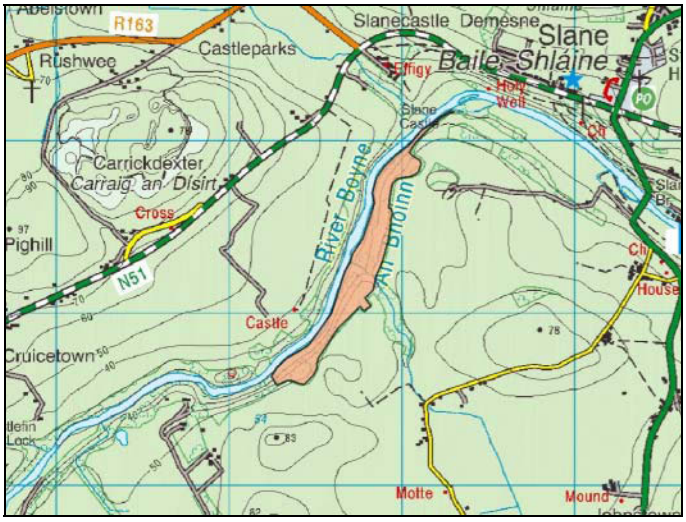
Main Geological or Geomorphological Interest
A number of exposures of Lower Carboniferous limestone and occasional shale can be found along or near the banks of the River Boyne. Although a number of smaller outcrops can be seen on the north banks of the river the best example can be seen at Rockwood, a forested area opposite Slane Castle, on the south banks of the River Boyne. These rocks form cliffs that reach heights of up to 25 metres and are predominantly composed of thick bedded to massive brown-grey locally fossiliferous limestone and shale. The cliffs were most likely formed by the erosive power of glacial meltwater during the last Ice Age. Meltwater would have passed through the valley scouring out a deep gorge in the underlying bedrock creating the cliffs.

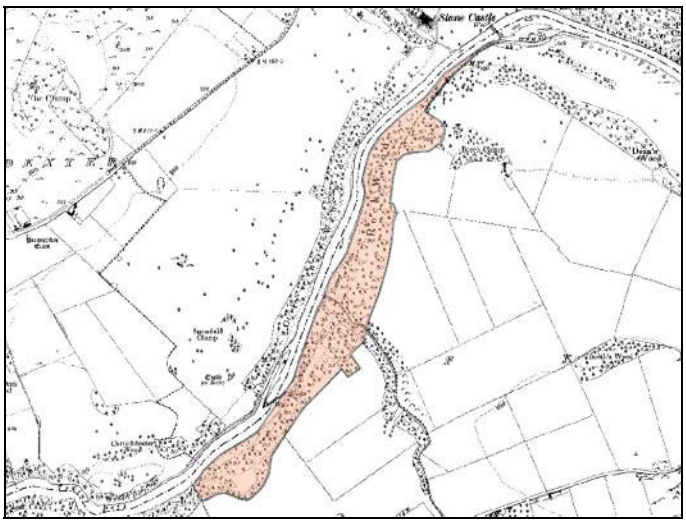
Site Importance
This is one of the best outcrop exposures along the Boyne Valley, which already lies within the existing Boyne Woods NHA. Natural well exposed outcrops such as these are rare, especially ones that are so easily accessible. It has good teaching potential. Its geological heritage value needs to incorporated into the already existing pNHA synopsis. It should also be listed as a County Geological Site in Meath.

Management/promotion issues
Although access to the cliffs is on private land (part of Slane Castle) it is a recognised public right of way. All of the outcrops described in this report can be accessed via this riverbank walkway, although in places dense forestry and vegetation obscure some sections of the cliffs.

Left: Riverbank exposure of thick bedded dark limestone and shale (Calp) of the Boyne Formation found on the south side of the River Boyne. These rocks can be seen shallowly dipping to the southwest.
Right: Fossilised coral found within the Waulsortian Limestone, opposite Slane Castle.

Rockwood Cliffs





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Carrickleck Quarry**		
Other names used for site	Roadstone – Silica Sand Ltd.		
IGH THEME:	IGH 9 (Upper Carboniferous)		
TOWNLAND(S)	Carrickleck		
NEAREST TOWN	Nobber		
SIX INCH MAP NUMBER	2, 3		
NATIONAL GRID REFERENCE	282200 292300 = N 822 923		
1:50,000 O.S. SHEET NUMBER	35	**1/2 inch Sheet No.**	13

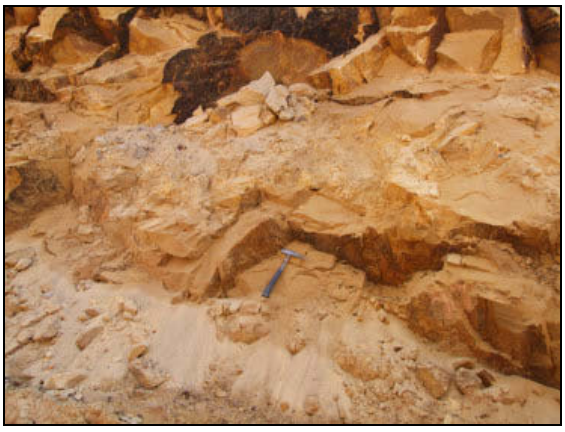
Outline Site Description
A working quarry.

Geological System/Age and Primary Rock Type
Upper Carboniferous (Namurian) disaggregated sandstone of the Carrickleck Sandstone Member.

Main Geological or Geomorphological Interest
Formally owned by Irish Glass Bottle this small working quarry now owned by Roadstone has excavated though a narrow strip of sandstone forming a long, narrow valley. The walls of this quarry reach up to 30m in some places. This exposed sandstone is locally disaggregated, meaning that its individual grains are no longer cemented together strongly. This produces an unusual situation where the sandstone, which appears to be solid rock as it still holds its structure (bedding, joints, etc), can be easily crushed by hand to produce a fine dusty sand. Due to this natural breakdown, it is possible to extract and sell this fine grained sand without having to crush or break the rock.

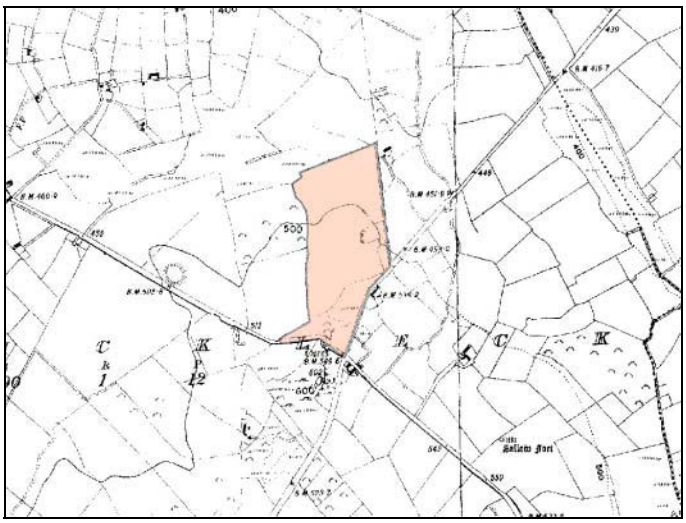
Site Importance
This quarry has an important historic significance as it is possible that rock quarried from this site was used in the production of the High Crosses at Kells. This is also a very interesting example of disaggregated sandstone and is probably the only one of its kind within Meath and is recommended for County Geological Site status.

Management/promotion issues
Due to the unusual characteristics of the sandstone this would make a good teaching locality. This site is adjacent to a quiet third class road and access is via a locked gate. Although small and relatively quiet this quarry is a potentially hazardous environment and would not be suitable for general promotion without appropriate access arrangements being made with Roadstone.



Left: Quarry operations have carved out this narrow valley exposing the rocks of the Carrickleck Sandstone Member.
Right: Disaggregated sandstone – bedding and other sedimentary structures are still visible but this weakened rock breaks down into a fine grained sand, even when squeezed between the hands.

Carrickleck Quarry



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Dunshaughlin**		
Other names used for site			
IGH THEME:	IGH 12 (Mesozoic and Cenozoic)		
TOWNLAND(S)			
NEAREST TOWN	Dunshaughlin		
SIX INCH MAP NUMBER			
NATIONAL GRID REFERENCE	297591 253243 = N 975 532		
1:50,000 O.S. SHEET NUMBER	43	**1/2 inch Sheet No.**	13

Outline Site Description
The site is unexposed at the surface.

Geological System/Age and Primary Rock Type
A basin shaped body of silica derived from decalcified limestone, undated but possibly formed from Tertiary weathering.

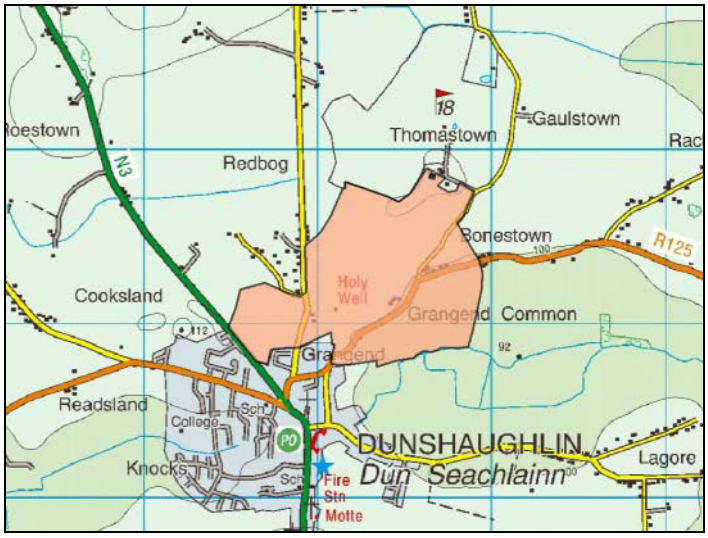
Main Geological or Geomorphological Interest
This site is of interest in the Mesozoic and Cenozoic history of Ireland, since it is a very large depression over 1km^2 in area composed of silica. Detected primarily by geophysical techniques, the limited investigation shows that the deposit contains white silica, red-brown clays and some black lignite. Reynolds (1974) used geophysics to define the depression. He suggested that it was formed by in situ solution of the limestone by sulphuric acid released from breakdown of pyrite in the rock.

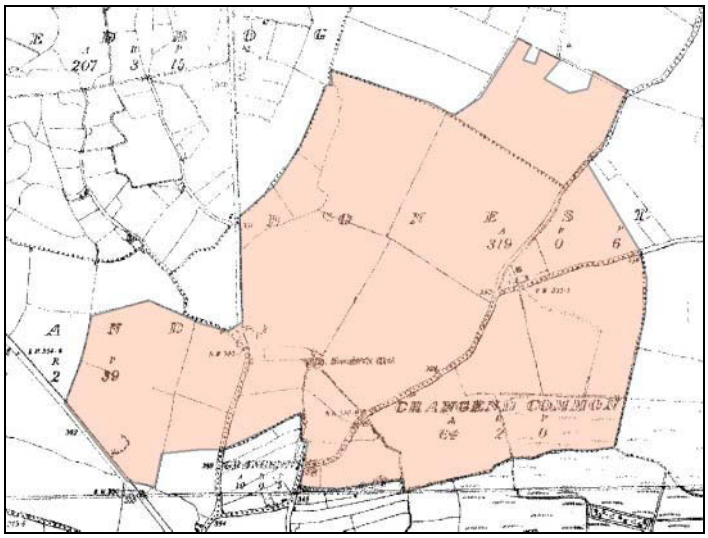
Site Importance
The site is a large scale enclosed limestone depression, now infilled with silica deposits, of similar magnitude to the Carran Depression in Clare, and although it is not actually exposed, it certainly merits recognition as a County Geological Site.

Management/promotion issues
This site is only known through geophysical surveys and from a limited drilling programme. There are no management issues. However, any planned developments that include ground investigations or excavations may provide a much more complete understanding of the deposit and GSI should be notified of any such works at the earliest stage. Such works may include a proposed railway line extension.

Above: Approximate limits of the infilled depression at Dunshaughlin.

Dunshaughlin





MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**Boyne River, Trim**		
Other names used for site			
IGH THEME:	IGH14 (Fluvial/Lacustrine Geomorphology)		
TOWNLAND(S)	Numerous		
NEAREST TOWN	Trim		
SIX INCH MAP NUMBER	31, 36, 37		
NATIONAL GRID REFERENCE	284350 258560 = N 8435 5856		
1:50,000 O.S. SHEET NUMBER	42	**1/2 inch Sheet No.**	13

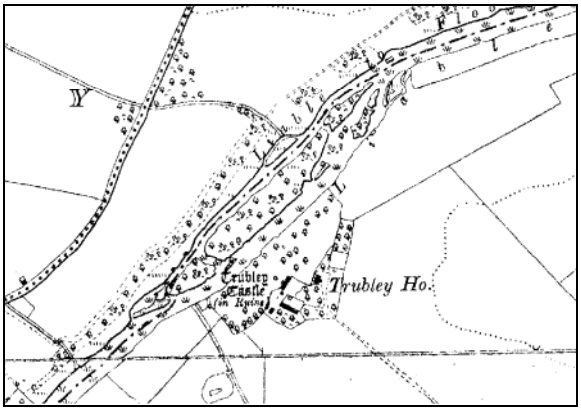
Outline Site Description
A section of the Boyne River.

Geological System/Age and Primary Rock Type
River with anastomosing (distributary) channels.

Main Geological or Geomorphological Interest
Along a 5.5km stretch of the Boyne River, just east of Trim are a number of sub-parallel distributaries known as anastomosing channels. These channels separate from the main river and may flow parallel to it for several kilometres before rejoining it. In the case of this site the anastomosing channels only run for a couple of hundred meters at any one time. These channels tend to form in areas of low relief with shallow gradients and generally have thick clay and silt banks.

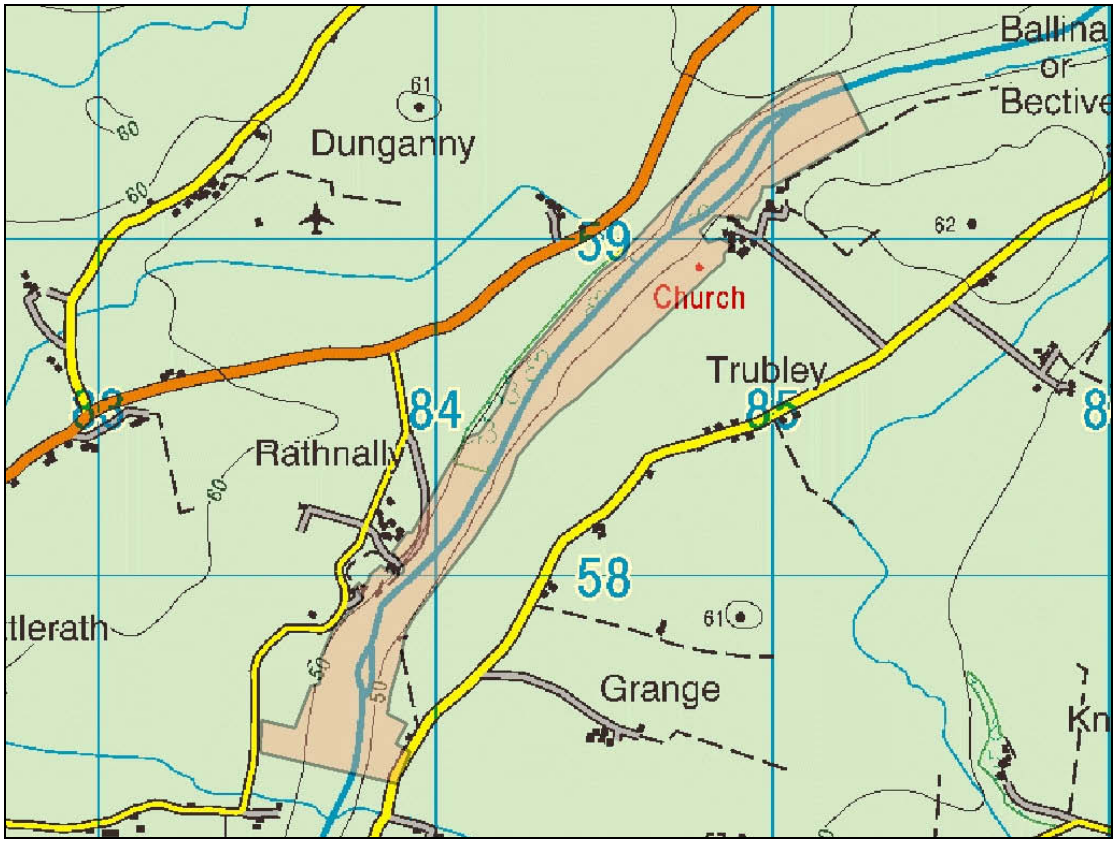
Site Importance
This is one of the few examples of an anastomosing channel system in Meath and is therefore recommended as a County Geological Site. Anastomosing channels are not common nationally.

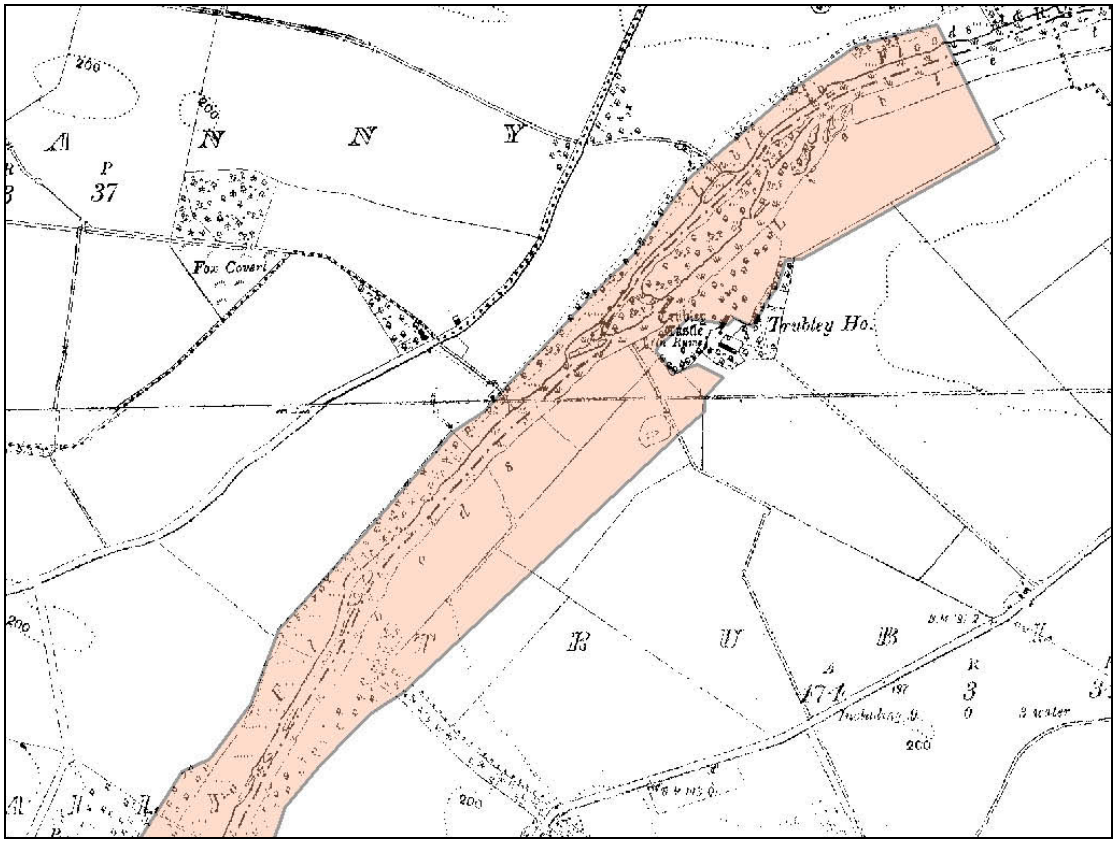
Management/promotion issues
Although these channels can be accessed in some areas, the feature is not readily recognisable from the ground. The use of aerial photography and the old six inch maps are probably the best way to distinguish these features.



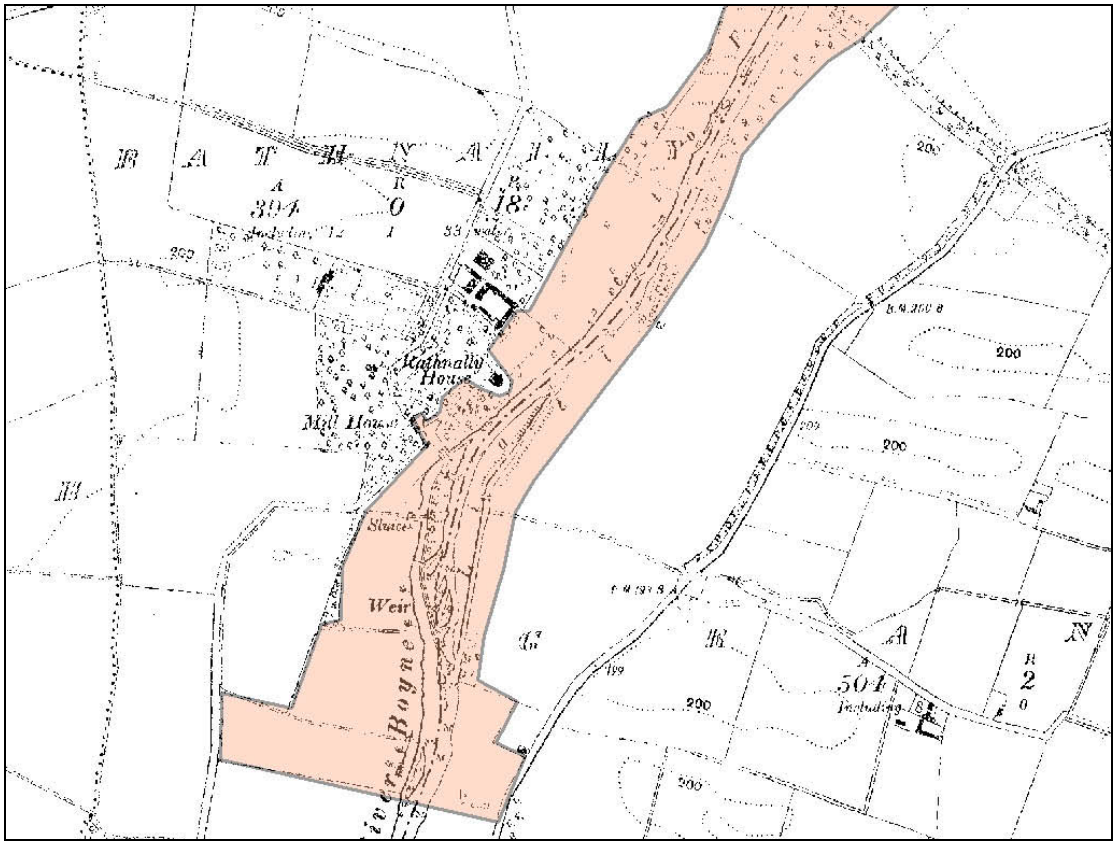
Above: Six inch base map and aerial photograph of a representative section of the River Boyne, displaying anastomosing channels.

Boyne River, Trim





Boyne River, Trim



MEATH - COUNTY GEOLOGICAL SITE REPORT

NAME OF SITE	**St. Gorman's Spring**		
Other names used for site	St. Gorman's Well, Hotwell House		
IGH THEME:	IGH 16 (Hydrogeology)		
TOWNLAND(S)	Ballynakill		
NEAREST TOWN	Summerhill		
SIX INCH MAP NUMBER	48		
NATIONAL GRID REFERENCE	274080 244200 = N 7408 4420		
1:50,000 O.S. SHEET NUMBER	49	**1/2 inch Sheet No.**	13

Outline Site Description
Warm spring.

Geological System/Age and Primary Rock Type
Lower Carboniferous (Waulsortian) limestone.

Main Geological or Geomorphological Interest
This warm spring found northwest of Enfield reportedly covers an area of approximately 40m^2 during periods of high discharge. Temperatures vary between 12° and 25° depending on climate conditions and seasonal variations. The spring occasionally overflows into an adjacent swamped area from where it is channelled into a local ditch drainage network. The substratum is primarily composed of large limestone fragments and gravel. St. Gorman's Spring is described as being seasonal, completely drying up towards the end of the summer.

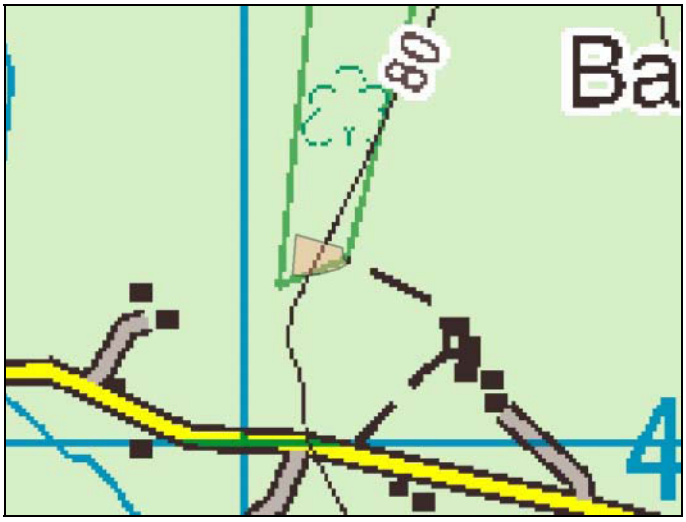
Site Importance
This spring is a very important example of the warm spring province of the Kildare-Meath border area in northwest Leinster. As it is one of the highest temperature warm springs, well studied and the least disturbed in the Leinster province, and probably in the whole of Ireland, it is to be proposed as an NHA. It should also be listed as a County Geological Site in Meath.

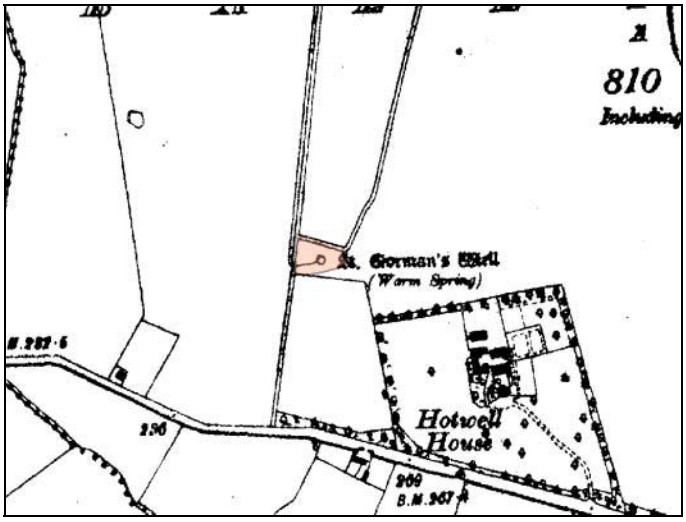
Management/promotion issues
The spring lies within the grounds of the aptly named Hotwell House. As this site is on private land it is not suitable for general promotion without first contacting the owner.

Left: A view of St. Gorman's Spring, taken in February.
Right: Steam rising from St. Gorman's Spring. This is generated by the geothermal processes that heat the water to as much as 25°. Photo taken in February.

Photos by Percy Foster

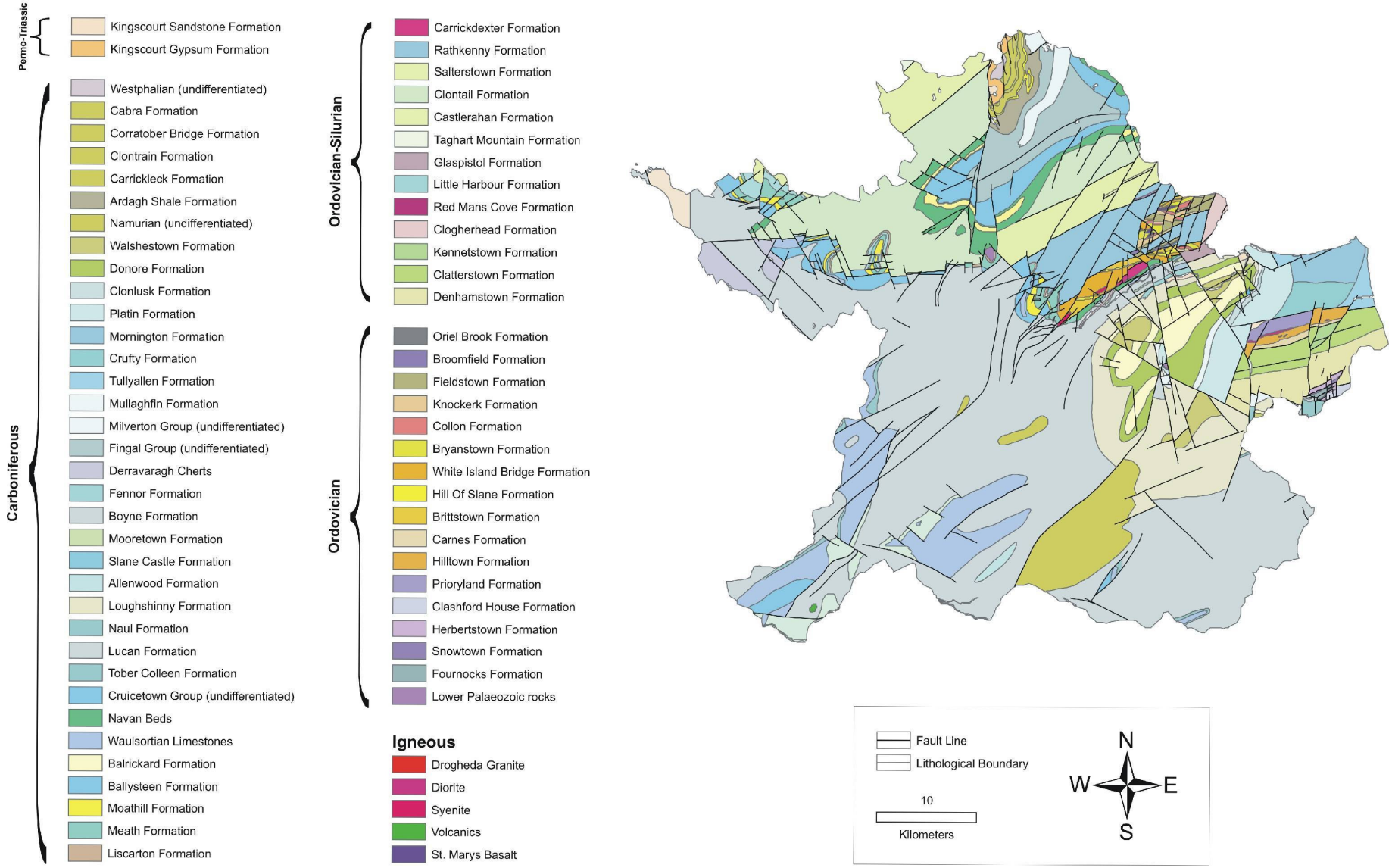
St. Gorman's Spring





Appendix 1

Detailed Geological Map of County Meath



Appendix 2 – Bibliography – Geology of County Meath

This bibliography is quite comprehensive, but is certainly not claimed to be definitive. Any additional references (and preferably a copy of the publication) relating to the geology, geomorphology or hydrogeology of County Meath will be welcomed by the Heritage Officer.

AALEN, F.H.A., WHELAN, K. and STOUT, M. (eds) 1997. *Atlas of the Irish rural landscape.* Cork University Press, Cork.

ALLEN, R.M. 1991. *The Geochemical and Structural Development of the Ordovician inliers of Ireland*. Unpublished Ph.D. Thesis, University of Dublin.

ANDERSON, I.K., ASHTON, J.H., BOYCE, A.J., FALLICK, A.E. and RUSSELL, M.J. 1998. Ore depositional processes in the Navan Zn–Pb deposit, Ireland. *Economic Geology* 93, 535–563.

ANDREW, C.J. and POUSTIE, A. 1986. Syndiagenetic or epigenetic mineralization–the evidence from the Tatestown zinc–lead prospect, Co. Meath. In: *Geology and Genesis of Mineral Deposits in Ireland* (eds C.J. Andrew, R.W.A. Crowe, S. Finlay, W.M. Pennell & J.F. Pyne). Irish Association for Economic Geology. Dublin. 281–296.

ASHTON, J.W., BLACK, A., GERAGHTY, J. HOLDSTOCK, M. and HYLAND, E. 1992. The geological setting and metal distribution patterns of Zn–Pb–Fe mineralization in the Navan Boulder Conglomerate. In: *The Irish Minerals Industry 1980–1990* (eds A.A. Bowden, G. Earls, P.G. O'Connor & J.F. Pyne). Irish Association for Economic Geology. Dublin. 171–210.

ASHTON, J.W., DOWNING, D.T. and FINLAY, S. 1986. The geology of the Navan Zn–Pb orebody. In: *Geology and Genesis of Mineral Deposits in Ireland* (eds C.J. Andrew, R.W.A. Crowe, S. Finlay, W.M. Pennell & J.F. Pyne). Irish Association for Economic Geology. Dublin. 243–280.

ASHTON, J.H., HOLDSTOCK, M., GERAGHTY, J.F.G., O'KEEFE, W.G.O., MARTINEZ, N., PEACE, W. & PHILCOX, M.E. 2000. The Navan Orebody-Discovery and geology of the South-west Extension. *Europe's Major Base Metal Deposits AbstractVolume.* IAEG Conference, Galway May 2000.

BRAITHWAITE, C.J.R. and RIZZI, G. 1997. The geometry and petrogenesis of hydrothermal dolomites at Navan, Ireland. *Sedimentology* 44, 421–440.

BRAND, S.F. and EMO, G.T. 1986. A note on Zn–Pb–Ba mineralization near Oldcastle, County Meath. In: *Geology and Genesis of Mineral Deposits in Ireland* (eds C.J. Andrew, R.W.A. Crowe, S. Finlay, W.M. Pennell & J.F. Pyne). Irish Association for Economic Geology. Dublin. 297–304.

BURNS, V. and RICKARDS, R. B. 1993. Silurian graptolite faunas of the Balbriggan Inlier, counties Dublin and Meath, and their evolutionary, stratigraphical and structural significance. *Proceedings of the Yorkshire Geological Society* 49, 283–291.

CARR, S.J. and MEEHAN, R.T. Glaciotectonised sediments at Mullaghmore, County Meath, Ireland: evidence of a large-scale readvance during ice sheet deglaciation? Quaternary Newsletter, No. 95, October 2001, pp. 23-26.

CLAYTON, G. and HIGGS, K. 1979. The Tournaisian marine transgression in Ireland. *Irish Journal of Earth Sciences* 2, 1–10.

CLARINGBOLD, K., FLEGG, A., MAGEE, R. and VONHOF, J. 1994. The Directory of Active Quarries, Pits and Mines. Geological Survey of Ireland Report Series 94/4.

CLARKE, C.D. and MEEHAN, R.T. 2001. Subglacial bedform geomorphology of the Irish Ice Sheet reveals major configuration changes during growth and decay. *Journal of Quaternary Science*, Vol. 16, Issue 5, pp. 483-496.

CLARKE, C.D. MEEHAN, R.T., HATTERSTRAND, C., CARLING, P., EVANS, D. And MITCHELL, W., 2001. Palaeoglaciological investigations exploiting remote sensing, elevation models and GIS. *Slovak Geological Magazine*. 7(3), 313.

COLE, G.A.J. 1922. *Memoir and Map of Localities of Minerals of Economic Importance and Metalliferous Mines in Ireland*. Geological Survey of Ireland. 155 pages.

DU NOYER, G.V. 1875. *Explanatory Memoir to accompany sheets 102 and 112 of the maps of the GeologicalSurvey of Ireland, illustrating part of the Counties of Dublin and Meath*. Geological Survey of Ireland. 70 pages.

EBDON, C.C., FRASER, A.J., HIGGINS, A.C., MITCHENER, B.C. and STRANK, A.R.E. 1990. The Dinantian stratigraphy of the East Midlands: a seismostratigraphic approach. *Journal of the Geological Society of London* 147, 519–536.

EXPLORATION AND MINING DIVISION 1999. *The "Top 55" Deposits*. Exploration and Mining Division Ireland Publication MP 3/99. 14 pages. FLEGG, A. 1987. *Industrial Minerals In Ireland; Their Geological Setting*. Geological Survey of Ireland Report Series 87/3. 27 pages.

FORD, C.V. 1996. *The integration of petrologic and isotopic data from the Boulder Conglomerate to determine the age of the Navan orebody, Ireland*. Unpublished Ph.D. thesis, University of Glasgow.

FORTEY, R.A., HARPER, D.A.T., INGHAM, J.K., OWEN, A.W. and RUSHTON, A.W.A. 1995. A revision of Ordovician series and stages from the historical type area. *Geological Magazine* 132, 15–30.

GARDINER, P.R.R. and McARDLE, P. 1992. The geological setting of Permian gypsum and anhydrite deposits in the Kingscourt district, Counties Cavan, Meath and Monaghan. In: *The Irish Minerals Industry 1980–1990* (eds A.A. Bowden, G. Earls, P.G. O'Connor & J.F. Pyne). Irish Association for Economic Geology. Dublin. 301–316.

GARDINER, P.R.R. and VISSCHER, H. 1971. Permian—Triassic transition sequence at Kingscourt, Ireland. *Nature Physical Science* 229, 209–210.

GRIFFITH, R. 1828. *Report on the metallic mines of the Province of Leinster, in Ireland*. Royal Dublin Society. 29 pages.

GRIFFITH, R.J. 1861. Catalogue of the several localities in Ireland where mines or metalliferous indications have hitherto been discovered. *Journal of the Geological Society of Dublin* 9, 140–155.

HARPER, D.A.T., MITCHEL, W.I., OWEN, A.W. and ROMANO, M. 1985. Upper Ordovician braciopods and trilobites from the Clashford House Formation near Herbertstown, Co. Meath, Ireland. *Bulletin of the British Museum Natural History (Geology)* 38, 287–308.

HARPER, D.A.T. PARKES, M.A., HOEY, A.N. and MURPHY, F.C. 1990. Intra-Iapetus brachiopods from the Ordovician of eastern Ireland: implications for Caledonide correlation. *Canadian Journal of Earth Sciences* 27, 1757–1761.

HARPER, J.C. 1952. The Ordovician rocks between Collon (Co. Louth) and Grangegeeth (Co. Meath). *Scientific Proceedings of the Royal Dublin Society* 26, 85–112.

HARPER, J.C. and RAST, N. 1964. The fanual succession and volcanic rocks of the Ordovician near Bellewstown, Co. Meath. *Proceedings of the Royal Irish Academy* B64, 1–23.

HARRISON, J. 1968. *Stratigraphy of Namurian Outliers adjacent to the Ballbriggan Massif, counties Dublin and Meath.* Unpublished M.Sc. Thesis, University of Dublin.

HITZMAN, M.W. 1992. *Bedrock Geology Map of the Carboniferous of Central Ireland. Sheet 13, 1:100,000 scale.* Geological Survey of Ireland.

HOWES, M.J. 1991. *Mineral Resources of County Meath*. Unpublished GSI Report.

HUNT, R. 1848. Sales of Irish copper ore from 1804 to 1847. *Memoir of the Geological Survey of Great Britain* 2, 713.

JACKSON, J.S. 1955*. The Carboniferous succession of the Kingscourt Outlier with notes on the Permo-Trias*. Unpublished PhD thesis, University of Dublin.

KENNAN, P. S. and MURPHY, F. C. 1993. Coticule in Lower Ordovician metasediments near the hidden Kentstown Granite, County Meath: a petrographic study. *Irish Journal of Earth Sciences* 12, 41–46.

LENZ, A. C. and VAUGHAN, A. P. M. 1994. A Late Ordovician to middle Wenlockian graptolite sequence from a borehole within the Rathkenny Tract, eastern Ireland and its relation to the palaeogeography of the Iapetus Ocean. *Canadian Journal of Earth Sciences* 31, 608–616.

MANISTRE, B. E. 1952. The Ordovician volcanic rocks between Collon (Co. Louth) and Grangegeeth (Co. Meath). *Scientific Proceedings of the Royal Dublin Society* 26, 113–128.

McCONNELL, B. 2000. The Ordovician Volcanic Arc and Marginal Basin of Leinster. *Irish Journal of Earth Sciences* 18, 41-49.

McCONNELL, B., PHILCOX, M, E. and GERAGHTY, M. 2001. *Geology Of Meath. A Geological Description To Accompany The Bedrock Geology 1:100,000 Scale Map Sheet 13, Meath.* Geological Survey of Ireland.

McKEE, K. 1976. *The geology of the Lower Palaeozoic rocks around Bellewstown, Co. Meath, Eire.* Unpublished M.Sc. Thesis, National University of Ireland.

McNESTRY, A. and REES, J.G. 1992. Environments and palynofacies of a Dinantian (Carboniferous) littoral sequence: the basal part of the Navan Group, Navan, County Meath, Ireland. *Palaeogeography, Palaeoclimatology, Palaeoecology* 96, 175–193.

MEEHAN, R.T. 1995. A new approach to Groundwater Protection Schemes in Ireland, incorporating detailed Quaternary Mapping as a basis for Vulnerability Ratings. Proceedings of the Royal Irish Academy, 95B, pp.140-141. Explains the approach to Quaternary Mapping for Meath Groundwater Protection Schemes.

MEEHAN, R.T. 1995. Quaternary Mapping in County Meath as a basis for Groundwater Vulnerability Ratings, "*Baile*": *Journal of the UCD Geography Society*, April 1995, pp. 51-54.

MEEHAN, R.T., 1999. Directions of ice flow during the last glaciation in counties Meath, Westmeath and Cavan, Ireland. *Irish Geography*, 32(1), pp.26-51. *Geographical Society of Ireland, Dublin*.

MEEHAN, R.T., 2000. Kells and adjacent areas, County Meath Ireland. *Glacial Landsystems Working Group Field Guide, Teagasc, Dublin, 70pp.*

MEEHAN, R.T., 2000. Evidence for several ice marginal positions in east central Ireland, and their relationship to the Drumlin Readvance Theory. In Ehlers, J. (Editor) "Extent and Chronology of Worldwide Glaciation", INQUA Commission on Glaciation, Work Group 5, Special Publication, 6pp.

MEEHAN, R.T. 2006. A regional glacial readvance in Ireland: self-promulgating theory, or science-based reality? In Knight, P.G., Glacier Science and Environmental Change. *Blackwell Scientific Publishing, pp. 264-266*.

MEEHAN, R.T. and WARREN, W.P. 1999. *The Boyne Valley in the Ice Age: A field guide to some of the valley's most important glacial geological features*. Meath County Council and the Geological Survey of Ireland. 84 pages.

MEEHAN, R.T., WARREN W. P. and GALLAGHER, C.J.D. 1997. The sedimentology of a late Pleistocene drumlin near Kingscourt, Ireland. Paper presented to 'Drumlin Symposium' at the XIV INQUA Congress, Berlin, 7 August 1995. *Sedimentary Geology*, 111, pp. 91-105. *Elsevier Scientific Publishers, Amsterdam*.

MURPHY, F.C. 1984a. *The Lower Palaeozoic stratigraphy and structural geology of the Balbriggan Inlier, Counties Meath and Dublin.* Unpublished Ph.D. thesis, University of Dublin.

NEVILL, W.E. 1957. The geology of the Summerhill Basin, Co. Meath, Ireland. *Proceedings of the Royal Irish Academy* 58B, 293–303.

O'REILLY, C., FEELY, M., HOLDSTOCK, M.P. and O'KEEFE, W.G. 1997. Fluid inclusion study of the unexposed Kentstown Granite, Co. Meath, Ireland. *Transactions of the Institution of Mining and Metallurgy* B107, 31– 37.

OWEN, A. W., HARPER, D. A. T., and ROMANO, M. 1992. The Ordovician biogeography of the Grangegeeth terrane and the Iapetus suture zone in eastern Ireland. *Journal of the Geological Society, London* 149, 3–6.

PARKES, M.A. 1992. Caradoc brachiopods from the Leinster terrane (S.E. Ireland) - a lost piece of the Iapetus puzzle? *Terra Nova* 4, 223–230.

PICKARD, N.A.H., JONES, G.Ll, REES, J.G., SOMERVILLE, I.D. and STROGEN, P. 1992. Lower Carboniferous (Dinantian) stratigraphy and structure of the Walterstown–Kentstown area, Co. Meath. *Geological Journal* 27, 35–58.

PRESTON, J. 1981. Tertiary Igneous Activity. In: *A Geology of Ireland* (ed. C.H. Holland). Scottish Academic Press. 213–224.

REES, J.R. 1987. *The Carboniferous Geology of the Boyne Valley area, Ireland*. Unpublished Ph.D. Thesis, University of Dublin.

REES, J.G. 1992 The Courceyan (Lower Carboniferous) succession at Slane, County Meath. *Irish Journal of nEarth Sciences* 11, 113–129.

ROMANO, M. 1980a. The stratigraphy of the Ordovician rocks between Slane (Co. Meath) and Collon (Co. Louth), Ireland. *Journal of Earth Sciences, Royal Dublin Society* 3, 53–79.

ROMANO, M. 1980b. The Ordovician rocks around Herbertstown (Co. Meath) and their correlation with the succession at Balbriggan (Co. Dublin), Ireland. *Journal of Earth Science, Royal Dublin Society* 3, 205–215.

RUSSELL, M.J. 1986. Extension and convection: a genetic model for the Irish Carboniferous base metal and barite deposits. In: *Geology and Genesis of Mineral Deposits in Ireland* (eds. C.J. Andrew, R.W.A. Crowe, S.

SOMERVILLE, I.D., STROGEN, P., JONES, G.Ll. & SOMERVILLE, H.E.A. 1996b. Late Viséan buildups at Kingscourt, Ireland: possible precursors for Upper Carboniferous bioherms. In: *Recent advances in Lower Carboniferous geology* (eds Strogen, P., Somerville, I.D. and Jones, G.Ll.). Geological Society of London, Special Publication 107, 127–144.

SOMERVILLE, I.D., STROGEN, P. and SOMERVILLE, Anne. 1997. Upper Viséan platform carbonates and buildups in the Kingscourt Outlier, Ireland. *Proceedings of the 13th International Congress on the Carboniferous & Permian* 1997, 143–152.

STOUT, G. 2002. *Newgrange and the Bend of the Boyne*. Irish Rural Landscapes: Volume 1, Cork University Press, Cork.

STROGEN, P., JONES, G.Ll, and SOMERVILLE, I.D. 1990. Stratigraphy and sedimentology of Lower Carboniferous (Dinantian) boreholes from west Co. Meath Ireland. *Geological Journal* 25, 103–137.

STROGEN, P., SOMERVILLE, I.D., PICKARD N.A.H. and JONES, G.Ll. 1995. Lower Carboniferous (Dinantian) stratigraphy and structure in the Kingscourt Outlier, Ireland. *Geological Journal* 30, 1–23.

VAUGHAN, A. P. M. 1991. *The Lower Palaeozoic geology of the Iapetus Suture Zone in eastern Ireland*. Unpublished Ph.D. thesis, University of Dublin.

VAUGHAN, A. P. M. and JOHNSTON, D. 1992. Structural constraints on closure geometry across the Iapetus suture in eastern Ireland. *Journal of the Geological Society, London* 149, 65–74.

VISSCHER, H. 1971. *The Permian and Triassic of the Kingscourt Outlier, Ireland*. Geological Survey of Ireland Special Paper 1. 114 pages.

WILKINSON, G. 1845. *Practical Geology and Ancient Architecture of Ireland*. John Murray, London.

WOODS, L., MEEHAN, R. and WRIGHT, G.R. 1998. *Meath County Council: Groundwater Protection Scheme*. Geological Survey of Ireland and Meath County Council.

YOUNG, D.G.G. 1976. A geophysical interpretation of the structural development of the Kingscourt graben. *Proceedings of the Royal Irish Academy* 76B,43–52.