The Geological Heritage of County Laois

An audit of County Geological Sites in County Laois

by Matthew Parkes Ronan Hennessy, Robert Meehan, Vincent Gallagher and Sarah Gatley

2016

The County Laois Geological Heritage Project was supported by

An Chomhairle Oidhreachta
The Heritage Council

Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Laois County Council
Áras an Chontae, Portlaoise, Co Laois

This report is an action of the County Laois Heritage Plan 2014 – 2019

For the:
Geoheritage Programme
Geological Survey Ireland
Beggars Bush
Haddington Road
Dublin 4
01-6782837

and

Catherine Casey
Heritage Officer
Laois County Council
Aras an Chontae
Portlaoise
Co. Laois
tel. 057 866 4129
email. ccasey@laoiscoco.ie

Contents

Section 1 – Main Report

Section 2 – Site Reports

Site reports – general points

Abbeyleix Bog
Arless Quarry
Ballyadams Quarry
Baunreagh Quarry
Carroll's Quarry
Castlecomer Borehole – Swan
Clogh River
Clonaslee Eskers
Clopook Cave
Darkin Well
Farnans Quarry
Flemings Fireclay Quarries
Glebe Quarry
Glenbarrow
Hollymount
Killeany Quarry
Killeshin Glen
Kyle Spring
Lisduff Quarry
Luggacurren Fireclay Pit
Luggacurren Stream Section
M7 Road Cut Derryvorrigan
M8 Road Cut Addergoole
Modubeagh
Moyadd Stream
Old Rossmore
Poulastore
Rathleague Spring
Ridge of Portlaoise
Rock of Cashel
Rock of Dunamase
Sluggory Cross Roads
Timahoe Esker

Executive Summary

County Laois is not widely known for its geological heritage. However, it has some fine but underappreciated geological sites. This report documents what are currently understood by the Irish Geological Heritage Programme (IGH) of the Geological Survey of Ireland (GSI) to be the most important geological sites within County Laois. It documents them as County Geological Sites (CGS), for inclusion within the County Development Plan (CDP). This audit provides a detailed study of sites to replace a provisional listing based on desk study which was adopted in the current 2011-2017 CDP, along with strong policies to protect it and enhance access where feasible.

Some 33 County Geological Sites are documented, including photographs and site boundary maps that delimit the extent of the geological heritage interest. Additional data in GIS format are supplied to the County Council to complement the report. The commission of this audit places County Laois at the current focus of geological conservation in Ireland.
This report is written in non-technical language for use by the Heritage Officer and the Planning department of Laois County Council. A chapter of the report includes recommendations on how to best present and promote the geological heritage of County Laois to the people of the county. It will also inform the work of the IGH Programme and be made available through the GSI website.

1. Laois in the context of Irish Geological Heritage

This report ensures County Laois remains active at the forefront of geological heritage within Ireland, as a majority of counties have now commissioned such an audit within the scope of the county-based Heritage Plan. By providing reliable data in a very cost-effective manner, it will hopefully encourage the remaining local authorities to follow what is now a tried and trusted methodology. In the absence of significant political and economic resources available at a national level to the relevant bodies for conservation of geological heritage as Natural Heritage Areas (NHA), it represents a significant level of progress in defining and safeguarding Ireland's geological heritage. In essence, County Geological Site audits are the only effective geological conservation at present, but only with advisory capacity (within the context of County Development Plans) and no real statutory protection where it is required.

It also 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 Heritage Act 1995, the Planning and Development Act 2000, Planning and Development Regulations 2001, and the Wildlife (Amendment) Act 2000 and the National Heritage Plan 2002. GSI views partnerships with the local authorities, exemplified by this report, as a very important element of its strategy on geological heritage (see Appendix 1).

The Irish Geological Heritage Programme (IGH) in GSI complements other nature conservation efforts of the last decade, by assessing Ireland's geodiversity. Geodiversity is the foundation of the biodiversity addressed under European Directives on habitats and species by the designations of Special Areas of Conservation (SAC) and more recently on a national scale by the introduction of Natural Heritage Areas (NHA) as the national nature conservation method. As a targeted conservation measure to protect the very best of Irish geology and geomorphology the IGH Programme fills a void which has existed since the abandonment of the Areas of Scientific Interest scheme, listed by An Foras Forbartha in 1981.

The IGH Programme does this by identifying and selecting the most important geological sites nationally for designation as NHAs. It looks at the entire spectrum within Irish geology and geomorphology under 16 different 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

A fundamental approach is that only the minimum number of sites necessary to demonstrate the particular geological theme is selected. This means that the first criterion is to identify the best national representative example of each feature or major sequence, and the second is to identify any unique or exceptional sites. The third criterion, identifying any sites of International importance, is nearly always covered by the other two.

Designation of geological NHAs will be by the GSI's partners in the Programme, the National Parks and Wildlife Service (NPWS). Once designated, any geological NHAs will be subject to normal statutory process within the County Laois Planning Department and other relevant divisions. **However, compared to many ecological sites, management issues for geological sites are generally fewer and somewhat different in nature. The subsequent section considers these issues**.

From a national perspective, as a result of extensive comparison of similar sites to establish the best among them, there is now a good knowledge of many other sites, which are not the chosen best example, but which may still be of national importance. Others may be of more local importance or of particular value as educational sites or as a public amenity. All these various important sites are proposed for County Geological Site (CGS) listing in the County Development Plan.

Currently, in 2016, a Master List of candidate CGS and NHA sites is being used in GSI, originally compiled with the help of Expert Panels for all the 16 IGH themes. For several themes, the entire process has been largely completed and detailed site reports and boundary surveys have been done along with a Theme Report. Due to various factors, none have yet been formally designated. In County Laois, no sites have been so far considered to be of national importance nor been put forward as a Natural Heritage Area (NHA). Therefore, inclusion of all sites as County Geological Sites (CGS) in County Laois's planning system will ensure that they are not inadvertently damaged or destroyed through lack of awareness of them outside of the IGH Programme in GSI.

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, or directly promoted by the Council itself, or by local communities wishing to draw attention to important sites for amenity or education with an intrinsic geological interest. New excavations, such as major road cuttings or new quarries, can themselves be significant and potential additions to this selection.

It was not possible within the scope of this study to identify landowners except in a few sites, but it is emphasised that CGS listing here is not a statutory designation, and carries no specific implications or responsibilities for landowners. It is primarily a planning tool, designed to record the scientific importance of specific features, and to provide awareness of them in any consultation or decision on any proposed development that might affect them. It thus also has an educational role for the wider public in raising awareness of this often undervalued component of our shared natural heritage.

1.1 Laois County Geological Sites

Site Name	Designation	IGH Primary	IGH Secondary	IGH Third	GIS Code
Abbeyleix Bog	County Geological Site	IGH7	IGH16		LS001
Arless Quarry	County Geological Site	IGH8			LS002
Ballyadams Quarry	County Geological Site	IGH8			LS003
Baunreagh Quarry	County Geological Site	IGH4			LS004
Carroll's Quarry	County Geological Site	IGH8			LS005
Castlecomer Borehole – Swan	County Geological Site	IGH16			LS006
Clogh River	County Geological Site	IGH14			LS007
Clonaslee Eskers	County Geological Site	IGH7			LS008
Clopook Cave	County Geological Site	IGH1			LS009
Darkin Well	County Geological Site	IGH1	IGH16		LS010
Farnans Quarry	County Geological Site; may be recommended for Geological NHA	IGH9	IGH15		LS011
Flemings Fireclay Quarries	County Geological Site; may be recommended for Geological NHA	IGH9			LS012
Glebe Quarry	County Geological Site	IGH10	IGH15		LS013
Glenbarrow	County Geological Site	IGH10	IGH7	IGH14	LS014
Hollymount	County Geological Site; may be recommended for Geological NHA	IGH3	IGH12		LS015
Killeany Quarry	County Geological Site	IGH8			LS016
Killeshin Glen	County Geological Site; may be recommended for Geological NHA	IGH3	IGH9		LS017
Kyle Spring	County Geological Site	IGH16			LS018
Lisduff Quarry	County Geological Site	IGH8			LS019
Luggacurren Fireclay Pit	County Geological Site	IGH9			LS020
Luggacurren Stream Section	County Geological Site; may be recommended for Geological NHA	IGH3	IGH9		LS021
M7 Road Cut Derryvorrigan	County Geological Site	IGH8			LS022
M8 Road Cut Addergoogle	County Geological Site	IGH8			LS023
Modubeagh	County Geological Site	IGH16	IGH15		LS024
Moyadd Stream	County Geological Site; may be recommended for Geological NHA	IGH9			LS025
Old Rossmore	County Geological Site; recommended for Geological NHA	IGH6	IGH9	IGH15	LS026
Poulastore	County Geological Site	IGH1			LS027
Rathleague Spring	County Geological Site	IGH16			LS028
Ridge of Portlaoise	County Geological Site	IGH7			LS029
Rock of Cashel	County Geological Site	IGH3	IGH8		LS030
Rock of Dunamase	County Geological Site	IGH1	IGH8	IGH12	LS031
Sluggory Cross Roads	County Geological Site	IGH1	IGH16		LS032
Timahoe Esker	County Geological Site	IGH7			LS033

1.2 Rejected sites

A range of sites had been previously flagged for consideration in the IGH Master site list, and included in the earlier County Development Plan, and some were assessed as unsuitable for County Geological Site status in this audit. Similarly a range of additional and new sites were assessed in the audit, based on new knowledge of County Laois's geology, and especially for Quaternary landscape sites and karst sites. Other sites were visited on spec during fieldwork. The rejected sites are listed below with brief notes as to why they were assessed as unsuitable for inclusion.

Boley Pit
This site is listed on the Geological Survey of Ireland Active Quarries Directory of 2014. Located at Boley, west of Abbeyleix, the sand and gravel pit is still active today, but has little exposure and much backfilled area. Given the lack of good sections and any representative sedimentology, the site was rejected for inclusion as a County Geological Site.

Figure 1. Boley Pit

Killeany Pit II
This site was surveyed in the field following its discovery as a large pit, on the aerial photographs of the River Barrow valley in the east of County Laois. The site is not listed on the Geological Survey of Ireland Active Quarries Directory of 2014.

Located at Killeany, between Ballybrittas and Vicarstown, the sand and gravel pit is no longer active, though it was a considerable operation in the past. The pit is being backfilled and has no extant faces left. Owing to this lack of good sections and any representative sedimentology, the site is rejected for inclusion as a County Geological Site.

Figure 2. Killeany Pit II

Biddy Aghaboe's Well

This well is located at the grid reference given (in error) for the Darken Well in the Irish Geological Heritage Master Site List. The well, though present, has been covered by a railway bridge and is therefore no longer visible, though a plaque erected by CIE when the bridge was constructed records the well location.

The site is an important one in the folklore of Portlaoise, as Biddy Aghaboe, who found the well as she walked the road out of the town towards Mountrath, is supposed to have saved the town from drought with the well's discovery.

Figure 3. Biddy Aghaboe's Well

Right: Sketch of the legend of Biddy Aghaboe's Well. From 'Laois Folk Tales' by Nuala Hayes, The History Press, 2015.

River Barrow, Athy to Carlow

This stretch of the River Barrow, along the Laois county boundary between Athy and Carlow Town, was included in the IGH Master Site List, as a good example of 'glaciofluvial inheritance'. The landscape here is quite subdued though, with no well-defined glaciofluvial terraces occurring, or any other distinctive glaciofluvial features. With no exposure either, the locality seems like a subdued expression of potential glaciofluvial gravels, rather than a definitive landform sequence. On this basis the site is rejected.

Figure 4. River Barrow, Athy to Carlow

New Rossmore

This is the site of an underground coal mine developed in the 1970s and 1980s. Like Old Rossmore, 1 km to the southeast, the mine exploited the No. 2 or Marine Band seam. The site covers some 2.5 ha and contains some derelict buildings and processing plant, including the remains of a large shed and conveyor. The excavation on the western part of the site has no exposure of coal and appears to have been quarried for sandstone. None of the features observed on the site have extant geological heritage interest and therefore New Rossmore is rejected as a County Geological Site.

Figure 5. New Rossmore

Ross Flagstone Quarry

This site is one of two quarries where Clonaslee Flagstones are seemingly being extracted, at least on a sporadic basis. However, detailed examination of the quarried area shows extensive amounts of disturbed ground, and rock piles, but only one small face of exposed rock where it is possible to examine the gross characteristics of the Clonaslee Member of the Cadamstown Formation. The lack of actual exposure and interest here means that it does not qualify as a County Geological Site.

Figure 6. Ross Flagstone Quarry

Trooper's Quarry

This site has two very small old flagstone quarries. The named quarry on Ordnance Survey maps is very small, perhaps only about 10m long and 2-3m wide. It is totally overgrown, very shallow and displays no geology. A slightly larger quarry close by, without a name, at the end of the vehicular track which is the access road to a house, does have a small face exposed. This is partly because some recent extraction (the subject of legal dispute) has left a few metres of rock visible, with flags on top of thicker sandstone beds. However, neither quarry is significant enough to consider as a County Geological Site.

Figure 7. Trooper's Quarry

2. Laois Council Policies regarding geological heritage

It is worth drawing attention to the excellent treatment of geological heritage in the Laois County Development Plan, which could be a model for any local authority to follow. The policy section on Designated Areas, clearly recognises the underlying geodiversity foundation of many biodiversity designations and incorporates it in a more holistic way than is frequently encountered in such Plans.

The specific section on geology is a concise statement of all essentials that could be aspired to in regard to geological heritage within a County Council. The completion of this geological heritage audit will ensure that the largely desk-based study and listing of County Geological Sites (CGS) is superseded in the new Draft County Development Plan 2017-2023 by a robust selection of sites that are important in County Laois. Whilst some are candidates for NHA designation in the future if the geological NHAs ever become a reality, new CGS that are purely of local importance have been added. Equally some sites have been rejected after proper field auditing.

It is the policy of the Council to:

NH9 No projects giving rise to significant cumulative, direct, indirect or secondary impacts on Natura 2000 sites arising from their size or scale, land take, proximity, resource requirements, emissions (disposal to land, water or air), transportation requirements, duration of construction, operation, decommissioning or from any other effects shall be permitted on the basis of this plan (either individually or in combination with other plans or projects[6]).

NH10 Assess, in accordance with the relevant legislation, all proposed developments which are likely to have a significant effect (directly or through indirect or cumulative impact) on designated natural heritage sites, sites proposed for designation and protected species;

NH11 Protect Natural Heritage Areas (NHA) from developments that would adversely affect their special interests;

NH 12 Recognise and protect the significant geological value of sites in County Laois and safeguard these sites, in consultation with the Geological Survey of Ireland and in accordance with the National Heritage Plan and “Geological Heritage Guidelines for the Extractive Industry”;

NH 13 Support and co-operate with statutory authorities and others in support of measures taken to manage designated nature conservation sites in order to achieve their conservation objectives;

NH 14 Promote development for recreational and educational purposes that would not conflict with maintaining favourable conservation status and the meeting of the conservation objectives for designated sites.

NH15 Engage with the National Parks and Wildlife Service to ensure Integrated Management Plans are prepared for all Natura sites (or parts thereof) and ensure that plans are fully integrated with the County Development Plan and other plans and programmes, with the intention that such plans are practical, achievable and sustainable and have regard to all relevant ecological, cultural, social and economic considerations and with special regard to local communities.

Geology is an intrinsic component of the natural heritage of Laois. The Geological Survey of Ireland established the Irish Geological Heritage Programme in 1998. The programme is identifying and selecting the very best nationally important CGS sites for NHA designation,

to represent the country's geology. It is also identifying many sites of national or local geological heritage importance, which are classed as County Geological Sites (CGS). These sites will be protected primarily through their inclusion in the County Development Plan.

GEOLOGY

It is the policy of the Council to

GEOL1 Protect from inappropriate development the County Geological Sites listed in Table 28 as notified by the Geological Survey of Ireland;

GEOL2 Protect geological NHAs as they become designated and notified to the Local Authority, during the lifetime of the Plan;

GEOL3 Encourage, where practicable and when not in conflict with ownership rights, access to geological and geomorphological features.

3. Geological conservation issues and site management

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 in the same areas as SAC and NHA sites. In these areas, the geological heritage enhances and cements the value of these sites for nature conservation, and requires no additional designation of actual land areas, other than citation of the geological interest.

Broadly speaking, there are two types of site identified by the IGH Programme. The first, and most common, includes small and discrete sites. These may be old quarries, natural exposures on hilly ground, coastal cliff sections, or other natural cuttings into the subsurface, such as stream sections. They typically have a feature or features of specific interest such as fossils or minerals or they are a representative section of a particular stratigraphical sequence of rocks. **The second type of site is a larger area of geomorphological interest, i.e. a landscape that incorporates features that illustrates the processes that formed it**. The Quaternary theme and the Karst theme often include such sites. In County Laois, with a high proportion of land area under grassland, the only such site is the Clonaslee Eskers. [See facing page]

It is also important from a geological conservation perspective that planners 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 County Laois. A lack of awareness in the past, has led to the loss of important geological sites and local character throughout the country. In County Laois a 2010 Draft Landscape Characterisation Assessment was completed and incorporated into the County Development Plan 2011-2017. This provides a tool for planners to help maintain the character of the County. An action in the Heritage Plan is to keep heritage concerns at the forefront of the Assessment. The Strategic Environmental Assessment within the County Development Plan also provides tools. In addition, the now routine pattern of consultations with GSI, either by the planning department or by consultants carrying out Environmental Impact Assessment, plus strategic environmental assessment (SEA), has greatly improved the situation.

There are large differences in the management requirements for geological sites in comparison to biological sites. Geological features are typically 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 that the relevant planning department is aware of the sites and, more generally, that consultation can take place if some development is proposed for a site**. In this way, geologists may get the opportunity to learn more about a site or area by recording and sample collection of temporary exposures, or to influence the design so that access to exposures of rock is maintained for the future, or occasionally to prevent a completely inappropriate development through presentation of a strong scientific case.

In many counties, working quarries may have been listed because they are the best representative sections available of specific rock sequences, in areas where exposure is otherwise poor. No restriction is sought on the legitimate operation of these quarries. However, maintenance of exposure after quarry closure is generally sought in agreement with the operator and planning authority in such a case. At present, working quarries like

Farnans Quarry, Carroll's Quarry and Ballyadams Quarry are now included as County Geological Sites in County Laois. These issues are briefly explored in a set of Geological Heritage Guidelines for the Extractive Industry, published jointly by the GSI and the Irish Concrete Federation in 2008.

A new quarry may open up a window into the rocks below and reveal significant or particularly interesting features such as pockets of fossils or minerals, or perhaps a karstic depression or cave. Equally a quarry that has finished working may become more relevant as a geological heritage site at that stage in its life. It may need occasional maintenance to prevent overgrowth of vegetation obscuring the scientific interest, or may be promoted to the public by means of a viewing platform and information panel.

Nationally, 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 opportunity for general collecting may need to be controlled. However, County Laois's sites are not likely to require such an approach.

Waste dumping

An occasional problem throughout the country, including in County Laois, is the dumping of rubbish in the countryside. The dumping of waste is not only unsightly and messy, but when waste materials are dumped in areas where rock is exposed, such as in quarries or disused gravel pits, they may leach into the groundwater table as they degrade. This can cause groundwater pollution and can affect nearby drinking water supplies in wells or springs. Groundwater Protection Schemes (DELG 1999) help to combat pollution risks to groundwater by zoning the entire land surface within counties into different levels of groundwater vulnerability. County Laois was included in a national scheme for Groundwater Protection in 2012, thus ranking the county land surface into vulnerability categories of 'Extreme', 'High', 'Moderate' and 'Low', and helping planners to assess which developments are suitable or not in some areas of County Laois.

New exposures in development

One less obvious area where the Local Authority can play a key role in the promotion and protection of geology is in the case of new roads. **Wherever major new carriageways are to be built,** or in other major infrastructural work, it should be a policy within the Planning Department, that **where new rock exposures are created, they be left open and exposed** unless geotechnical safety issues arise (such as where bedding dips are prone to rock failure). The grading and grassing over of slopes in cuttings is largely a civil engineering convenience and a mindset which is difficult to change. However, it leads to sterile and uninteresting roads that look the same throughout the country. Leaving rock outcrops exposed where they are intersected along the road, improves the character and interest of the route, by reflecting the geology and landscape of the locality. Sympathetic tree or shrub planting can still be done, 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. This can also potentially save money on the construction costs. It may also contribute to road safety by providing diversity of surroundings to maintain drivers' attention.

In Laois, because of the relatively subdued terrain, the opportunity for such rock road cuttings has been limited. The motorway improvements on the M8 and M7 have produced two long cuttings at Addergoole near Rathdowney and at Derryvorrigan near Borris in

Ossory, respectively, that are included as CGSs in this audit. Other roads in the county are less likely to be significantly upgraded but the option should be borne in mind for all future road improvements.

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. A **Geopark is a territory** with a well-defined management structure in place (such as Local Authority support), **where the geological heritage is of outstanding significance and is used to develop sustainable tourism opportunities**. Initially it was largely a European Geoparks Network (EGN) but since 2004 has expanded worldwide as the Global Geoparks Network (GGN) and is fully assisted by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) [see www.globalgeopark.org and www.europeangeoparks.org]. A fundamental theoretical 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. The Geopark branding therefore helps promote the geological heritage resource so that the community can benefit from it.

In Ireland there are three members of the Geoparks Network. One is the cross-border Marble Arch Caves Global Geopark in Fermanagh and Cavan [see www.marblearchcaves.net and www.cavancoco.ie/marble-arch-caves-global-geopark]. The Copper Coast Geopark in Waterford also joined the Network in 2001 [see www.coppercoastgeopark.com]. A now well established addition has been the Burren and Cliffs of Moher in County Clare [see www.burrengeopark.ie]. In addition there are aspirant groups exploring the work and infrastructure required for applications in other areas such as Joyce Country in Mayo and Galway, and the cross-border Mourne Cooley Gullion area. At present, we do not consider the geodiversity in the county as likely to meet the criteria for a Geopark application.

3.1 A Note on Esker Conservation in County Laois

What is an esker?

Eskers are long, sinuous ridges of glaciofluvial sands and gravels. The term “esker” is an English rendering of the Gaelic word *eiscir* which means 'a high ridge separating two flat plains'. They range from a few tens of metres to over a hundred kilometres in unbroken length, and range locally from a few metres to over 50m in height, and from ten metres to hundreds of metres in width at their base. Eskers have been reported from all over mid-latitudes, and are common in Ireland, Britain, Scandinavia, Canada, Alaska, the northeastern U.S., and Patagonia. .

Since eskers are made up of highly permeable sand and gravel, they are frequently excavated for construction. They have been considered an endangered geomorphological species in many parts of the world for some time (notably, southern Quebec and Finland), since they have been used either to develop roadways, offering natural elevated, dry terrain, or they have been ripped up for gravel to build nearby roads. The latter has been the case in Ireland for some time, and recent efforts have focussed on conserving eskers for their geomorphological, habitat, groundwater and educational resource.

How are eskers formed, geologically?

Eskers are usually the infillings of ice-walled river channels. Just as rivers on land carry and deposit sediment, meltwater that flows in the openings beneath, above and within a glacier also carries and deposits sediment. Tunnels near the base of retreating glaciers fill with transported sediments, which remain as sandy or gravelly ridges that look like raised, upside-down stream beds after the glacier melts away.

Eskers in Ireland.

A large system of esker landforms spans the ‘Irish Midlands’, or central lowland portion of the country. These ridges have been the subject of geomorphological and geological study since the mid-nineteenth century. The eskers are composed of sorted, layered sediments but range in size, orientation and morphology, generally related to the movement patterns and ice margin locations of the last ice sheet to cover the country.

Esker conservation and the aggregate industry

Aggregates can only be extracted where they occur. Extraction is limited to certain geological areas, which are often areas of inherent beauty or value because of the relationship between geology and the landscape. This is a problem particularly with eskers, as they are upstanding, dry ridges of sand and gravel which can be easily quarried, and yet are important in the landscape topographically, ecologically and historically.

Many of the best examples of eskers in County Laois have been extensively quarried, to such an extent that little of them actually remain anymore. In particular, much of the Ridge of Maryborough has been removed, relatively recently, in the southern outskirts of Portlaoise, and of the five separate segments of the Timahoe Esker, only two remain intact. It is imperative that the balance is found between geological heritage conservation and aggregate extraction in the future, to ensure that the best examples of our eskers are protected. The Irish Geological Heritage Audit of County Laois should help in this process.

4. Summary and Recommendations

Since it is one of the smaller Irish counties and because bedrock is generally not well exposed, County Laois is not widely known for its geological heritage. However, it has some fine but underappreciated geological sites. The County Council's support for this audit is critical in raising the profile of geological heritage in County Laois and for maximising its potential, since some of the sites may be otherwise overlooked.

This report documents what are currently understood by the Irish Geological Heritage Programme (IGH) of the Geological Survey of Ireland (GSI) to be the most important geological sites within County Laois. It documents them as County Geological Sites (CGS), for inclusion within the County Development Plan (CDP). The audit provides a detailed study of sites to replace a provisional listing based on desk study which was adopted in the current 2011-2017 CDP, along with strong policies to protect it and enhance access where feasible. [See facing page]

County Geological Sites do not receive direct statutory protection like Natural Heritage Areas (NHA) but receive an effective protection from their inclusion in the planning system. Some of the sites described in this report are considered to be of national importance as a best representative example of a particular geological formation or feature. Old Rossmore, for example, is perhaps the only good exposure of a coal measure sequence, including a coal seam, on a national basis. If resources within GSI and National Parks and Wildlife Service (NPWS) allow, such sites may be notified to the NPWS by the GSI for designation as a Natural Heritage Area (NHA) once due survey and consultation with landowners is complete. In other counties, many of the sites fall within existing pNHAs and SACs where the ecological interest is actually founded upon the underlying geodiversity. In Laois, one CGS lies within a SAC/NHA: the Clonaslee Eskers (000859), whilst the Timahoe Esker CGS forms pNHA 000421.

The commission of this audit and adoption of the sites within the CDP ensure that County Laois follows a now established and effective methodology for ensuring that geological heritage is not overlooked in the general absence of allocated resources for progress at national level. It places County Laois at the current focus of geological conservation in Ireland.

This report is written in non-technical language (with a glossary for unavoidable geological terminology) as a working document for use by the Heritage Officer and the Planning department of Laois County Council. It will also be made available via the Council website for the people of County Laois. A chapter of the report includes recommendations on how to best present and promote the geological heritage of County Laois to the people of the county. It will also inform the work of the IGH Programme and be made available through the GSI website.

The preliminary sections, summary geological history and accompanying map, timescale and stratigraphical column particularly may be used as they stand to preface a booklet or as website information in the development of this work, and for information, as seen fit by the Heritage Officer. The contents also provide the essential ingredients for a public-oriented book on the geological heritage of County Laois, if the funding can be found to produce it.

4.1 Proposals for promotion of geological heritage in County Laois

The Laois Heritage Plan 2014-2019 included a specific action (20) regarding a geological heritage audit and the decision by the Heritage Officer to commission an audit of geological heritage sites in Laois (along with those in County Offaly in a joint approach) in conjunction with the Geological Survey of Ireland in 2016. This is a most welcome and positive step, for a topic that is often undervalued and poorly known in the wider community.

This section examines the existing objectives in the Laois Heritage Plan relating in any way to geological heritage and provides specific suggestions as to how these may be implemented, supported or enhanced by this audit of geological heritage sites in the county.

OBJECTIVES AND ACTIONS OF THE LAOIS HERITAGE PLAN

Objective 1: Increase understanding of the heritage of Laois

2. Develop the Laois Heritage website and use as a showcase for the heritage of Laois, the work of the Forum and as a portal allowing access to other sources of heritage information, including the Heritage Council's Heritage Map Viewer and the websites of State agencies which display valuable data on the heritage of the County.
Audit Action: It is hoped that the geological site data in this audit will contribute to the Laois Heritage website.

3. Continue to raise awareness of the benefits of new technology for interpretation of heritage sites – run training in the development of interpretation using new technology, in association with Laois Partnership.
Audit Action: The audit provides much data and material that could form an interpretation project using new technology, with a focus on training.

4. Disseminate information on the heritage of the County through the use of digital technologies such as Smartphone apps, multi-media presentations (audio, video guides, etc.) and social networking sites such as Facebook, Twitter, Google+, Pinterest, etc.
Audit Action: The audit provides much data and material that could form an interpretation project using new technology.

5. Continue publication of books, posters and leaflets on various aspects of the heritage of Laois (both by theme and by target group).
Audit Action: The audit report provides the material which could be readily distilled into an accessible book on the geological heritage of Laois, if sufficient resources are available for the preparation and production.

6. Investigate the feasibility of developing downloadable applications to increase awareness of heritage sites, *e.g.* Laois Gardens Trail, Timahoe Esker Trail, and important monuments, *e.g.* Rock of Dunamase.
Audit Action: The audit may provide sufficient raw material to provide applications on some geological heritage sites.

7. Continue to organise conferences, talks and seminars on heritage-related topics, including the annual *Celebrating Laois Heritage Conference*. Target staff of Laois County Council through awareness raising seminars and workshops at lunchtime.
Audit Action: The authors of this geological heritage audit could potentially provide a talk or seminar on geological heritage for an appropriate occasion and audience, by arrangement with the Heritage Officer.

9. Continue to promote wider awareness of all aspects of heritage in Laois through participation in national programmes and events such as Heritage Week, Water Day, Biodiversity Day and Tree Week.
Audit Action: The authors of this geological heritage audit could potentially provide an event on geological heritage for an appropriate programme, by arrangement with the Heritage Officer.

12. Liaise with Teagasc and the Farming Organisations to produce and distribute heritage related information of relevance to the farming community. Support the work of Teagasc in co-ordinating the delivery of agri environmental awareness events for farmers, to raise awareness of wildlife habitats, watercourses, farm built heritage (architecture and archaeology) and traditional orchards.
Audit Action: The authors of this geological heritage audit could potentially provide an input on geological heritage for an appropriate training programme or information publication, by arrangement with the Heritage Officer

14. Support efforts to promote heritage-related tourism, including in the Slieve Blooms and in particular Eco-tourism. Work with Laois Tourism and other tourism groups to promote and maximise the economic and tourism value of our heritage, particularly harnessing the goodwill and publicity associated with existing festivals and events.
Audit Action: The audit may provide some tourism providers with additional elements of interest, on the geological heritage, which could enhance their offerings.

Objective 2: Record the heritage of Laois

19. Audit existing surveys/inventories of heritage relating to Laois. Use these to develop and implement a prioritised programme for research and surveys where there are gaps in knowledge, in partnership with national and regional bodies. Continue to support the Heritage Council's Heritage Map Viewer and use this to highlight gaps in heritage data.
Audit Action: It is envisaged that the relevant data in the audit of geological heritage report will be added to the Heritage Council Map Viewer

20. Carry out an audit of County Geological Sites, using existing resources such as data held by the Geological Survey of Ireland, and the recent publication *The Geology of Laois and Offaly* by Dr. John Feehan. Use the results of this audit to inform County Development Plan policy in relation to geological heritage.
Audit Action: The delivery of this audit report achieves this action, once the County Development Plan has integrated the data and adopted appropriate policy.

23. Support Bord na Móna in the implementation of the Bord na Móna Biodiversity Action Plan 2010-2015, which includes plans to carry out a baseline ecological survey of its various properties within Laois.

Audit Action: The geodiversity foundation of many biodiversity sites, such as Abbeyleix Bog, should not be overlooked in this action.

24. Support Coillte in carrying out surveys of designated Biodiversity sites in its ownership and sites selected for inclusion in the various LIFE-Nature Programmes around the county.
Audit Action: The geodiversity foundation of many biodiversity sites should not be overlooked in this action.

25. Support the National Parks and Wildlife Service in protecting important sites for biodiversity and carrying out ecological survey work throughout Laois.
Audit Action: The geodiversity foundation of many biodiversity sites should not be overlooked in this action.

26. Work with NGOs such as the Irish Peatland Conservation Council, Bat Conservation Ireland, The Irish Wildlife Trust, BirdWatch Ireland and others in promoting awareness and collecting biodiversity data for Laois.
Audit Action: The geodiversity foundation of many biodiversity sites should not be overlooked in this action.

Objective 3: Protect and promote active conservation of the heritage of Laois

29. Work with relevant agencies and individuals to promote opportunities for ecological rehabilitation of disturbed sites such as quarries, landfills, cutaway peatland and forestry.
[In the cases where rehabilitation projects are in or adjacent to Natura 2000 sites then Appropriate Assessment Screening will required of individual projects.]
Audit Action: A holistic approach to such rehabilitation can ensure that both newly-engendered ecology and rock and subsoil exposures can complement each other in such localities.

32. Continue to work with communities to ensure the ongoing conservation and maintenance of graveyards.
Audit Action: The geodiversity component and character of local and imported rock types for gravestones should not be overlooked in this action.

35. Work with Bord na Móna and the Abbeyleix Bog Committee in their work to conserve and develop educational opportunities at Abbeyleix Bog, and provide advice when required through the Technical Advisory Group.
Audit Action: The geodiversity component of the site should not be overlooked and the site report and the authors of this geological heritage audit report may provide appropriate advice.

39. Support the development of Architectural Conservation Areas in Laois through collection of data, promotion of community participation and awareness raising
Audit Action: The importance of geological character of available local rock sources for both ashlar work and vernacular buildings and walls should not be overlooked in this action.

Objective 5: Promote enjoyment and accessibility of heritage

45. Publish a list with accompanying maps of heritage sites which are open to the public in Laois. This to be published online with interactive mapping.

Audit Action: The online mapping can include any County Geological Sites which are accessible to the public, such as the Timahoe Esker.

49. Investigate development of a Geological Heritage Trail using the recent publication *The Geology of Laois and Offaly* by Dr. John Feehan, and the results of the Survey outlined in Action 20.
Audit Action: The authors of this geological heritage audit are willing to collaborate on this and some suggestions are given elsewhere in the report.

50. Support the maintenance of existing way-marked ways and other recreational routes in Laois, and promote development of new walking and cycling routes in association with communities, landowners and State agencies. Promote the principle of heritage audits of routes and interpretation of heritage features along recreational routes. Work with Forward Planning and Sports Office to promote development of high quality new cycling and walking routes in association with communities, landowners and State Agencies
Audit Action: The authors of this geological heritage audit are able to provide relevant geological heritage and geodiversity input to any route developments that progress.

4.2 Ideas for projects

Leaflets
No existing leaflets on the geological heritage of County Laois are known, other than the Geoschol one included as an appendix here. There is some scope for other and different leaflets. Any leaflets produced could simply be made available as pdf downloads on the Council's website to avoid printing costs.

Guides
There are no known specific guides to the geology of County Laois, apart from the superb book 'The Geology of Laois and Offaly' by John Feehan, which is as comprehensive and readable an account as you could wish for. The 1:100,000 GSI map reports for Sheets 15, 16, 18 and 19 cover County Laois and are also essential resources.

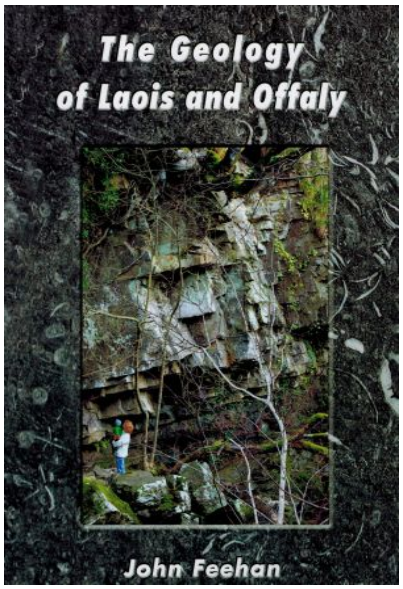


Figure 8. Cover of The Geology of Laois and Offaly

There is scope for guides at different levels of detail and accessibility to non-specialists. A wide 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. It is suggested that **with only modest editing and reorganisation the main content of this report would distil into a good general short guide to the geological heritage of County Laois**, in a broadly similar style to those books produced for Sligo, Meath, Fingal, Waterford, Roscommon and Clare following audits in those counties.

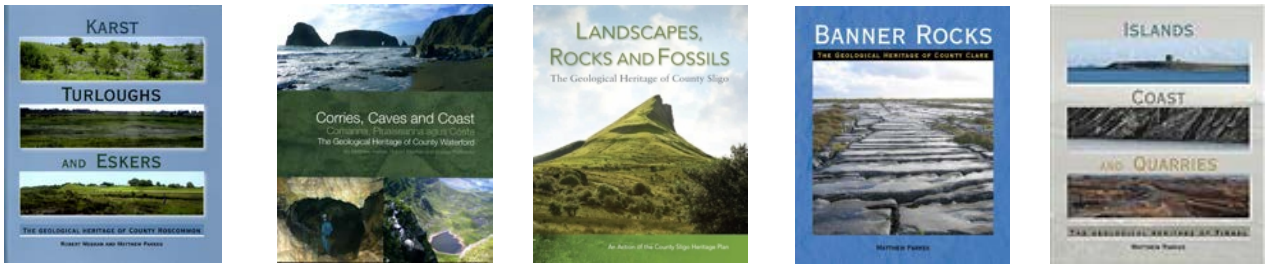


Figure 9. Covers of various county popular style books

Signboards
Simple explanatory or interpretive signboards may be advisable at key 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. The Planning Section should clearly have a controlling input, in conjunction with the Heritage Office. It is most likely that a panel combining various heritage interests at a place is preferred to single interest panels. It is important to consult with potential partners in the planning stage so that duplication does not occur.

The successful integration of text and graphics on information panels is a fine art, and the IGH Programme in GSI can offer input if signs are planned for key visitor localities. The authors of this report are also able to write, review or provide content on geological heritage for any proposed panels.

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 research covering human dependence on geology and resources, an interesting exhibition can be put together for display in the Laois Council Offices, County Library branches or other venues. The model followed was that used for Carlow, Dun Laoghaire-Rathdown and Waterford. Images of those and other similar ones can be seen on the Geological Heritage/Exhibitions section of the GSI website [www.gsi.ie].

New media
There are increasing numbers of examples of new methods of promoting Earth Sciences, *via* mobile phone applications and other electronic media. Self-guiding apps on specific sites would be one of these, such as those produced by Ingenious Ireland for Dublin city geology and the app for tourists in the Burren and Cliffs of Moher Geopark. Plans for such products would require some considerable effort to produce and imaginative effort, to link sites in any coherent ways, other than by their county.

Information on the heritage sites of County Laois can already be found on the 'Laois Heritage Trail' audioguide app available to download for both Android and Apple Devices. See

http://abartaaudioguides.com/Laois%E2%80%93Heritage%E2%80%93Trail

It is to be hoped that in due course these apps can be updated to include suitable geological heritage information arising from the audit.

Earth Science Ireland Group and magazine [www.earthscienceireland.org]
The group Earth Science Ireland is an all-Ireland group promoting awareness of Earth sciences and supporting educational provision in the subject. A main vehicle for the efforts is the twice a year magazine *Earth Science Ireland* and this is distributed free to thousands of individuals, schools, museums, centres and organisations. The editors would welcome more material from the Republic of Ireland and on County Laois's geological heritage.

Geoschol website [www.geoschol.com]
Geoschol is an educational project, now essentially represented by a website, which was largely aimed at producing educational materials on geology for primary schools. A four page pdf summarising the geology and some highlights of County Laois is already part of

the available material (see Appendix 6). Working links to the Heritage section of County Laois Council's website, as well as to other heritage websites, should be established.

Geological Heritage Research Archive

If the Heritage Officer wanted to do something similar to that produced in the Burren and Cliffs of Moher Geopark, with downloadable (or links to) free access papers, then a lot of groundwork is already provided by the reference lists in this audit. Making available technical references of direct relevance to County Laois geology and geomorphology will assist many users and researchers into the future. An alternative is that a geological heritage section with a bibliography pdf on the Heritage web pages for Laois could suffice for most users.

Maps

It is hoped that geological heritage sites as a data layer might be adopted by the Ordnance Survey of Ireland in their future map editions of the 1:50,000 Discovery Series, for all counties where an audit has been completed (similar to the East West maps of Wicklow which include such data from GSI).

5. A summary of the Geology of County Laois

A single paragraph summary

County Laois has three main episodes in its geological story. The oldest story is represented by the Slieve Bloom Mountains, where older Silurian marine rocks, from around 425 million years ago are found in patches where erosion of the uplands has stripped off the younger Devonian sandstones and conglomerates from river environments, which overlay them. Over most of the county, the plains are founded on Carboniferous Limestone from around 330 million years ago. These are shelf limestones from open marine environments. Around 320 million years ago these limestone seas were replaced by the build-up of sandstones and shales in deltas that extended seawards from the land. Gradual shallowing of the nearshore led to the emergence of swampy environments filled with lycopod trees which formed the coal seams of the Leinster (or Castlecomer) coalfield. Around 5 million years ago, the limestones around Stradbally and Portlaoise may have been tropical tower karst with limestone pinnacles, but if so we see only remnants today, like the Rock of Dunamase, since the glaciers removed so much during the Ice Age. A veneer of till and some esker ridges are the other result of the Ice Age.

A simple summary

The landscape of Co. Laois is mostly rather low-lying. In the north-west lies the eastern part of the Slieve Bloom Mountains, which are formed of the oldest rocks in the county, while in the south-east is the northern tip of the Castlecomer Plateau, formed of the youngest bedrock in the county. The oldest rocks in the county occur in several patches towards the centre of the Slieve Bloom Mountains where erosion has stripped away the younger rocks, but they are only exposed in the banks of a few streams. These grey mudstones, siltstones and sandstones are Silurian in age, around 425 million years old (Ma), and were deposited on a deep ocean floor.

Lying above them are red to brown mudstones, sandstones and pebble beds, with occasional peculiar knobbly limestones called ‘cornstones’. All of these were deposited on river floodplains in an Equatorial semi-desert environment, with the ‘cornstones’ actually forming within the soils of the time. Spores are the only fossils that have been found, but they show that these rocks are of earliest Carboniferous age, just a little less than 360 Ma.

Soon after the start of the Carboniferous, sea level rose to flood across these low plains. The first of the marine rocks to be deposited were dark grey fossiliferous mudstones, but above these is a series of thick grey limestones which underlie much of the low ground across the county. At certain levels these limestones are quite fossiliferous, with shells of brachiopods and nautiloids, corals, fragments of crinoids, and rarer fossils such as trilobites. Mostly these limestones accumulated as horizontal layers on a fairly shallow ‘shelf’ sea floor although some of the younger layered limestones, around 325 Ma, are much darker in colour and were deposited in considerably deeper water. Although the limestones mostly form low ground across the centre of the county, they are well exposed in various working and disused quarries and on some of the low hills in the south of the county.

The low hills in the south-east corner of the county are of younger Carboniferous rocks, between 320 and 315 Ma. The earliest of these particular rocks are black mudstones and thin limestones. Above them lie sandstones and mudstones that were deposited by river deltas as sea level fell. Younger still is a series of sandstones and mudstones with thin coal seams, formed from plant material buried in a swamp, which formed the basis of the once thriving Leinster Coalfield.

A subtle but interesting component of the Laois landscape is the probable relict tower karst seen in the numerous small hills between Stradbally and Portlaoise, such as Killone Hill, the Rock of Dunamase, Clopook, Luggacurren and Hewson Hill. These are sometimes called hums, and are thought to be the glacially eroded remnants of tower karst, of the type seen today in China and SE Asia.

As elsewhere across Ireland, the ice sheets and glaciers of the last Ice Age have modified the Laois landscape, although in a more subdued way than in some of the more mountainous regions of Ireland. The main effect has been to blanket much of the lowlands with glacial till, or 'boulder clay'.

Many small quarries were opened in the Carboniferous limestones for building stone and agricultural lime but today only a few are still worked for limestone aggregate and agricultural lime. Mining of high grade anthracite coal formerly took place in the Leinster Coalfield, but all of the seams are thin and none of the mines, underground or opencast, are still working.

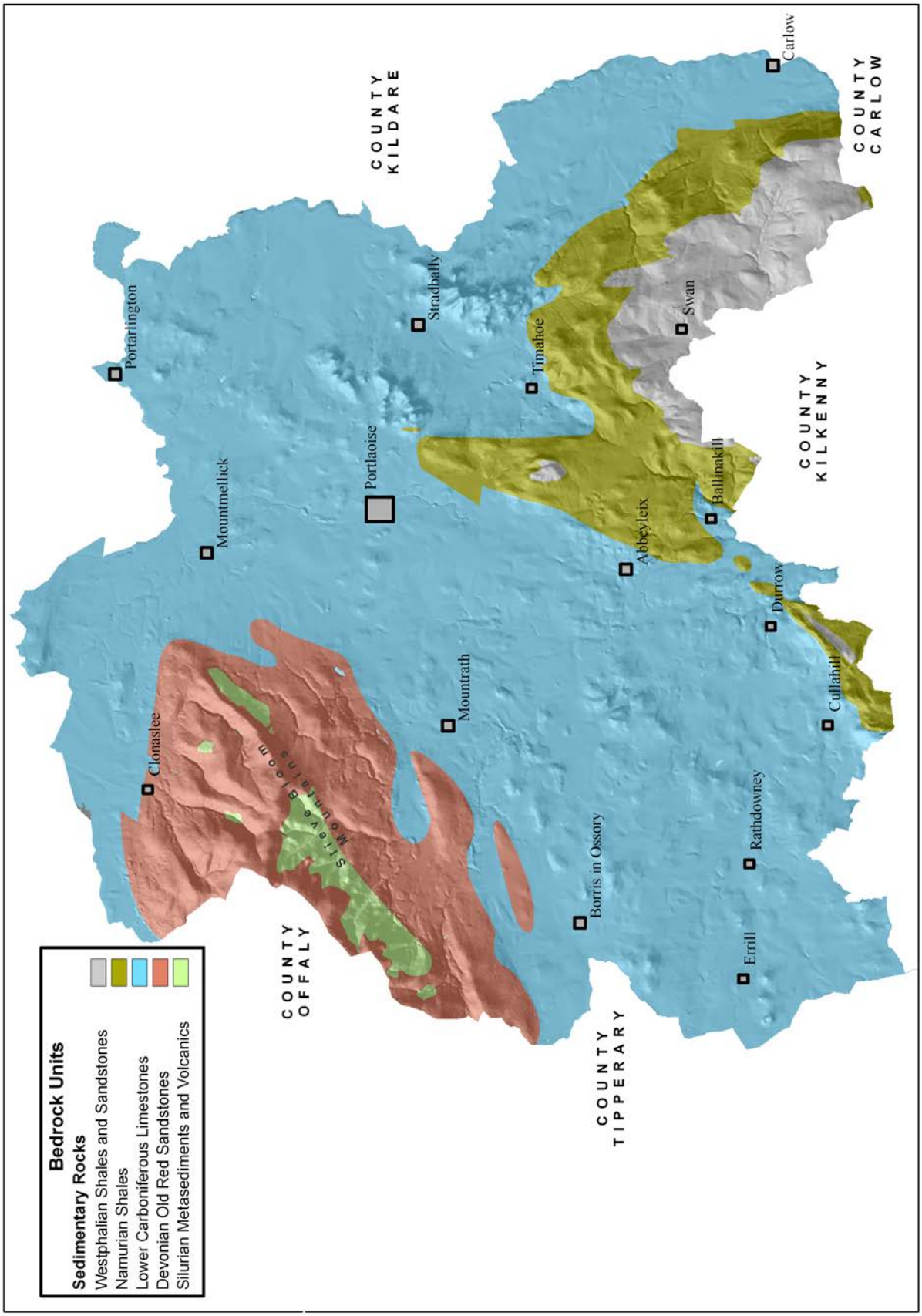


Figure 10. Simplified Geological Map of County Laois outlining the main geological units.

AGE (Million Years Ago)	ERA	PERIOD	EVENTS IN LAOIS	IF THIS TIMESCALE WAS A DAY LONG ...
2.58	Cenozoic	Quaternary	Several ice ages smothering Laois, followed in the last 10,000 years by the spread of vegetation, growth of bogs and arrival of humans. Deposition of (till) boulder clay in crag-and-tails and till plains, as well as sands and gravels in eskers, fans and deltas. Dissolution of limestone beneath Quaternary sediments.	The ice ages would begin 38 seconds before midnight
66		Tertiary	Erosion, especially of limestone. Caves, swallow holes, cavities and underground streams developing in the lowlands of south and east Laois.	The Tertiary period begins at 11.40 pm
145	Mezozoic	*Cretaceous*	*Erosion.* *No record of rocks of this age in Laois.*	11.15 pm
201		*Jurassic*	*Uplift and erosion.* *No record of rocks of this age in Laois.*	The age of the dinosaurs, starting at 10.55 pm
252		*Triassic*	*Desert conditions on land.* *No record of rocks of this age in Laois.*	10.42 pm
299	Palaeozoic	*Permian*		10.30 pm
359		Carboniferous	Land became submerged, limestones with some shales deposited in tropical seas across the lowlands in the central, southern and eastern portions of Laois. Limestones remaining today are pure and unbedded in the south and east of the county, with areas of muddier limestones toward the Slieve Blooms at the west. Shales and sandstones with coal seams deposited in the Leinster Coalfield.	Much of Laois's current rocks (limestone, sandstone and shale) deposited around 10.10 pm
419		Devonian	Caledonian mountain building. 'Old Red' sandstones deposited in the Slieve Blooms.	'Old Red' Sandstone deposited at 9.52 pm
443		Silurian	Shallow seas, following closure of the Iapetus Ocean. Greywackes, siltstones, mudstones deposited in the central portion of Slieve Bloom.	Starts at 9.42 pm
485		*Ordovician*	Closure of the Iapetus Ocean. *No record of rocks of this age in Laois.*	Begins at 9.28 pm
541		*Cambrian*	Opening of the Iapetus Ocean. *No record of rocks of this age in Laois.*	Starts at 9.11 pm
2500	Proterozoic	*Precambrian*	*Some of Irelands oldest rocks deposited in Mayo and Sligo.*	Beginning 11.00 am
4000	Archaean		*Oldest known rocks on Earth.*	Beginning 3.00 am
4600			*Age of the Earth.*	Beginning 1 second after midnight

Figure 11. The Geological Timescale and County Laois

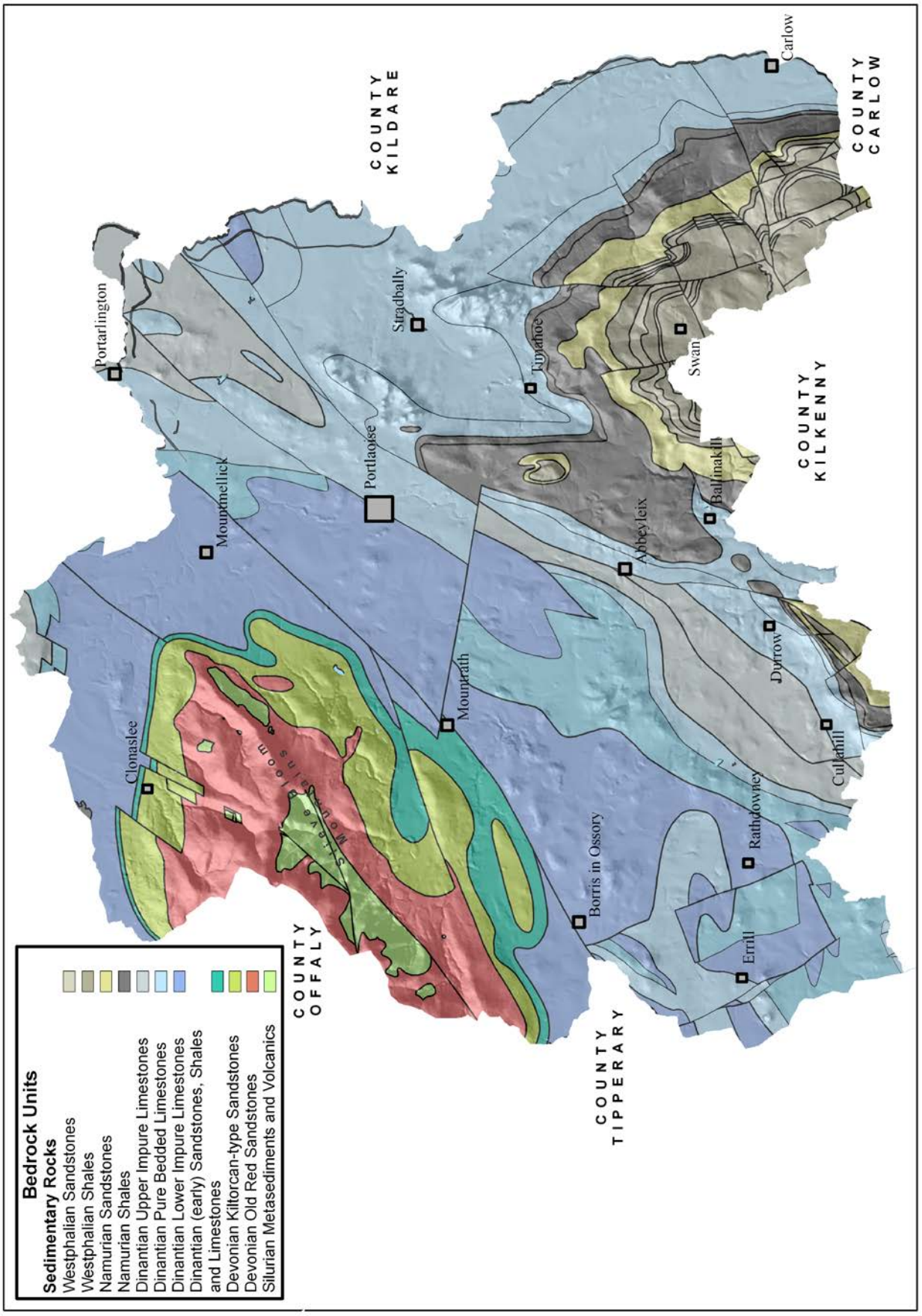


Figure 12. A detailed geological map of County Laois.

6. Acknowledgements

The authors would like to gratefully acknowledge the assistance of Catherine Casey, Heritage Officer from Laois County Council in the development of this project. Likewise Amanda Pedlow, Heritage Officer in County Offaly worked closely with Catherine and with the authors as the two counties were audited in a joint project. Funding from the Heritage Council and Laois County Council is also acknowledged. 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.

Teddy Fennelly of the Laois Heritage Forum provided invaluable information on Biddy Aghaboe's Well and the Darkin Well, and Brendan McGarry provided access to the Darkin Well compound. Coran Kelly of Tobin Consulting Engineers and Stan Cullen of Laois County Council Environment Section are thanked for discussions on hydrogeological localities in County Laois.

The following are thanked for allowing access for the audit visits, and their kindness in answering questions and providing valuable assistance with information or guidance: Tony Maher, Mrs Whelan, Oliver Whelan, James Kavanagh**,** Michael Deevy, Kathleen Goucher, Kieran Cosey, Pat Kerwin, Michael Lynch, Raymond Lacey, Tom Mullen, Shannon Leech.

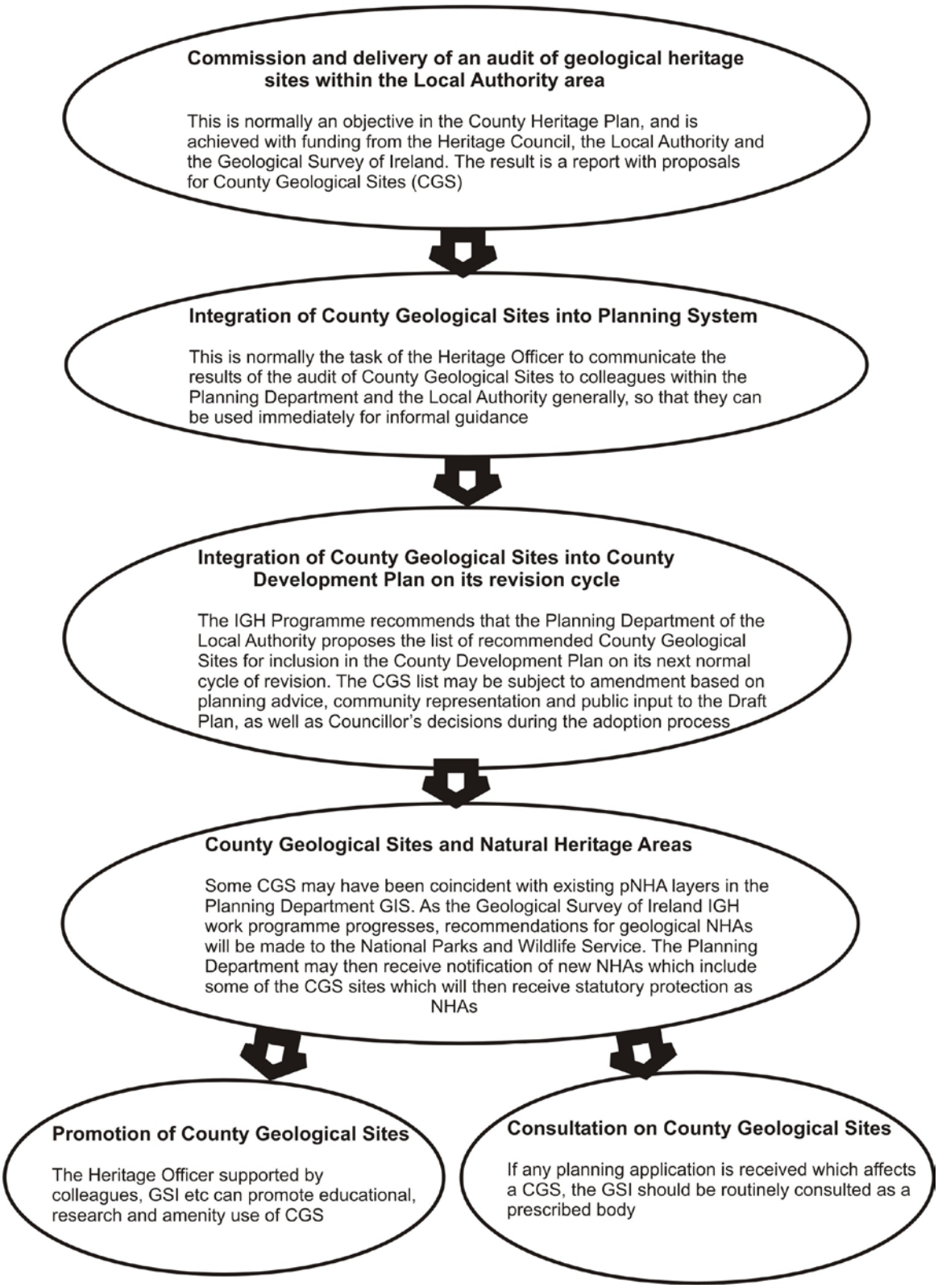
Appendix 1 – Geological heritage audits and the planning process

This appendix contains more detail on the legal framework behind geological heritage audits conducted by County Councils, and the process which operates as a partnership between the Geological Heritage and Planning Programme of the GSI and the local authority Heritage Officer.

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: the Planning and Development Act 2000 [e.g. Sections 212 (1)f; Part IV, 6; First Schedule Condition 21], the Planning and Development Regulations 2001, the Wildlife (Amendment) Act 2000 (enabling Natural Heritage Areas) and the Heritage Act 1995. The Planning and Development Act 2000 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 chart below illustrates the essential process, established by the Irish Geological Heritage Programme in GSI, over the course of numerous county audits since 2004.

County Geological Sites - a step by step guide



Appendix 2 – References

Shortlist of Key Geological References

This reference list includes a few **key** papers, books and articles on the geology and geomorphology of County Laois that are recommended as access points to County Laois's geological heritage.

Archer, J.B., Sleeman, A.G. and Smith, D.C. 1996. *Geology of Tipperary. A geological description of Tipperary and adjoining parts of Laois, Kilkenny, Offaly, Clare and Limerick, to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 18, Tipperary, with contributions by K. Claringbold, G. Stanley (Mineral Resources) and G. Wright (Groundwater Resources),* Geological Survey of Ireland vii + 77pp.

Feehan, J. 1982. The Silurian rocks of the Slieve Bloom Mountains, Counties Laois and Offaly. *Proceedings of the Royal Irish Academy*, 82B, 153 – 167.

Feehan, J. 2013. The Geology of Laois and Offaly. Offaly County Council. 403pp.

Gatley, S., Somerville, I., Morris, J.H., Sleeman, A.G. and Emo, G. (Ed. A.G. Sleeman) (2005). *Geology of Galway-Offaly. A geological description of Galway-Offaly and adjacent parts of Westmeath, Tipperary, Laois, Clare and Roscommon to accompany the bedrock geology 1:100,000 scale map series, Sheet 15, Galway-Offaly*. Geological Survey of Ireland.

Hardman, E.T. 1881. Explanatory Memoir on the Geology of the Leinster Coalfields, to accompany parts of Sheets 127, 128, 136, 137, 145, 146, 147, 155, 156, and 166 of the Maps of the Geological Survey of Ireland, with Palaeontological notes by W.H. Baily*, Memoirs of the Geological Survey of Ireland,* 96pp.

McArdle, P. 2008. *Rock around Ireland*. A guide to Irish Geology. Science Spin Discovery 2. Albertine Kennedy Publishing. 112pp.

McConnell, B., Philcox, M.E., Sleeman, A. G., Stanley, G., Flegg, A.M., Daly, E.P. and Warren, W.P. 1994. *Geology of Kildare - Wicklow. A geological description to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 16, Kildare - Wicklow. Edited by B. McConnell*, Geological Survey of Ireland, 57pp.

Tietzsch-Tyler, D., Sleeman, A. G., McConnell, B.J., Daly, E.P., Flegg, A.M., O'Connor, P.J., Philcox, M.E. and Warren, W.P. 1994. *Geology of Carlow- Wexford, a geological description to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 19, Carlow- Wexford.* Geological Survey of Ireland, 56pp.

****

The following references are a list of all papers, books, articles and some unpublished reports etc. relating to the geology and geomorphology of County Laois that could be traced. Many papers that refer to the Midlands area in general, may or may not be specifically relevant to County Laois. Similarly there are many papers addressing the geology and wider development of the Leinster Coalfield. Many of these may have no significant detail on the rocks of Laois itself.

GEOLOGICAL REFERENCES WITH DIRECT REFERENCE TO LAOIS

Aldwell, C.R., and D.J. Burdon, 1986, Energy potential of Irish groundwaters, *Quarterly Journal of Engineering Geology*, 19, 133-141.

ALI, CH.M. 1967. *The Lower Carboniferous Limestones in parts of Counties Laois and Tipperary, Eire.* Unpublished Ph.D. thesis, University of London.

Archer, J.B., Sleeman, A.G. and Smith, D.C. 1996. *Geology of Tipperary. A geological description of Tipperary and adjoining parts of Laois, Kilkenny, Offaly, Clare and Limerick, to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 18, Tipperary, with contributions by K. Claringbold, G. Stanley (Mineral Resources) and G. Wright (Groundwater Resources),* Geological Survey of Ireland vii + 77pp.

Boulter, M.C. (1980). Irish Tertiary plant fossils in a European context. *Journal of Earth Sciences of the Royal Dublin Society* **3**, 1-11.

Burgess, P. (1973). *A pollen study of an Upper Pliocene Deposit, Hollymount, Co. Laois.* Unpublished undergraduate thesis, Trinity College Dublin.

Conry, M.J. (1987). *Soils of County Laois*. Teagasc, Soil Survey Bulletin 41, National Soil Survey of Ireland.

Conry, Michael J. (1999). *Culm Crushers. Edge-runner Grinding Stones for Tempering Culm*. Carlow, Chapelstown Press.

Conry, Michael J. (2001). Dancing the *Culm. Burning Culm as a Domestic and Industrial Fuel in Ireland*. Carlow, Chapelstown Press.

Cozar, P and Somerville, I.D. 2005. Stratigraphy of upper Visean carbonate platform rocks in the Carlow area, southeast Ireland, *Geological Journal*. 40, 35–64.

Daly, D., J.W. Lloyd, B.D.R. Misstear and E.P. Daly (1980). Fault control of groundwater flow and hydrochemistry in the aquifer system of the Castlecomer Plateau, Ireland. *Quarterly Journal of Engineering Geology, Geological Society of London.* 13, 167-175.

Daly, D. and Misstear, B.D.R. (1976). *A preliminary hydrogeological survey of the Castleccomer Plateau, S.E. Ireland*. Unpublished M.Sc. Dissertation, University of Birmingham. 65pp.

Daly, E.P. 1983. Water in the landscape: Groundwater resources in Co. Laois, an environmental history. *In:* J. Feehan (ed.), *Laois an environmental history.* Ballykilcavan Press, Co. Laois, 59-70.

Deakin, J. and Pracht, M. 1998. *Devonian Sandstones and Aquifer Development in the Slieve Phelims, Slieve Bernaghs, Slieve Aughtys and Slieve Blooms*. Internal report on a field visit, Geological Survey of Ireland, 7pp.

Deakin, J., Fitzsimons, V., Gately, C. and Wright, G. (2004). *County Laois groundwater protection scheme. Main Report*. Geological Survey of Ireland.

Department of Industry and Commerce (1964). *Report of the Diamond Drilling Programme 1959-63 carried out in the Leinster Coalfield*. Geological Survey of Ireland.

Dooley, Michael and Feehan, J. (1981). *Exploring Northeastern Slieve Bloom*. County Laois Vocational Education Committee, 18pp.

Dowds, J. 1987. Some caves of the Midlands. *Irish Speleology,* 4, 1, 23-25.

Drew, D.P. and Jones, G.Ll. (2000). Post-Carboniferous Pre-Quaternary karstification in Ireland. *Proceedings of the Geologists' Association* **111**, 345-307.

Du Noyer, G.V., Forbes, E., Jukes, J.B., Baily, W.H., Wilson, W/L. and Wynne, A.B. (1858). *Data and Descriptions to accompany Quarter Sheet 35 N.E. [one-inch sheet119] of the Maps of the Geological Survey of Ireland* (Parts of Counties Kildare, King's and Queen's Counties). Dublin, HMSO, 32pp.

EPA, 2011. Water Framework Directive Groundwater Monitoring Programme Kyle Spring. Available at: www.epa.ie/pubs/reports/water/ground/gwmpinfo/EPA_GWMP_Kyle%20PWS.pdf. Accessed on 02/05/2016

Feehan, J. (1973). *Looking at Local Rocks. Aspects of the Geology of Laois and North Kilkenny*. Salesian Press.

Feehan, J. 1977. *The Lower Palaeozoic and Old Red Sandstone rocks of north western Slieve Bloom, County Offaly,* Unpublished M.Sc. thesis, University of Dublin.

Feehan, J. 1980a. *The Geology of the Slieve Bloom and North Eastern Devilsbit Mountains,* Unpublished Ph.D. thesis, University of Dublin.

Feehan, J. 1980b. Alluvial fan sediments from the Old Red Sandstone of the Devilsbit Mountain, County Tipperary, *Journal of Earth Sciences Royal Dublin Society*, 3, 179-194.

Feehan, J. (1979). *The Landscape of Slieve Bloom: a study of its natural and human heritage*. Dublin, Blackwater Press.

Feehan, J. (1979). *The Landscape of Slieve Bloom*. Blackwater Press, reprinted 2008 by Slieve

Bloom Rural Development Association.
Feehan, J. 1982a. The Silurian rocks of the Slieve Bloom Mountains, Counties Laois and Offaly. *Proceedings of the Royal Irish Academy*, 82B, 153 – 167.
Feehan, J. 1982b. The Old Red Sandstone rocks of the Slieve Bloom and northeastern Devils bit Mountains, Counties Laois, Offaly, and Tipperary. *Journal of Earth Sciences Royal Dublin Society,* 5, 11-30.
Feehan, J. 1983. *Laois, an environmental history.* Ballykilcavan Press, Stradbally, Ireland.
Fitzsimons, V. and Wright, G. (2000. *An assessment of the quality of public and group scheme groundwater supplies in County Laois*. Unpublished Report. Geological Survey of Ireland.
Flegg, A. (1980). Brick clays at Tinwear, County Laois. Extracts from the Minerals Inventory of the Geological Survey of Ireland, with some comments.
Gatley, S., Somerville, I., Morris, J.H., Sleeman, A.G. and Emo, G. (Ed. A.G. Sleeman) (2005). *Geology of Galway-Offaly. A geological description of Galway-Offaly and adjacent parts of Westmeath, Tipperary, Laois, Clare and Roscommon to accompany the bedrock geology 1:100,000 scale map series, Sheet 15, Galway-Offaly*. Geological Survey of Ireland.
Griffith, R. (1814). *Geological and mining report on the Leinster Coalfield*. Royal Dublin Society.
Hardman, E.T. 1881. Explanatory Memoir on the Geology of the Leinster Coalfields, to accompany parts of Sheets 127, 128, 136, 137, 145, 146, 147, 155, 156, and 166 of the Maps of the Geological Survey of Ireland, with Palaeontological notes by W.H. Baily*, Memoirs of the Geological Survey of Ireland,* 96pp.
Heery, S. (2007). A survey of tufa-forming (petrifying) springs in the Slieve Bloom, Ireland. A Report for Offaly and Laois County Councils.
Higgs, K.T. (1986). The stratigraphy of the Namurian rocks of the Leinster Coalfield. *Geological Survey of Ireland Bulletin* **3**, 2576-276.
Higgs, K.T. and O'Connor, G. (2005). Stratigraphy and palynology of the Westphalian strata of the Leinster Coalfield, Ireland. *Irish Journal of Earth Sciences* **23**, 65-84.
Holland, C.H. and Smith, D.G. (1979). Silurian rocks of the Capard inlier, county Laois. *Proceedings of the Royal Irish Academy* **79B**, 99-113.
Howes, M.J. 1991. *Mineral Resources of County Laois*. Internal Report, Geological Survey of Ireland.
Jukes, J.B. and Kinahan, G.H. 1859. Explanations to accompany Sheet 128 (Formerly Quarter sheet 35 S.E.) of the Maps of the Geological Survey oflreland, illustrating parts of the County of Kildare and Queen's County. *Mem. geol. Surv. Ire.* 31pp.
Jukes, J.B. and Wynne, A.B. 1860. *Explanations to accompany Sheet 135 of the Maps of the Geological Survey of Ireland illustrating parts of the Co. of Tipperary and of King 's and Queen's Counties, with Palaeontological Notes by W.H.Baily.* Memoirs of the Geological Survey of Ireland, 32pp.
Keegan, J. and Feehan, J. (1981). Palynofloras from Tournaisian lacustrine and tidal sequences in Slieve Bloom, Counties Laois and Offaly. *Geological Journal* **16**, 271-85.
McConnell, B. and Philcox, M. (1994). *A geological description to accompany the Bedrock Geology 1:100,000 scale map series, Sheet 16, Kildare-Wicklow*. Geological Survey of Ireland, 70pp.
McHugh, M. and Wright, G. 2000. Kyle & Orchard Springs. Groundwater Source Protection Zones. *Published by Geological Survey of Ireland and Laois County Council.*
McConnell, B., Philcox, M.E., Sleeman, A. G., Stanley, G., Flegg, A.M., Daly, E.P. and Warren, W.P. 1994. *Geology of Kildare - Wicklow. A geological description to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 16, Kildare - Wicklow. Edited by B. McConnell*, Geological Survey of Ireland, 57pp.
Misstear, B.D.R., E.P. Daly, Daly, D. and J.W. Lloyd (1980). The groundwater resources of the Castlecomer Plateau. Geological Survey of Ireland Report Series RS 80/3, 31 pp.
Nevill, W.E. (1956). The Millstone Grit and Lower Coal Measures of the Leinster Coalfield. *Proceedings of the Royal Irish Academy* 58B (1), 1-16 + 5 plates.
O'Conor, K. 1996. Dunamase Castle. The Journal of Irish Archaeology, 7, 97-115.
O'Kelly, J. (1866). *Explanations to accompany sheets 117 and 118 of the maps of the Geological Survey of Ireland, illustrating a portion of the King's and Queen's Counties and the counties of Galway and Tipperary*. Dublin, HMSO.

O'Kelly, J. and Baily, W.H. (1862). *Explanations to accompany Sheet 127 of the Maps of the Geological Survey of Ireland, illustrating a portion of the Queen's County.* Revised Edward T. Hardman 1879; Silurian revised J.R. Kilroe 1901. Dublin, HMSO.

O'Kelly, J. and Wynne, A.B.(1866). *Explanations to accompany sheets 117 and 118 of the maps of the Geological Survey of Ireland, illustrating a portion of the King's and Queen's Counties and the counties of Galway and Tipperary*. Silurian revised J.R. Kilroe 1901. Dublin, HMSO, 32pp.

O'Meara, M. (1964). *Leinster Coalfield, 1959-1963*. Unpublished drilling report, Geological Survey of Ireland.

Orr, P.J. and Briggs, D.E.G. (1999). Exceptionally preserved conchostracans and other crustaceans from the Upper Carboniferous of Ireland. *Spec. Pap. Palaeontol. Ser.* **62**, 5-68.

Orr, P.J. and Briggs, D.E.G. and Parkes, M.A. (1996). The 'Castlecomer Fauna': a new *Konservat-Langerstätte* from the Upper Carboniferous of Ireland. *Spec. Pap. Palaeontol. Ser.* **15**, 93-106.

Somerville, I.D. and Cozar, P. 2005. Late Asbian to Brigantian (Mississippian) foraminifera from southeast Ireland: comparison with northern England assemblages. *Journal of Micropalaeontology*, 24: 131–144.

Stanley, G., Gallagher, V., Ní Mhairtín, F., Brogan, J., Lally, P., Doyle, E., and Farrell, L. (2010). Historic Mine Sites – Inventory and Risk Classification, Volume 1: A joint study carried out by The Environmental Protection Agency and The Geological Survey of Ireland. EPA, Wexford.

Tobin Consultants, 2010. Establishment of Groundwater Source Protection Zones - Portlaoise Water Supply Scheme Meelick Borehole. *Prepared by:* Coran Kelly, Robert Meehan and Jenny Deakin. *Published by Geological Survey of Ireland and Laois County Council.*

Tietzsch-Tyler, D., Sleeman, A. G., McConnell, B.J., Daly, E.P., Flegg, A.M., O'Connor, P.J., Philcox, M.E. and Warren, W.P. 1994. *Geology of Carlow- Wexford, a geological description to accompany the Bedrock Geology 1:100,000 Map Series, Sheet 19, Carlow- Wexford.* Geological Survey of Ireland, 56pp.

Wright, G. 2000. Swan Water Supply Scheme. Groundwater Source Protection Zones. *Published by Geological Survey of Ireland and Laois County Council.*

Wright, G. (2001). *County Laois groundwater protection scheme – summary report*. Geological Survey of Ireland.

GEOLOGICAL REFERENCES ON A NATIONAL OR REGIONAL TOPIC WITH INFORMATION CITED ON SITES OR AREAS IN LAOIS

ALLEN, J.R.L. 1960. Cornstones. *Geological Magazine*, 97, 43.

ALLEN, J.R.L. 1965. A review of the origin and characteristics of Recent alluvial sediments. *Sedimentology*, 5, 89-191.

ANDREW, C.J. 1992. Basin development chronology of the lowermost Carboniferous strata in the Irish north-Central Midlands, *In*: Bowden, A.A., Earls, G., O'Connor, P.G. and Pyne, J.F. 1992 (eds)*. The Irish Minerals Industry 1980 - 1990,* Irish Association for Economic Geology, 143-169.

ANDREW, C.J. 1993. Mineralization in the Irish Midlands, *In*: Patrick, R.A.D. and Polya, D.A. (eds) *Mineralization in the British Isles,* Chapman and Hall, London, 208-269.

ANON. 1998. *The 'Top 55' Deposits*. Exploration and Mining Division Ireland Publication MP 3/99, 14pp. Geological Survey of Ireland **73**

BEESE, A.P. BRÜCK, P.M., FEEHAN, J. and MURPHY, T. 1983. A silica deposit of possible Tertiary age in the Carboniferous Limestone near Birr, County Offaly, Ireland. *Geological Magazine*, 120, 331-40.

BISHOPP, D.W. and McCLUSKEY, J.A.G. 1948. Sources of industrial silica in Ireland. *Geol. Surv. Ire.* book Series 21, 3-23.

BRITISH MINING CONSULTANTS LTD. 1982. *Report on Irish Coal to the Minister for Industry and Energy, Republic of Ireland,* 3 vols.

BRITISH MINING CONSULTANTS LTD. 1982. *Report on Irish coal.* Unpubl. Rep. to Geol. Surv. Ire. Vol. 1 & 2.

BROWN, C. and WILLIAMS, B. 1985. A gravity and magnetic interpretation of the structure of the Irish Midlands and its relation to ore genesis, *Journal of the Geological Society of London*, 142, 1959-1975.

BRÜCK, P.M. 1985. The Geology of the country between Slieve Aughty, the Silvermines-Devilsbit Mountains and Slieve Bloom, Central Ireland*., Department of Geology, University College Cork, Occasional Report series,* RS85/12, 60pp.

BRUCK, P.M., GARDINER, P.R.R., MAX. M.D. & STILLMAN, C.J. with contributions from BALL, D., CLAYTON, G., HAUGHEY, N., SEVASTOPULO, G.D. & BURNETT, R. 1989. *Thermal maturation levels in the Devonian and Carboniferous rocks in Ireland.* Geol. Surv. Ire. 36pp and map.

CARLISLE, P. 1992. *The stratigraphy of the Slieveardagh Coalfield Co. Tipperary* Unpublished M.Sc. thesis, National University of Ireland (UCC).

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, 111pp.

CLAYTON, G. HIGGS, K., KEEGAN, J.B. and SEVASTOPULO, G.D. 1978. Correlation of the palynological zonation of the Dinantian of the British Isles, *Palinologica,* 1, 137-147.

COLE, G.A.J. 1922. *Memoir and map of localities of minerals of economic importance and metalliferous Mines in Ireland.* Memoirs of the Geological Survey of Ireland, 155 pp.

CÓZAR, P. and SOMERVILLE, I.D. 2002. Problems in lithostratigraphic correlation of Upper Viséan rocks in the Carlow district, SE Ireland, *Abstracts, 45thrd Annual Irish Geology Research Meeting,* University College Dublin, p.27.

CRUISE, M.D. 1996. Replacement Origin of Crinkill Ironstone: Implications for Genetic Models of Base Metal Mineralization, Central Ireland. *Exploration and Mining Geology*, 5, 241-249.

DALY, D. and MISSTEAR, B.D.R. 1976. *A preliminary hydrogeological survey of the Castlecomer Plateau, S.E. Ireland.* Unpublished M.Sc. thesis, University of Birmingham.

DEVUYST, F.X. and LEES, A. 2001. The initiation of Waulsortian buildups in Western Ireland, *Sedimentology,* 48, 1121-1148.

EAGAR, R.M.C. 1964. The Succession and Correlation of the Coal Measures of south eastern Ireland. *CR. 5me. Cong. int. Strat. Geol. Carb.,* Paris 1963 359-374.

EAGAR, R.M.C. 1975. Neuere Arbeiten uber das Westfal in Irland. *Zbl. Geol. Palaont.* 1, 291-308.

EDWARDS, D. and FEEHAN, J. 1980. Records of Cooksonia-type sporangia from late Wenlock strata in Ireland. *Nature.* 287,41-42.

FLEGG, A. 1978. *Brick clays of County Offaly*. Unpublished Report, Geological Survey of Ireland, 3pp.

FLEGG, A.M. 1980. *Clay report.* Geological Survey of Ireland Unpublished Report.

GRAHAM, J.R. 2001a. Devonian. *In: The Geology of Ireland* (Ed) C.H. Holland, Dunedin Academic Press,

GRAHAM, J.R. 2001b. Variscan Structures *In*: C.H. Holland (Ed), *The Geology of Ireland.* Dunedin Academic

GRIFFITH, R. 1838. *Second Report of the Commissioners appointed to consider and recommend a general system of railways for Ireland*.

GRIFFITH, R. *et al.* 1811. *The Second Report of the Commissioners Appointed to enquire into the Nature of the several Bogs in Ireland and the Practicability of Draining and Cultivating them.*

HAUGHEY, N. & McARDLE, P. 1990. Vitrinite reflectance data from a preliminary study on selected Irish coal seams. *Geol. Surv. Ire. Bull.* 4, 201-209.

HITZMAN, M. 1992. *Bedrock geological maps of the Carboniferous of Central Ireland (1:100,000 scale.O.S. Sheets 12. 13, 15, 16, 17, 18 and 19*. Geological Survey of Ireland.

HOLLAND, C.H. and SMITH, D.G. 1979. Silurian rocks of the Capard Inlier, County Laois, *Proceedings of the Royal Irish Academy*, 99-110.

HOWES, M.J., BOLAND, M.A., FLEGG, A.M. and MacKENNA, K. 1988. Quarry directory of active quarries and pits in Ireland. *Geol. Surv. Ire. Rep. Ser.* RS88/3.

HUXLEY, T.H. AND WRIGHT, E.P. 1867. On a collection of Fossil Vertebrata from the Jarrow Colliery, County Kilkenny, Ireland. *Sci. Trans. R. Irish Acad.* 24, 1-19.

JOHNSTON, I.S. 1976. The Conodont Biostratigraphy of some Lower Carboniferous (Courceyan Stage) rocks of Central Ireland. Unpublished Ph.D. thesis, University of Dublin.
JOHNSTON, J.D., COLLER, D., MILLAR, G. and CRITCHLEY, M.F. 1996. Basement structural controls on Carboniferous-hosted base metal mineral deposits in Ireland, *In* : *Recent Advances in Lower Carboniferous Geology* (eds) Strogen, P., Somerville, I.D., and Jones, G.Ll.), Geological Society, Special Publication, No. 107, 1-21.
JONES, G.LL. and SOMERVILLE, I.D. 1996. Irish Dinantian biostratigraphy: practical application. *In*: Strogen, P., Somerville, I.D. and Jones, G.Ll (eds). *Recent Advances in Lower Carboniferous Geology*. Geological Society, Special Publication, No. 107, 253-262.
JUKES, J.B. and WYNNE, A.B. 1860. *Explanations to accompany sheet 145 of the Maps of the Geological*
JUKES, J.B., KINAHAN, G.H.K., BAILY, W.H. & DU NOYER, G.V. 1859. Explanation of Sheet 137 (F orillerly Quarter Sheet 40 N .E.) of the Maps of the Geological Survey oflreland. *Me m. Geol. Surv. Ire.* 54pp.
KANE, R. 1844. *Industrial Resources of Ireland.* Dublin. pp. xii + 417.
KANE, R., 1844. *The Industrial Resources of Ireland.* Dublin, 417pp.
KINAHAN, G.H. 1886. Irish marbles and limestones. *Scientific Proceedings of the Royal. Dublin Society*, **5**, 372- 444.
KINAHAN, G.H. 1888. Slates and clays (Bricks, etc.). *Scientific Proceedings of the Royal. Dublin Society*, **6**, 69-106.
KINAHAN, G.H. 1889. Economic geology of lreland. *JR. Geol. Soc. Jr.* 8.
LEES, A. 1964. The structure and origin of the Waulsortian (Lower Carboniferous) 'reefs' of west-central Eire. *Philosophical Transactions of the Royal Society London,* 247B, 483-531.
LEES, A. and MILLER J. 1985. Facies variation in Waulsortian buildups: Part 2 : Mid Dinantian buildups from England and North America, *Geological Journal,* 20, 159-180.
LEES, A. and MILLER, J. 1995. Waulsortian Banks, *Special Publications of the International Association of Sedimentologists*, 23, 191-271.
LEWIS, H. and COUPLES, G.D. 1999. Carboniferous basin evolution of central Ireland –simulation of structural controls on mineralization. *In*: McCaffrey, K.J.W., Lonergan, L and Wilkinson, J.J. (eds). *Fractures, Fluid flow and Mineralization* Geological Society, Special Publication No. 151, 233-245.
LOUGHLIN, W.E. 1976. Graptolites of Lower Wenlock age from the Slieve Bloom Inliers, Kinnity, Co. Offaly. *Irish Naturalists Journal*, 18, 282–283.
MacDERMOT, C.V. and SEVASTOPULO, G.D. 1972. Upper Devonian and Lower Carboniferous stratigraphical setting of Irish Mineralization. *Geological Survey of Ireland Bulletin*, 1, 267-280.
MARCHANT, T.R. and SEVASTOPULO, G.D. 1980. The Calp of the Dublin District, *Journal of Earth Sciences Royal Dublin Society,* 3, 195-203.
MILLER, J. 1986. Facies relationships and diagenesis in Waulsortian mudmounds from the Lower Carboniferous of Ireland and N. England. *In* : (eds) Schroeder, J.H. and Purser, B.H. *Reef diagenesis*, Springer-Verlag, Berlin, 311-335.
MORRIS, P. and MAX, M.D. 1995. Magnetic crustal character in Central Ireland. *Geological Journal*, 30, 49-68.
MURPHY, F.C. 1988. *Southern Uplands Workshop: Itinerary for Central Ireland*. Southern Uplands/Longford-Down Field Workshop guide, unpublished, 5pp.
MURPHY, F.C., ANDERSON, T.B., and 17 co-authors. 1991. An appraisal of Caledonian Suspect Terranes in Ireland. *Irish Journal of Earth Sciences*, 11, 11-41.
MURPHY, F.C., ANDERSON, T.B., DALY, J.S., GALLAGHER, V., GRAHAM, J.R., HARPER, D.A.T., JOHNSTON, J.D., KENNAN, P.S., KENNEDY, M.J., LONG, C.B., MORRIS, J.H. , O'KEEFFE, W.G., PARKES, M., RYAN, P.D., SLOAN, R.J., STILLMAN, C.J., TIETZSCH-TYLER, D., TODD, S.P. and WRAFTER, J.P. 1991. Appraisal of Caledonian suspect terranes in Ireland. *Irish Journal of Earth Sciences,* 10, 181-198.
NAGY, ZS. R., SOMERVILLE, I.D., BECKER, S., GREGG, J. M., WRIGHT, W. JOHNSON, A.W. and SHELTON, K. L. 2001. Petrology and biostratigraphy of carbonate rocks from the ?lower to upper Viséan (Lower Carboniferous) Milford Formation, Co. Carlow, Ireland. Abstracts, *Geological Society of America* Annual Meeting, Boston, November 5-8, 2001, A-443.

NEVILL, W.E. 1956. The Millstone Grit and Lower Coal Measures of the Leinster Coalfield, with an appendix on the non-marine fauna by R.M.C. Eagar. *Proc. R. Jr. Acad.* 58, Sect. B, 1-16.
NEVILL, W.E. 1957b. Sand volcanoes, sheet slumps and stratigraphy of part of the Slieveardagh Coalfield, Co. Tipperary. *Scient. Proc. R. Dub/. Soc.* 27, 313-324.
NEVILL, W.E. 1961. The Westphalian of lreland; Monaghan Coalfield by J.S.Jackson, with a note on the non-marine lamellibranch faunas and their zonal significance in the Leinster, Slieveardagh and Kanturk Coalfields by R.M.C. Eagar. *CR. 4me. Cong. int. Strat. Geol. Carb.,* Heerlen 1958 2, 453-460.
O'MEARA, M. 1964. *Leinster Coalfield, 1959-63 drilling report.* Geol. Surv. Ire. Unpubl. Rep. 169pp.
PHILCOX, M.E. 1984. *Lower Carboniferous lithostratigraphy of the Irish Midlands*, Irish Association for Economic Minerals. special publication, 89pp.
PHILCOX, M.E. 1994. Summary of the Succession in GSI Borehole 91-25 (Milford, Co. Carlow). *Geol. Surv. Ire. Unpubl. Rep.* 11 pp.
PHILCOX, M.E. 1994a. The Lower Carboniferous Geology of 1:100,000 Sheet 16, Kildare-Wicklow. *Geol. Surv. Ire. Unpubl. Rep.* 25pp.
SEVASTOPULO, G.D. 1981. Carboniferous (Silesian). *In:* Holland, C.H. (ed.). *A Geology of Ireland,* Dunedin Academic Press, Edinburgh, 289-312.
SEVASTOPULO, G.D. 1981. Upper Carboniferous. *In:* C.H. Holland (ed.) *A geology of Ireland.* Scottish Academic Press, 173-187.
SEVASTOPULO, G.D. and WYSE JACKSON, P.N. 2001. Carboniferous (Dinantian). *In:* Holland, C. H. (ed.). *The Geology of Ireland,* Dunedin Academic Press, Edinburgh, 241-288.
SLEEMAN, A. G. 1990. *Preliminary Geological Map of the Rathdowney District.* 1:100,000 scale Geological Map, Special Edition, Geol. Surv. Ire.
SMITH, D.G. 1979. The distribution of trilete spores in Irish Silurian rocks. *In*: Harris, A.L., Holland, C.H., and Leake, B.E. (eds). *The Caledonides of the British Isles-Reviewed* Geological Society of London Special Publication, 8, 423431.
SOMERVILLE, I.D. 2002. Review of Irish Lower Carboniferous (Mississippian) mud-mounds: depositional setting, biota, facies and evolution*. Society for Economic Paleontologists and Mineralogists Special Publication.* In press.
SOMERVILLE, I.D. and COZAR, P. 2002. Depositional setting and palaeocecology of *Siphonodendron* biostromes in Upper Viséan of SE Ireland. *Abstracts 46th Annual Meeting Palaeontological Association, Cambridge, December 15-18, 2002.*
SOMERVILLE, I.D., JONES, G.LL. and PHILCOX, M.E. 1996. *Supra-WaulsortianWorkshop*. Irish Association for Economic Geology. Dublin, p. 1-78.
STROGEN, P. 1974. The sub-Palaeozoic basement in Central Ireland. *Nature* 250, 562-563.
WYNNE, A.B. 1862. Explanation to accompany Sheets 126 and 125 (eastern part) of the maps of the Geological Survey of Ireland. *Memoirs of the Geological Survey of Ireland,* 40pp.
YOUNG, C.P. 1963/64. *Field mapping notes and unpublished interpretation of the sedimentary geology of the Old Red Sandstone of the Slieve Bloom Mountains.* Unpublished manuscript, 19 pp, 10 enclosures.

Appendix 3 - Bibliography – County Laois Quaternary References

These references all cover the Quaternary, or Ice Age, geology of County Laois. They are split into references specifically covering sites or features in County Laois, and a section of national or regional papers which have some data from or on County Laois included.

QUATERNARY REFERENCES WITH DIRECT REFERENCE TO LAOIS

ADAMS, A.L., 1878. On the recent and extinct Irish mammals. *Scientific Proceedings of the Royal Dublin Society*, **2**, 45-86.

BOWEN, D.Q., PHILIPPS, E.M., MCCABE, A.M., KNUTZ, P.C. and SYKES, G.A., 2002. New data for the last glacial maximum in Great Britain and Ireland. *Quaternary Science Reviews*, **21**, 89-101.

BRADSHAW, R.H.B. and BROWNE, P., 1987. Changing patterns in the post-glacial distribution of *Pinus sylvestris* in Ireland. *Journal of Biogeography*, **14**, 237-248.

CHARLESWORTH, J.K., 1928. The glacial retreat from central and southern Ireland. *Quarterly Journal of the Geological Society of London*, **84**, 293-344.

CHARLESWORTH, J.K., 1963a. Some observations on the Irish Pleistocene. *Proceedings of the Royal Irish Academy*, **62B**, 295-322.

CHARLESWORTH, J.K., 1963b. *Historical geology of Ireland*. Oliver and Boyd, 565 pp..

CHARLESWORTH, J.K., 1973. Stages in the dissolution of the last ice sheet in Ireland and the Irish Sea Region. *Proceedings of the Royal Irish Academy*, **73B**, 79-85.

CLOSE, M.H., 1867. Notes on the General Glaciation of Ireland, *Journal of the Royal Geological Society of Ireland*, **1**, 207-242.

CONRY, M., 1987. *Soils of County Laois*. Soil Survey Bulletin Number **41**. An Forás Talúintais, Dublin, 260pp.

COXON, P. and BROWNE, P., 1991. Glacial deposits of central and western Ireland. In: Ehlers, J., Gibbard, P.L. and Rose, J. (Editors), Glacial deposits in Great Britain and Ireland. Balkema, Rotterdam, pp. 355-365.

COXON, P. and MCCARRON, S., 2009. Cenozoic, Tertiary and Quaternary. In: Holland, C.H. and Sanders, I.H. (Editors) *The Geology of Ireland*. Second Edition, 355-396.

CRUSHELL, P., 2000. Irish Fen Inventory – a review of the status of fens in Ireland*. Irish Peatland Conservation Council*, Dublin, 100 pp.

DALY, D. AND MISSTEAR, B.D.R., 1976. *A preliminary hydrogeological study of of the Castlecomer Plateau, S.E. Ireland*. Unpublished MSc. Dissertation, University of Birmingham, 65pp.

DALY, D., LLOYD, J.W., MISSTEAR, B.D.R. and DALY, E.P., 1980. Fault control of groundwater flow and hydrochemistry in the aquifer system of the Castlecomer Plateau, Ireland. *Quarterly Journal of Engineering Geology,* **13**, 167-175.

DALY, E.P., 1983. Water in the landscape: groundwater resources. In: Feehan, J. (Editor) Laois: an environmental history. Ballykilcavan Press, Stradbally,

DEAKIN, J., FITZSIMONS, V., GATELY, C. and WRIGHT, G., 2004. *County Laois Groundwater Protection Scheme: Main Report*. Geological Survey of Ireland, Dublin, 48pp.

DOWLING, L.A. and COXON, P., 2001. Current understanding of Pleistocene stages in Ireland. *Quaternary Science Reviews*, **20**, 1631-1642.

FEEHAN, J., 1979. *The landscape of Slieve Bloom: a study of its natural and human heritage*. Dublin, Blackwater Press, 284pp.

FEEHAN, J., 1980. *The geology of Slieve Bloom and the northern Devilsbit Mountains.* Unpublished PhD. Thesis, Trinity College, Dublin.

FEEHAN, J., 1983. Laois: an environmental history. Ballykilcavan Press, Stradbally, 552pp.

FEEHAN, J., 2010. *The spirit of place: sacred character in the landscape of Laois*. O'More College of Design, 2010 Anthology, 68-124. Franklin, Tennesse.

FEEHAN, J., 2013. *The Geology of Laois and Offaly*. Offaly County Council in association with Laois County Council and the Geological Survey of Ireland, 405pp.,

FEEHAN, J. and O'DONOVAN, G., 1996. *The Bogs of Ireland*. The Environmental Institute, University College Dublin.
FEEHAN, J., O'DONOVAN, G., RENOU-WILSON, F. And WILSON, D., 2008. *The Bogs of Ireland: an introduction to the Natural, Cultural and Industrial Heritage of Ireland Peatlands* (Revised Edition). The Environmental Institute, University College Dublin.
FITZSIMONS, V. and WRIGHT, G., 2000. *An assessment of the quality of public and group scheme groundwater supplies in County Laois*. Unpublished report, Geological Survey of Ireland, Dublin, 32pp.
FLEGG, A., 1980. *Brick clays at Tinwear, County Laois*. Extracts from the Minerals Inventory of the Geological Survey of Ireland, Dublin.
GALLAGHER, C.J.D., 1991. *Geomorphology of alluvial heavy mineral distributions in the Slieve Bloom Mountains, central Ireland*. Unpublished PhD Thesis, National University of Ireland.
GALLAGHER, C.J.D., 1997. Alluvial heavy minerals as indicators of Late Pleistocene Ice Flow in the Irish Midlands. *Irish Geography*, **30(1)**, 37-48.
GALLAGHER, C.J.D. and THORP, M., 1995. The fluvial concentration of alluvial heavy minerals in the Slieve Bloom Mountains, central Ireland. *Irish Geography*, **28**, 14-34.
GALLAGHER, C.J.D., THORP, M. and STEENSON, P., 1996. Glacier dynamics around the Slieve Bloom Mountains, central Ireland. *Irish Geography*, **29(2)**, 67-82.
GEISSEL, H., 2006. *A road on the long ridge: in search of the ancient highway of the eiscir riada*. CRS Publications, 72pp.
GIBSON, P., 2007. *Heritage Landscapes of the Irish Midlands*. Geography Publications, Dublin, 340 pp.
HAMMOND, R.F. and DALY, D., 1987. *Offaly and West Kildare: Field Guide Number 10*. Irish Association for Quaternary Studies, Dublin.
HEERY, S., 2007. *A survey of tufa-forming (petrifying) springs in the Slieve Bloom, Ireland*. Unpublished report for Offaly and Laois County Councils.
KILROE, J.R., 1907. The River Shannon: its present course and geological history. *Proceedings of the Royal Irish Academy*, **26B**, 74-96.
MCCABE, A.M., 1985. Glacial geomorphology. In: Edwards, K.J. and Warren, W.P., (Editors), *The Quaternary history of Ireland*, pp. 67-93. Academic Press, London.
MCCABE, A.M., 1987. Quaternary deposits and glacial stratigraphy in Ireland. *Quaternary Science Reviews*, **6**, 259-299.
MCCABE A.M., 1991. The distribution and stratigraphy of drumlins in Ireland. In: Ehlers J, Gibbard PL, Rose J. (Editors), *Glacial deposits in Great Britain and Ireland*. Balkema, Rotterdam, 421-435.
MCCABE, A.M., 2008. *Glacial Geology and geomorphology: The Landscapes of Ireland*. Dunedin Academic Press, 274pp.
MISSTEAR, B.D.R., DALY, E.P., DALY, D. and LLOYD, J.W., 1980. *The groundwater resources of the Castlecomer Plateau*. Geological Survey of Ireland Report Series **RS 80/3**, 31pp.
MITCHELL, F.J.G., 2009. The Holocene. In: Holland, C.H. and Sanders, I.H. (Editors) *The Geology of Ireland*. Second Edition, 397-404.
MITCHELL, F. and DELANEY, C., 1997. The Quaternary of the Irish Midlands. *Irish Association for Quaternary Studies (IQUA) Field Guide Number 21*.
MITCHELL, G.F., 1998. The Ice Age. Chapter 2 of Mitchell, G.F. and Ryan, M., *Reading the Irish Landscape*, Townhouse Press, pp. 35-80.
O'KELLY, J., 1866. *Explanation to accompany Sheets 117 and 118 of the maps of the Geological Survey of Ireland, illustrating portions of the King's and Queen's Counties and the counties of Galway and Tipperary*. Geological Survey of Ireland, Dublin.
SOLLAS, W.J.,1896. A map to show the distribution of eskers in Ireland. *Scientific transactions of the Royal Dublin Society* **5** Series 2, 795-822.
STEENSON, P., 1993. *A study of preserved till fabrics east of the Slieve Bloom Mountains, County Laois*. Unpublished B.A. dissertation, Geography Department, University College Dublin.
SYNGE, F.M., 1983. The Quaternary Period: the Ice Age and its deposits. In: Feehan, J. (Editor) *Laois – An Environmental History*, 49-57.
SYNGE, F.M. and STEPHENS, N., 1960. The Quaternary period in Ireland-an assessment,

Irish Geography, **4**, 121-130.
TEDD, K., MISSTEAR, B.D.R., COXON, C., DALY, D., HUNTER WILLIAMS, N.H., CRAIG, M. and MANNIX, M, 2011. *Review of groundwater level data in the South Eastern River basin District. EPA STRIVE Programme 2007-2013*. Environmental Protection Agency, Dublin, 254pp.
TEDD, K., MISSTEAR, B.D.R., COXON, C., HUNTER WILLIAMS, N.H. and DALY, D., 2012. Hydrogeological insights from groundwater level hydrographs in SE Ireland. *Quarterly Journal of Engineering and Hydrogeology,* **45***, 19-30.*
TEDD, K.M., COXON, C.E., MISSTEAR, B.D.R., DALY, D., CRAIG, M., MANNIX, A. and HUNTER WILLIAMS, N.H., 2014. An integrated pressure and pathway approach to the spatial analysis of groundwater nitrate: a case study from the southeast of Ireland. *Science of the Total Environment*, **46**, 460-476
VAN DER MEER, J.J.M. and WARREN, W.P., 1997. Sedimentology of late glacial clays in lacustrine basins, Central Ireland. *Quaternary Science Reviews*, **16**, 779-791.
WARREN, W.P., 1987a. Pleistocene Geology. In: Hammond, R.F. and Daly, D. (Editors). *Offaly and West Kildare: Field Guide Number 10*. Irish Association for Quaternary Studies, Dublin, 14-16.
WARREN, W.P., 1987b. Site 8: Slieve Bloom. In: Hammond, R.F. and Daly, D. (Editors). *Offaly and West Kildare: Field Guide Number 10*. Irish Association for Quaternary Studies, Dublin, 49-56.
WARREN, W.P., 1991*. Ireland 1991: INQUA Commission on formation and properties of glacial deposits. Field Guide for excursion*, Geological Survey of Ireland, Dublin, 65pp.
WARREN, W.P., 1992. Drumlin orientation and the pattern of glaciation in Ireland. *Sveriges Geologiska Undersokning, Research Papers*, Series Ca **81**, 359-366.
WARREN, W.P. and ASHLEY, G., 1994. Origins of the ice contact stratified ridges (eskers) of Ireland. *Journal of Sedimentary Research*, **64A**, 433-449.
WARREN, W.P., SMYTH, M., VAN DER MEER, J.J.M. and HAMMOND, R.F., 2002. Chapter 2: Geology. In: Schouten, M.G.C. (Editor) *Conservation and restoration of raised bogs. Geological, Hydrological and Ecological Studies*. Dublin and Driebergen, Duchas, Staatsbosbeheer and the Geological Survey of Ireland, 16-31.
WYNNE, A.B., 1862. *Explanation to accompany Sheet 126 of the one-inch map of the Geological Survey of Ireland, illustrating portions of County Tipperary and the King's and Queen's Counties*. Geological Survey of Ireland, Dublin.

QUATERNARY REFERENCES ON A NATIONAL OR REGIONAL TOPIC WITH INFORMATION CITED ON SITES OR AREAS IN LAOIS

AALEN, F.H.A., WHELAN, K. and STOUT, M., 1997. *Atlas of the Irish Rural Landscape*. Cork University Press, 352pp.
ASHLEY, G.M. and WARREN, W.P., 1995. *Irish Eskers; Origin of ice contact stratified deposits. INQUA Commission on Formation and properties of Glacial Deposits Symposium and field excursion handbook*. Geological Survey of Ireland, Dublin. 59pp.
BELLAMY, D., 1986. *The Wild Boglands: Bellamy's Ireland*. Country House Publishers, Dublin, 178pp.
CARVILLE LEWIS, H., 1894. *Papers and notes on the glacial geology of Great Britain and Ireland*. Longman, Green and Company, London, 649pp.
CHARLESWORTH, J.K., 1963. Some observations on the Irish Pleistocene. *Proceedings of the Royal Irish Academy* **62B**, 295-322.
COLE, G.A.J., 1901. The topography and geology of Ireland. In: Coyne, W.P. (Editor) *Ireland Industrial and Agricultural*. Department of Agriculture, Dublin, 450 pp.
COXON, C.E., 1987a. The spatial distribution of turloughs. *Irish Geography* **20**, 11-23.
COXON, C.E., 1987b. Irish lake Marls. *Appendix 1 in 'Offaly and West Kildare' Irish Quaternary Association Field Guide,* No. 10, pp. 69-72.
COXON, P., 1993. Irish Pleistocence biostratigraphy. *Irish Journal of Earth Sciences* **12**, 83-105.

DAVIES, G.L., 1970. The Enigma of the Irish Tertiary. In: Stephens, N. and Glasscock, R.E. (Editors), *Irish Geographical Studies*. Queens University of Ireland, Belfast, pp. 1-16.
EDWARDS, K.J. and WARREN, W.P., 1985. *The Quaternary history of Ireland*. Academic Press, London.
EHLERS, J., GIBBARD, P. and ROSE, J., 1989 *Glacial Deposits in Great Britain and Ireland*. Balkema, Rotterdam.
FARRINGTON, A. and SYNGE, F.M., 1970. Three local studies of the Irish Pleistocene. In: Stephens, N. and Glasscock, R. (Editors) *Irish Geographical Studies in honour if E. Estyn Evans*. Queens University of Belfast, 49-52.
FEALY, R.M., GREEN, S., LOFTUS, M., MEEHAN, R.T., RADFORD, T., CRONIN, C. and BULFIN, M., 2009. *Teagasc EPA Soil and Subsoil Mapping Project –Final Report. Volumes I and II*. Teagasc, Kinsealy, Dublin.
FEEHAN, J., 2007. Periglacial ventifacts in Ireland. *Irish Geography*, **40(2)**, 206-209.
FEEHAN, J. and O'DONOVAN, G., 1996. *The Bogs of Ireland*. The Environmental Institute, University College Dublin.
FLINT, R.F., 1930. The origin of the Irish 'eskers'. *Geographical Review* **20**, 615-620.
GALLAGHER, P.H. and WALSH, T., 1943. Characteristics of Irish Soil Types – I. *Proceedings of the Royal Irish Academy* **42**, 205-250.
GARDINER, M. and RADFORD, T., 1980. Soil Associations of Ireland and their land-use potential. *Soil Survey Bulletin* **No. 36**, An Foras Taluintais, Dublin, 142 pp.
GLANVILLE, C. and WARREN, W.P., 1995. Eskers and associated gravels map of Ireland (Draft), 1:120,000 scale. Quaternary Section, Geological Survey of Ireland, Dublin.
GREENWOOD, S.L. and CLARK, C.D., 2008. Subglacial bedforms of the Irish ice sheet. *Journal of Maps* 2008, 332-357.
GREENWOOD, S.L. and CLARK, C.D., 2009a. Reconstructing the last Irish Ice Sheet 1: changing flow geometries and ice flow dynamics deciphered from the glacial landform record. *Quaternary Science Reviews* **28**, 3085-3100.
GREENWOOD, S.L. and CLARK, C.D., 2009b. Reconstructing the last Irish Ice Sheet 2: a geomorphologically-driven model of ice sheet growth, retreat and dynamics. *Quaternary Science Reviews* **28**, 3101-3123.
GREGORY, J.W., 1920. The Irish Eskers: Royal Society (London), *Philosophical transactions* Ser. B, v. 210, 115-151.
HAMMOND, R.F., 1981. The Peatlands of Ireland. *Soil Survey Bulletin* **No. 35** (to accompany the Peatland Map of Ireland, 1978). An Foras Taluintais, Dublin, 60pp.
HOLLAND, C.H., 2001. *The Geology of Ireland* (Second Edition). Edinburgh, Dunedin Academic Press, 532 pp.
HULL, E., 1878. *The physical geology and geography of Ireland*. London, 328pp.
KILROE, J.R., 1907. *A description of the soil geography of Ireland*. Her Majesty's Stationery Office, Dublin, 300pp.
KINAHAN, G. H., 1878. *Manual of the Geology of Ireland*. Dublin. 444pp.
KINAHAN, G.H, 1887a. Irish arenaceous rocks – sands, sandstones, grits, conglomerates, quartz rocks and quartzytes. *Scientific Proceedings of the Royal Dublin Society*, **5**, 507-620.
KINAHAN, G.H, 1887b. Irish marbles and limestones. *Scientific Proceedings of the Royal Dublin Society*, **5**, 372-444.
KINAHAN, G.H, 1888. Slates and clays of Ireland. *Scientific Proceedings of the Royal Dublin Society*, **6**, 143-166.
LEWIS, C.A., 1978. Periglacial features in Ireland: an assessment. *Journal of Earth Science, Royal Dublin Society* **1**, 135-142.
LEWIS, C.A., 1985. Periglacial features. In: Edwards, K.J. and Warren, W.P. (Editors) *The Quaternary History of Ireland.* Academic Press, London, pp. 95-113.
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.
MIR PELLICER, X., WARREN, W.P., GIBSON, P. and LINARES, R., 2012. Construction of an evolutionary deglaciation model for the Irish Midlands based on the integration of

morphostratigraphic and geophysical data analyses. *Journal of Quaternary Science*, **27(8)**, 807-818.
MITCHELL, G.F., 1980. The search for Tertiary Ireland. *Journal of Earth Sciences of the Royal Dublin Society*, **3**, 13-33.
PRAEGER, R.L., 1937. *The Way that I Went*. Collins Press, Dublin. 394pp.
SMITH, M.J. and KNIGHT, J., 2011. Palaeoglaciology of the last Irish Ice Sheet reconstructed from striae. *Quaternary Science Reviews* **30** (1-2), 147-160.
SYNGE, F.M., 1970. The Irish Quaternary: current views 1969. In: Stephens, N. and Glasscock, R.E. (Editors) *Irish Geographical Studies in honour of E. Estyn Evans*. Geographical Society of Ireland, Dublin.
WARREN, W.P., 1985. Stratigraphy. *In* Edwards, K.J. and Warren, W.P. (Editors), *The Quaternary history of Ireland*. Academic Press, London, pp. 39-65.
WATTS, W. A., 1970. Tertiary and interglacial floras in Ireland. In: Stephens, N. and Glasscock, R.E. (Editors), *Irish Geographical Studies in honour of E. Estyn Evans*, Queens University Belfast, pp. 17-33.
WATTS, W.A., 1985. Quaternary vegetation cycles. *In* Edwards, K. And Warren, W.P. (Editors), *The Quaternary History of Ireland*, Academic Press, London, 155-185.
WHITTOW, J.B., 1974. *Geology and scenery in Ireland*. Dublin, Penguin Books, 304 pp.
WILLIAMS, P.W., 1970. Limestone morphology in Ireland. In: Stephens, N. and Glasscock, R.E. (Editors), *Irish Geographical Studies in honour of E. Estyn Evans*, Geographical Society of Ireland, Dublin. 105-124.
WOODMAN, P. C., McCARTHY, M. and MONAGHAN, N. T. 1997. The Irish Quaternary fauna project. *Quaternary Science Reviews* **16**, 129-15.

Appendix 4 - Geological heritage versus geological hazards

Ireland is generally considered to be a country with very low risk of major geological hazards: there are no active volcanoes, Ireland's location on stable tectonic plates mean earthquakes are relatively rare and its recorded human history is not peppered with disastrous landslides, mudflows or other geological catastrophes. There are of course risks of one-off events, and this section looks at the record and nature of geological hazards in County Laois and the relationship of the County Geological Sites to those hazards.

The difference between human timescales and geological timescales can be difficult to comprehend but, for many geological processes, there are periods of sudden activity and major events, with quiet periods in between. The sites in this audit represent evidence of past geological environments and processes, such as the building of high mountain chains, ice sheets covering the land surface and so on. However, in Laois there are few sites representing the active geomorphological or land-forming processes of today, although some of the stratigraphical sites like Killeshin Glen, are actively eroding river valleys.

Landslides and bog flows
The Geological Survey of Ireland has been compiling national data on landslides in the past decade. There were 50 events recorded in Laois, the majority of which occurred in the Slieve Bloom uplands. http://www.gsi.ie/Programmes/Quaternary+Geotechnical/Landslides/

Flooding
There are two types of flooding which need consideration. River flooding occurs inland when the rainfall exceeds the capacity of the ground to absorb moisture, and the river channels cannot adequately discharge it to the sea. The OPW website, www.floods.ie, can be consulted for individual flood events in County Laois. Karstic flooding can occur when underground passages are unable to absorb high rainfall events. The Carboniferous limestone bedrock in County Laois is not known to become heavily karstified, like upland limestone areas such as the Burren or the Bricklieve Mountains, although significant karst sites occur at Sluggory Cross Roads and the Darkin Well, just outside Portlaoise.

Radon
Radioactive minerals and gases can potentially cause cancer, particularly where humans are exposed to high concentrations over prolonged periods. Radon gas can seep into homes and workplaces and can be carried in water supplies. A map showing the areas predicted to be at particular risk from radon in Ireland, called High Radon Areas, can be seen on the EPA website at http://www.epa.ie/radiation/#.VRu9OVROPcs. The Office of Radiological Protection, a division of the EPA, is responsible for radiological protection.

Groundwater pollution
Whilst not such an obvious hazard as physical collapses, flooding and landslides, the pollution of groundwater supplies carries a serious risk to human health. Laois is a county quite dependent on groundwater supplies, and therefore the risk is more serious than for most other counties. As the groundwater is largely contained within limestone, it should be noted that karstic springs are especially vulnerable to pollution since the flow is mainly within fissure conduits allowing rapid transmission of pollution from source to water supply. The opportunity for microbial attenuation of pollutants is far less in limestone fissures (as there are no natural barriers to stop pollutants) than it would be in granular deposits, which act as natural filters.

Appendix 5 - Data sources on the geology of County Laois

This section is a brief summary of relevant GSI datasets, to assist any enquiry concerning geology and to target possible information easily. The GSI has very many datasets, accumulated since it began mapping Ireland's geology in 1845. A Document Management System (called GOLDMINE) is freely available online, into which about half a million documents and maps have been scanned. This means that any user can search on screen for data of relevance to them. **Data is available free of charge**.

Key datasets include:

GOLDMINE (**G**SI **O**n**L**ine **D**ocument, **M**aps and **I**nformatio**N** **E**xplorer). The GSI online digital archive enables visitors to search the Geological Survey of Ireland online data archive database and download full-size resampled pdfs and/or original high resolution TIFF image files. The data consists of: Scanned Capture of 450,000 pages and maps, including all of GSI principal datasets, (Mineral Exploration Reports-Open File, Geotechnical Reports, boreholes & tests, Historic 6":1 mile and 1":1 mile Geological Maps, GSI Publications, Bulletins, Published and Unpublished Reports, Groundwater Well Hydrographs, Marine Maps, Airborne Geophysical Maps, Mineral Locality Reports and Mine Record Reports and Maps). The database runs on Oracle© and the stored imagery is currently 1.4TB in size.

https://secure.dcenr.gov.ie/goldmine/index.html

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. Sheets 15 and 16 covers most of County Laois.

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.

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 parts of Sheets 125, 126, 127, 128, 135, 136 and 137 cover County Laois. Each sheet or several sheets were accompanied by a Memoir which described the geology of that area in some detail. These still provide valuable records of observations even though interpretations may have changed with better geological understanding. Memoirs are in the GSI's Customer Centre library and scanned on GOLDMINE.

Historical geological mapping is now available via a website:
http://www.geologicalmaps.net/irishhistmaps/history.cfm

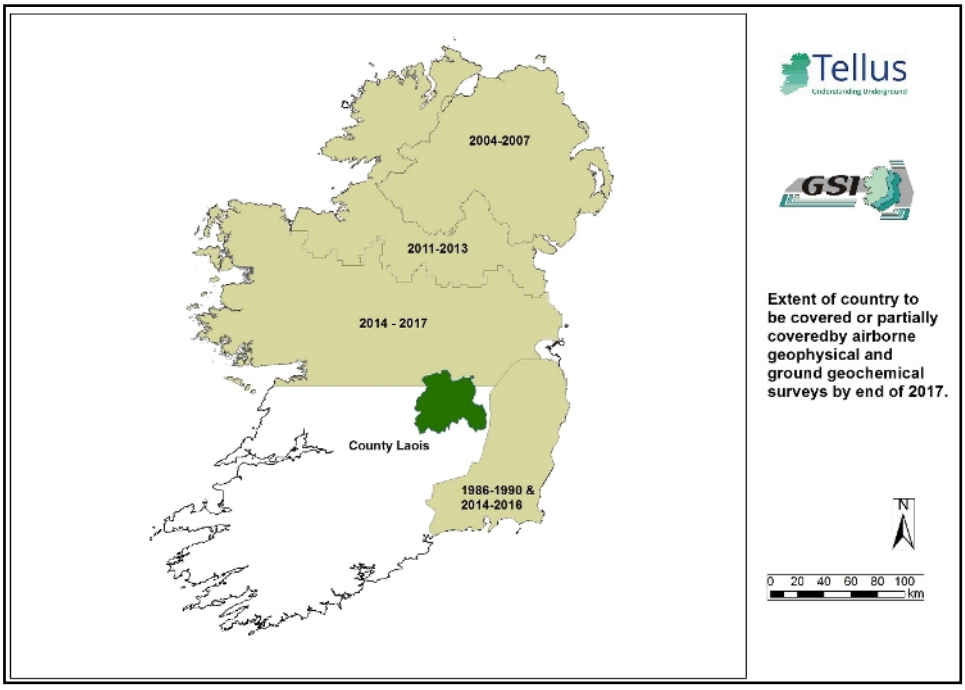
Open File Data
Each Mineral Prospecting Licence issued by the Exploration and Mining Division (EMD), currently of the Department of Communications, Energy and Natural Resources, carries an obligation on the exploration company to lodge records of the work undertaken, for the common good. These records 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. Licences relate to numbered prospecting areas, and these are available on a map from EMD. See also www.mineralsireland.ie

MinLocs Data
The MinLocs Database records all known mineral occurrences, however small, from GSI records, such as 19th century field sheets and Open File data.

Subsoils Mapping
Since a Groundwater Protection Scheme has been completed by GSI (2012) for the whole country, a modern map of the subsoil types and depths across County Laois exists, as well as the previously completed bedrock mapping. This provides a significant resource in general terms as well as for groundwater protection. Customised output is possible. Furthermore, detailed compilation of glacial geology datasets, including a revision published by GSI in late 2014, now provides more data. Digital mapping of many different datasets is now available via an easy to use public viewer on the GSI website: www.gsi.ie

Tellus Mapping
Tellus is a regional mapping project, combining airborne geophysical and geochemical surveys to provide geoscientific information for the island of Ireland.
Since 2004, more than 40,000 km^2 of the island of Ireland has been surveyed or partially surveyed through the **Tellus** surveys, which support mineral exploration, environmental management, agriculture and research activity. The Geological Survey of Ireland aims to complete Tellus surveying in 50% of the country by the end of 2017, with the view to completing the country in subsequent phases. This will include the northern portion of County Laois. Data will be freely available from www.tellus.ie



Tellus North Midlands Survey Area

Historic Mine Records
Abandonment plans and varied other material exists for the various mining ventures in the country.

Appendix 6 - Further sources of information and contacts

Sarah Gatley of the Geological Survey of Ireland, who is the Head of the Geological Heritage and Planning Programme, can be contacted in relation to any aspect of this report. Catherine Casey, the Heritage Officer of Laois County Council is the primary local contact for further information in relation to this report. Other contacts include the Conservation Rangers of the National Parks and Wildlife Service, currently in the Department of Arts, Heritage and the Gaeltacht. The names and phone numbers of current staff may be found in the phone book, or at www.npws.ie.

Web sites of interest

www.gsi.ie - for general geological resources
www.geology.ie – the website of the Irish Geological Association who run fieldtrips and lectures for members, including many amateur enthusiasts
www.earthscienceireland.org - for general geological information of wide interest
http://www.iqua.ie - for information, fieldtrips, lectures etc in relation to Ireland's Ice Age history
http://www.progeo.se/ - for information about ProGEO the European Association for the Conservation of Geological Heritage

Appendix 7 - Geoschol leaflet on the geology of County Laois

[see page 25 for information on Geoschol]

LAOIS

AREA OF COUNTY: 1,719 square kilometres or 663 square miles

COUNTY TOWN: Portlaoise

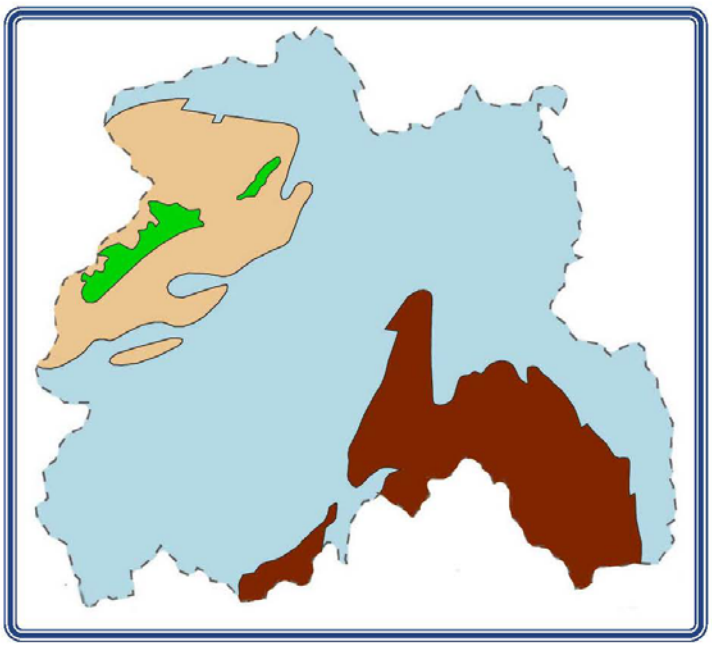
OTHER TOWNS: Abbeyleix, Mountmellick, Mountrath

GEOLOGY HIGHLIGHTS: Limestone quarries, Rock of Dunamase and the Stradbally Hills

AGE OF ROCKS: Silurian - Carboniferous, Pleistocene

Rock of Dunamase

Carboniferous limestone forms the Stradbally Hills and the Rock of Dunamase.



Geological Map of County Laois

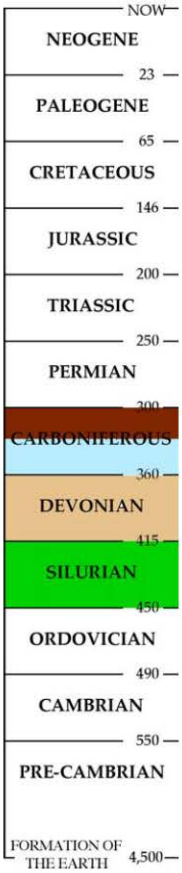
Green: Silurian; **Beige:** Devonian; **Light blue:** Lower Carboniferous limestone; **Brown:** Upper Carboniferous shales.

Geological history

The landscape of Co Laois is mostly rather low-lying. In the north-west lies the eastern part of the heavily wooded Slieve Bloom Mountains, which are formed of the oldest rocks in the county, while in the south-east is the northern tip of the Castlecomer Hills, formed of the youngest bedrock in the county.

The oldest rocks in the county occur in several patches towards the centre of the Slieve Bloom Mountains where erosion has stripped away the younger rocks, but they are only exposed in the banks of a few streams. These grey mudstones, siltstones and sandstones are Silurian in age, around 425 million years old (Ma), and were deposited on a deep ocean floor. Lying above them are red to brown mudstones, sandstones and pebble beds, with occasional peculiar knobbly limestones called 'cornstones'. All of these were deposited on river floodplains in an Equatorial semi-desert environment, with the 'cornstones' actually forming within the soils of the time. Spores are the

Waterfall on the River Barrow flowing over Carboniferous sediments in the Slieve Bloom Mountains



Geological timescale showing age of rocks in Laois.

only fossils that have been found, but they show that these rocks are of earliest Carboniferous age, just a little less than 360 Ma.

Soon after the start of the Carboniferous, sea level rose to flood across these low plains. The first of the marine rocks to be deposited were dark grey fossiliferous mudstones, but above these is a series of thick grey limestones which underlie much of the low ground across the county. At certain levels these limestones are quite fossiliferous, with shells of brachiopods and nautiloids, corals, fragments of crinoids, and rarer fossils such as trilobites. Mostly these limestones accumulated as horizontal layers on a fairly shallow sea floor but for a time, around 340 Ma, peculiar steep-sided limestone 'mud mounds' formed on the sea bed. Some of the younger layered limestones, around 325 Ma, are much darker in colour and were deposited in considerably deeper water. Although the limestones mostly form low ground across the centre of the county, they are well exposed in various working and disused quarries and on some of the low hills in the south of the county, notably the Rock of Dunamase.

The low hills in the south-east corner of the county are of younger Carboniferous rocks, between 320 and 315 Ma. The earliest of these particular rocks are black mudstones and

thin limestones, often containing patches of iron pyrite or 'fools gold', that accumulated in deep, poorly oxygenated water. Above them lie sandstones and mudstones that were deposited by river deltas as sea level fell. Younger still is a series of sandstones and mudstones with thin coal seams, formed from plant material buried in a swamp, that formed the basis of the now defunct Leinster Coalfield.

As elsewhere across Ireland, the ice sheets and glaciers of the last Ice Age have modified the Laois landscape, although in a more subdued way than in some of the more mountainous regions of Ireland. The main effect has been to blanket much of the lowlands with glacial till, or 'boulder clay'.

Laois fossils

Fossils, particularly corals and brachiopods, are common in the Carboniferous limestones exposed in quarries and hillside crags. Slightly younger fossils, particularly plant remains and marine animals called goniatites (right), occur in some of the rocks of the Leinster Coalfield but since the abandonment of the coal mines these rocks are seldom exposed.

Mining & Building Stones

Flagstone Quarry (Upper Carboniferous) at Wolfhill

Many small quarries were opened in the Carboniferous limestones for building stone and agricultural lime but today only the large Ballyadams Quarry is still worked for limestone aggregate and agricultural lime. Mining of high grade coal formerly took place in the Leinster Coalfield, but all of the seams are thin and none of the mines, underground or opencast, are still working.

Map adapted with permission from Geological Survey of Ireland 1:1,000,000 map 2003.
Image credits: Mike Simms 1, 4 (bottom); Kevin Higgins 3 (licensed for reuse under the Creative Commons Licence).

Appendix 8 - Glossary of geological terms

Geological term	Definition
Alluvial Deposit	unconsolidated clay, silt, sand and gravel, deposited by a body of running water.
Alluvium	a term for unconsolidated clay, silt, sand and gravel, deposited by a body of running water.
Anthracite	a coal of high rank, that is high in carbon and low in gas and volatile components.
Aquifer	a permeable water saturated rock unit.
Artesian Well	a well from which water flows under natural pressure without pumping.
Basin	low areas in the Earth's crust, of tectonic origin, in which sediments have accumulated.
Bedrock	a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
Bioclast	fragment of a shell or fossil forming part of a sedimentary rock.
Blanket Bogs	bog covering a large, fairly horizontal area, which depends on high rainfall or high humidity, rather than local water sources for its supply of moisture.
Boulder Clay	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock or silt. Also known as till.
Bryozoa	invertebrates belonging to the phylum Bryozoa, ranging from Ordovician to present, often found as frond-like fossils.
Calcite	a pale mineral composed of calcium carbonate, which reacts with dilute hydrochloric acid.
Calp	dark grey, fine-grained, muddy limestone.
Channel	a landform consisting of the outline of a path of relatively shallow and narrow body of fluid, most commonly the confine of a river, river delta or strait.
Chert	a sedimentary rock comprising of very fine-grained quartz.
Chironomid	a family of flies, similar in size and form to mosquitoes.
Coal Seam	a coal seam is a strata or bed of coal, outcropping over a wide area, but not necessarily very thick.
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.
Crinoid	a variety of sea-urchin, with a long flexible stem, usually anchored to the sea-floor and a body cup with arms which may be branching (a sea lily).
Diatom	a major group of algae, among the most common types of phytoplankton.
Dip/dipping	when sedimentary strata are not horizontal they are dipping in a direction and the angle between horizontal and the inclined plane is measured as the dip of the strata or beds.
Doline	circular/oval closed depression found in karst terrain.
Dolomite	calcium- and magnesium-bearing carbonate mineral; also a rock composed of the mineral.
Drumlin	a streamlined mound of glacial drift, rounded or elongated in the direction of the original flow of ice.
Echinoderm	marine organisms with interlocking plates (skeletal) covered by spines.
Erratic	a large rock fragment that has been transported, usually by ice, and deposited some distance from its source. It therefore generally differs from the underlying bedrock, the name "erratic" referring to the errant location of such boulders. Tracing their source can yield important information about

	glacial movements.
Esker	an elongated ridge of stratified sand and gravel which was deposited in a subglacial channel by meltwaters. Eskers are frequently several kilometres in length.
Fan	a usually triangular deposit of sand and gravel deposited by a glacial stream, either under a lake or under air.
Fault	planar fracture in rocks across which there has been some displacement or movement.
Floodplain	a flat or nearly flat land area adjacent to a stream or river that experiences occasional or periodic flooding.
Fluvial	pertaining to a river or stream.
Glacial	of or relating to the presence and activities of ice or glaciers.
Glaciofluvial	pertaining to the meltwater streams flowing from wasting glacier ice and especially to the deposits and landforms produced by such streams.
Grading	a sorting effect with the coarsest material at the base of the bed and finest grained material at the top.
Greywacke	an impure sandstone, characterised by poorly-sorted, angular grains in a muddy matrix, that was deposited rapidly by turbidity currents (submarine avalanches).
Hum	residual, isolated hill formed through karst processes, sometimes stubby and smoothed out by later erosional processes, e.g. glaciation.
Hummock	a small hill or knoll in the landscape, which may be formed by many different processes.
Ice margin	the edge of an ice sheet or glacier.
Igneous	a rock or mineral that solidified from molten or partially molten material i.e. from a magma.
Inlier	area of older bedrock completely surrounded by younger bedrock.
Interglacial	the time interval between glacial stages, or pertaining to this time.
Joint	a fracture in a rock, which shows no evidence of displacement.
Lava	magma extruded onto the Earth's surface, or the rock solidified from it.
Limestone	a sedimentary rock consisting chiefly of calcium carbonate (CaCO3), primarily in the form of the mineral calcite.
Lithology	the description of rocks on the basis of such characteristics as colour, composition and grain size.
Meander	a bend in a sinuous watercourse or river which forms when moving water in a stream erodes the outer banks and widens its valley, and the inner part of the river has less energy and deposits fine sediment.
Meltwater	water from melted snow or ice.
Meltwater channel	a channel cut by glacial meltwater, either under, along or in front of an ice margin.
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.
Metasediments	metamorphosed sediments.
Moraine	any glacially formed accumulation of unconsolidated debris, in glaciated regions, such as during an ice age.
Ore	a mineral which is concentrated enough to be exploited by mining.
Outcrop	part of a geologic formation or structure that appears at the surface of the Earth.
Raised Bogs	an area of acid, peaty soil, in which the centre is relatively higher than the

	margins.
Shaft	a vertical or inclined hole dug in a mine for access, ventilation, for hauling ore out or for pumping water out.
Shale	A fine-grained sedimentary rock, formed by the compaction and lithification of clay, silt, or mud. It has a finely laminated (composed of layers) structure that gives it a fissility, or tendency to split along bedding planes.
Spring	the point where an underground stream reaches the surface.
Stratigraphy	the study of stratified (layered) sedimentary and volcanic rocks, especially their sequence in time and correlation between localities.
Terrace	terraces are remnants of the former floodplain of a stream of river, formed by the downcutting of a river or stream channel into and the abandonment and lateral erosion of its former floodplain.
Till	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock as sand, silt or clay.
Volcaniclastic	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.
Volcanic Rock	any rock produced from volcanic material, e.g. ash, lava.
Waulsortian	Lower Carboniferous age limestones consisting of skeletal debris and carbonate mud. The sediments commonly form individual and coalesced mounds with depositional dips of 20-40 degrees. Named after rocks in Belgium.