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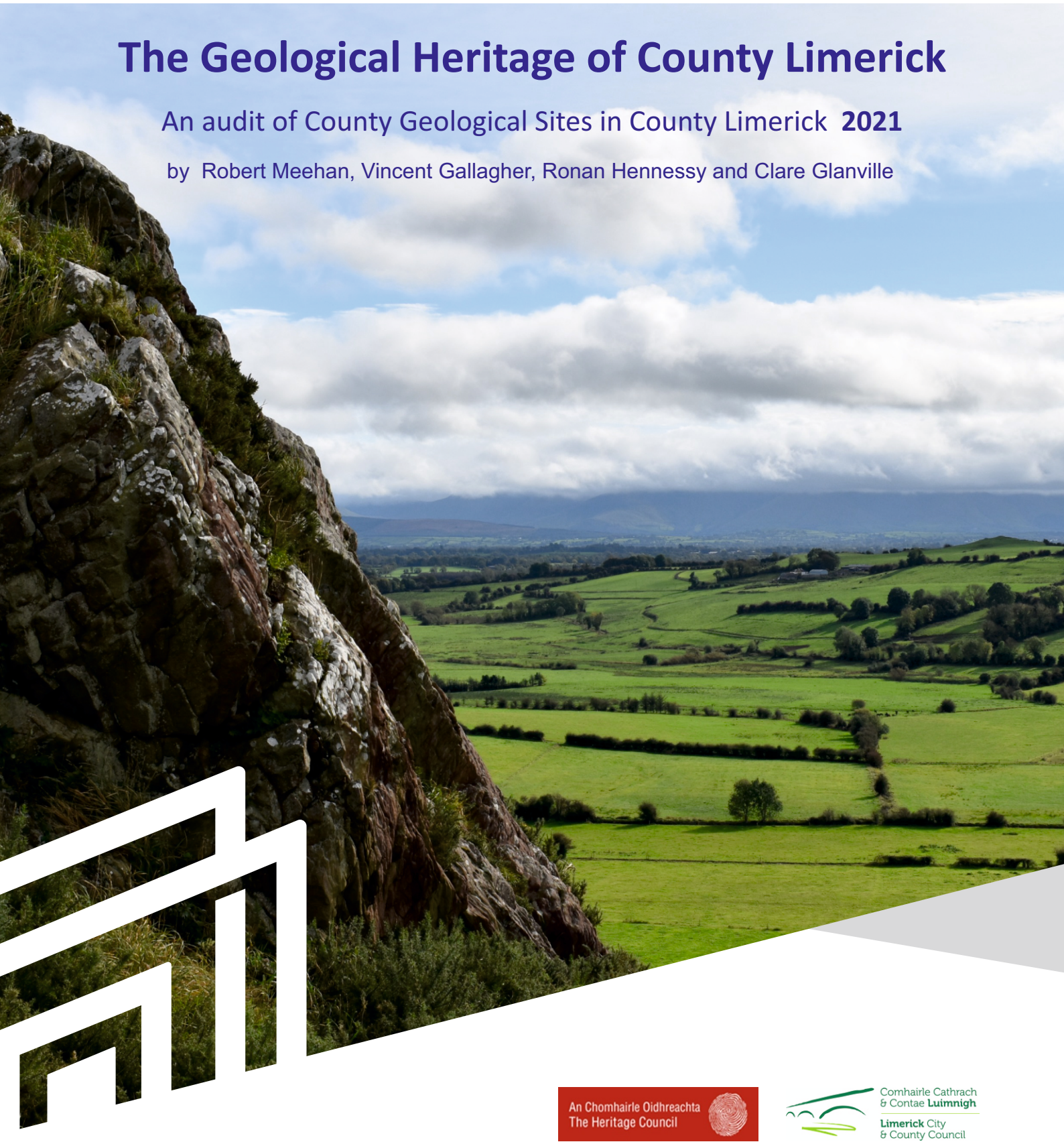
The Geological Heritage of County Limerick

An audit of County Geological Sites in County Limerick **2021**

by Robert Meehan, Vincent Gallagher, Ronan Hennessy and Clare Glanville



An Chomhairle Oidhreachta
The Heritage Council

Comhairle Cathrach & Contae Luimnigh
Limerick City & County Council

Geological Survey Ireland is a division of the Department of the Environment, Climate and Communications

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& Contae **Luimnigh**

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(Front Cover image: 'Trachyte plug forming Kilteely Hill stands out from the lowlands underlain by Lower Carboniferous limestone and basalt')

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Craggs Turlough
Gorteennamrock Fen
Knocksouna
Lough Gur

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Not represented in County Limerick

IGH 3 Carboniferous to Pliocene Palaeontology
Site name
Foynes Island
Foynes Road Sections
Kilmeedy

IGH 4 Cambrian-Silurian
Site name
Not represented in County Limerick

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Site name
Not represented in County Limerick

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Executive Summary

County Limerick is widely known for its unspoilt landscape and stunning scenery, but relatively few people are aware of its rich geodiversity which is considered in this audit report as the geological heritage of the county. For its relatively modest size, County Limerick has an extensive and diverse range of geological heritage sites. Many of them represent the primary geological foundation of Old Red Sandstone rocks, forming the uplands, and Carboniferous limestone that underlies the county's extensive lowlands. The upland areas feature a range of different sandstone strata while karstic landscape features and glacial landforms abound on the lowlands. The City and County Council's support for this audit is critical in raising the profile of geological heritage in County Limerick and for maximising its potential for foreign and domestic tourism and for the people of the county.

This report documents what are currently understood by the Geoheritage Programme (Irish Geological Heritage Programme) of Geological Survey Ireland (GSI) to be the most important geological sites within County Limerick. It proposes them as County Geological Sites (CGS), for inclusion within the County Development Plan (CDP). The audit provides a reliable, field-based study of sites to replace a provisional outline list of sites based on desk study that was previously adopted in the previous 2010-2016 CDP.

County Geological Sites do not receive statutory protection like Natural Heritage Areas (NHA) but receive an effective protection from their inclusion in the planning system. 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. They may have been notified to the National Parks and Wildlife Service (NPWS) by Geological Survey Ireland for designation as a Natural Heritage Area (NHA). Designation would only occur once due survey and consultation with landowners is complete. In parts of the county, some of the sites fall within existing pNHAs and SACs where the ecological interest is actually founded upon the underlying geodiversity.

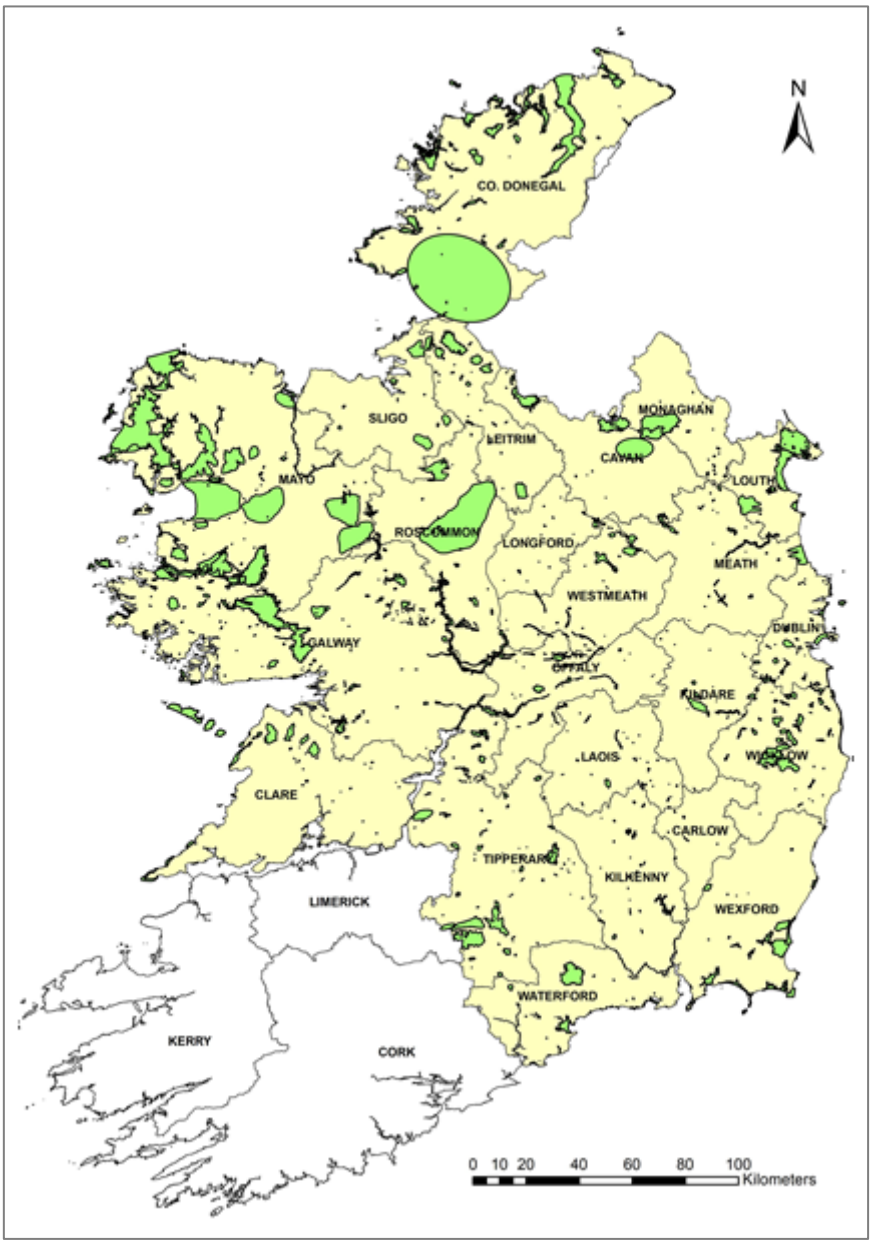
The commission of this audit and adoption of the sites within the CDP ensure that County Limerick follows a now established and effective methodology for ensuring that geological heritage is not ignored in the absence of progress with designation of geological NHAs at national level. It brings County Limerick to the forefront 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, Area Engineers and the Planning Department of Limerick City and County Council. It should also be made available via the County Council website for the people of County Limerick. A chapter of the report includes recommendations on how to best present and promote the geological heritage of County Limerick to the people of the county. It will also inform the work of Geological Survey Ireland Geoheritage Programme, and be made available at www.gsi.ie.

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, and as funding permits. The contents also provide the essential ingredients for a public-oriented book or other publications on the geological heritage of County Limerick, if the funding can be found to produce them.

1. County Limerick in the context of Irish Geological Heritage

This report brings County Limerick to the forefront of geological heritage within Ireland, as the majority of the counties have now commissioned such an audit within the scope of the county-based Heritage Plan, and Limerick has so far not received the attention that its geological heritage deserves. The provision of reliable data in a very cost-effective manner should 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, albeit only with advisory capacity (within the context of County Development Plans) and no statutory protection where it is required in their own right, although the statutory County Development Plan provides capacity to preserve sites where necessary.



Counties shown as yellow have been audited prior to 2021. County Geological Sites in green.

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 (as amended), Planning and Development Regulations 2001 (as amended), and the Wildlife (Amendment) Act 2000 and the National Heritage Plan (2002). Geological Survey Ireland 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 Geoheritage Programme in Geological Survey Ireland complements other nature conservation efforts of the last decade, by identifying and assessing Ireland's geodiversity, building towards a national inventory of geological heritage sites. 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 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 Geoheritage Programme fills a void which has existed since the end of the Areas of Scientific Interest scheme, listed by An Foras Forbartha in 1981.

The Geoheritage 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 IGH themes:

IGH THEMES

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

A fundamental approach for NHA selection 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 Geological Survey Ireland'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 Limerick City and County 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 listing in the County Development Plan.

Currently, in 2021, a Master List of candidate CGS and NHA sites is being used in Geological Survey Ireland, 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 completed along with a Theme Report. Due to various factors, none have yet been formally designated. Therefore, inclusion of all sites as County Geological Sites in Limerick City and County's planning system will ensure that the sites are not inadvertently damaged or destroyed through lack of awareness of them outside of the Geoheritage Programme in Geological Survey Ireland.

The sites proposed here as County Geological Sites have been visited and assessed specifically for this project, and represent our current state of knowledge. The audit 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 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 Limerick County Geological Sites

Site Name	Designation	IGH Primary	IGH Secondary	IGH Third	GIS Code
Ballyhoura Mountains	County Geological Site	IGH7			LK001
Ballylanders-Kilfinnane Moraine	County Geological Site	IGH7			LK002
Ballymorrisheen Fen	County Geological Site	IGH1	IGH16		LK003
Caherconlish Quarry	County Geological Site	IGH11	IGH8		LK004
Cappagh Fen	County Geological Site	IGH1	IGH16		LK005
Carrigkerry Esker	County Geological Site	IGH7			LK006
Carrigogunnell	County Geological Site, may be recommended for Geological NHA	IGH8			LK007
Clare Glens	County Geological Site	IGH10	IGH14	IGH7	LK008
Craggs Turlough	County Geological Site	IGH1	IGH16		LK009
Cromwell Hill	County Geological Site	IGH11	IGH8		LK010
Eyon Cross Quarry	County Geological Site	IGH8			LK011
Foynes Island	County Geological Site	IGH9	IGH3		LK012
Foynes Road Sections	County Geological Site	IGH8	IGH3		LK013
Galbally	County Geological Site, may be recommended for Geological NHA	IGH7			LK014
Galtee Mountains	County Geological Site, recommended for Geological NHA	IGH7			LK015
Gorteennamrock Fen	County Geological Site	IGH1	IGH16		LK016
Grange	County Geological Site	IGH8			LK017
Kilmeedy	County Geological Site	IGH8	IGH3		LK018
Kilteely Hill	County Geological Site	IGH11	IGH8		LK019
Knockderc Quarry	County Geological Site	IGH11			LK020
Knockseefin	County Geological Site	IGH8			LK021
Knocksouna	County Geological Site	IGH1	IGH16	IGH7	LK022
Linfield Quarry	County Geological Site	IGH8			LK023
Lough Gur	County Geological Site	IGH1	IGH16	IGH8	LK024
Mantlehill (Deel River Section)	County Geological Site	IGH8			LK025
Mungret Quarry	County Geological Site	IGH8	IGH15		LK026
N18 Road Cut Ballykeeffe	County Geological Site	IGH8			LK027
St. Bridget's Well – Newcastle West	County Geological Site	IGH16			LK028
Tobergal	County Geological Site	IGH16			LK029
Tory Hill	County Geological Site	IGH7	IGH14		LK030

1.2 Rejected, Combined and Renamed Sites

A range of sites was previously flagged for consideration in the IGH Master site list and some were assessed in this audit as unsuitable for County Geological Site status. Similarly, a wide range of additional sites was assessed in the audit, based on the authors' expert knowledge of County Limerick's geology, especially in the lowland limestone / karst areas. Here, a number of karstic features have been mapped for the first time in recent years, documenting significant turloughs and associated features. It was also known, for example, that some quarry localities had not been adequately considered in the preparation of the IGH Master Site List. Other sites were visited on speculation during fieldwork. It should be noted that in a number of cases in Limerick, along with other counties, the original expert panel process of developing a Master Site List, which was largely desk based, has created some of the issues described below. Some of the sites were poorly defined in the first instance and there were multiple names used for the same site in different themes. The rejected, or otherwise modified, sites are listed below with brief notes as to why they were assessed as unsuitable for inclusion.

Curraghturk

The Curraghturk site was listed as a potential County Geological Site in the IGH 7 Quaternary Theme Master List, as well as on the original An Foras Forbartha Sites of Scientific Interest list from 1971, as an incised glacial spillway that had formed when the glacial lake in the Glen of Aherlow at the end of the last Ice Age drained away.

Upon visiting the site, it was observed that though there is a marked incision into the northern footslopes of the ridge at Curraghturk, just south of Ballylanders, the channel itself is quite shallow, and only extends for a few hundred metres lateral distance. Thus, given that there are several thousand meltwater channels in Ireland, there is nothing marked or unusual about the Curraghturk channel. Hence this site is rejected as a County Limerick County Geological Site.

The short and shallow meltwater channel at Curraghturk, Ballylanders.

Baggotstown

Ireland has few interglacial sites (sites with sediments that date to times before the last Ice Age when climate was temperate, as it is now). Only about 20 are known, with two occurring in County Limerick.

At Baggotstown, just south of Knockainy Hill along the Bruff to Hospital road, interglacial deposits were discovered during well-digging in 1959. A long sequence of vegetation development was recorded, from the beginning of interglacial times to the onset of the last glaciation. These sediments extended from 5m to 9m below ground level, and the samples were analysed by the Department of Botany in Trinity College, Dublin, and Geological Survey of Ireland.

Today, only an old pump house is visible, in poor repair. There is nothing of the original sediment left or visible, and the well site itself is just a narrow hole in the ground. Given this, the site is rejected as a County Geological Site.

The site of the dug well and interglacial deposit at Baggotstown.

Kildromin

The second interglacial site in Limerick is at Kildromin, between Herbertstown and Pallas Green. At this locality, interglacial deposits were discovered during well-digging in 1960. Here, only a partial sequence of vegetation development was recorded, from the middle portion of interglacial times to the onset of the last glaciation. These sediments extended from 4m to 10m below ground level, and the samples were analysed by the Department of Botany in Trinity College, Dublin.

Today, nothing is visible at the location of the well, and the feature has been backfilled. Though there does seem to be a shallow karstic depression at the former well locality, there is nothing of the original sediment, or indeed the well itself, left or visible. Owing to this, the site is rejected as a County Geological Site.

The small hollow where the interglacial deposit at Kildromin was dug out.

Ballycummin Turlough

Though not mentioned as a locality on the Irish Geological Heritage Master list, it was known that a number of turloughs exist in Limerick, in two clusters adjacent to the City, as well as near Askeaton. The turlough locality at Ballycummin, on the southwestern fringes of the city area, was visited, and the feature observed to be a very small, restricted in area, portion of land that floods, adjacent to a very small area of karstified limestone bedrock outcrop. It is difficult to discern the turlough as a discrete landform and to separate it out from surrounding hills. Hence, this site is rejected as a County Geological Site.

The restricted hollow that floods as part of Ballycummin Turlough.

Loughmore Common Turlough

Another site not mentioned as a locality on the Irish Geological Heritage Master list, the turlough at Loughmore Common just outside Limerick City had been studied previously by Dr. Catherine Coxon of Trinity College Dublin in her PhD work in the 1980s. The turlough locality at Loughmore Common, on the southwestern edge of the city area, was visited, and the feature lies in a shallow basin, elongated in an east-west direction, and floods shallowly (30 – 40cm) in winter.

The turlough does not have any unusual geomorphology, or flora associated with it, and it is difficult to separate out the turlough from surrounding hills. As well as this, Loughmore is apparently drier today than it has been in the past, and it seems that drainage of the surrounding land rather than of the site itself may be the reason. Hence, this site is rejected as a County Geological Site.

The centre of the hollow that floods shallowly as Loughmore Commons Turlough.

Blackboy Delta

The Irish Geological Heritage Master list mentions the 'Blackboy Delta' as an important glacial feature deposited in a lake at the exit of the Gortnageragh valley in the Slieve Felim Mountains, which marks a late stage in ice sheet decay from the Golden Vale. The 'Blackboy' placename is an erroneous one, and the name actually refers to a landform at Bilboa.

The delta itself is a triangular shaped area approximately 4 kilometres northwest-southeast by 2 kilometres northeast-southwest, and is assumed to comprise glaciofluvial and glaciolacustrine sands and gravels which form a delta feature. Exposure is poor, and though there are flat-topped localities within the overall area, the topography is not in any way typical of what would be expected of a delta deposited in a lake. Thus, given that sands and gravels are rarely exposed in the area and as the topography is somewhat in question, this may not form a delta feature at all. It is therefore rejected as a County Geological Site.

A portion of the area demarcated as the Bilboa Delta.

Brittas Morainic Ridge

The Irish Geological Heritage Master list mentions the Brittas Morainic Ridge as a prominent glacial drift ridge across the northern part of the Golden Vale, cut through by the Mulkear River. The moraine feature was thought to mark an important ice limit associated with ice moving southwards across the Shannon Lowlands, and was suggested by Francis Synge of Geological Survey Ireland in the 1960s as possibly relating to a readvance after the formation of the Southern Irish End Moraine.

The concept of the Southern Irish End Moraine forming an important, ultimate still-stand of the Irish Ice Sheet across the southern portion of Ireland has long been an outdated one, and the ridge itself is only a subtle rise in the general landscape elevation. Thus, given that moraine sediments are not exposed in the area and as the topography is somewhat in question, this may not form a moraine feature at all, and it is therefore rejected as a County Geological Site.

A small, disused gravel pit in the feature delineated as the 'Brittas Morainic Ridge'.

Castleconnell Terraces

Though not mentioned as a locality on the Irish Geological Heritage Master list, it was known that a number of glaciofluvial terraces flank Castleconnell Village, demarcating the former elevation and extent of the River Shannon at the end of the Ice Age. The localities were visited, and if was discovered that the terraces have been heavily quarried over the years, and little remains of their original form; what does is heavily settled and largely covered in one-off houses. Thus, as the terrace topography is in essence invisible, and as much of the materials forming them have been quarried out, the site is rejected as a County Geological Site.

A portion of intact glaciofluvial terrace at Gooig, Castleconnell, flanked by one-off houses.

Ballyvogue Fen

Though not mentioned as a locality on the Irish Geological Heritage Master list, it was known that a number of fens and marshes occur southeast of Askeaton. Ballyvogue Fen was listed on the An Foras Forbartha Areas of Scientific Interest listing for Limerick in 1971. Upon visiting the feature, it was seen that much of its area has been drained in the last fifty years, since that survey had been completed, and little of the original wetland still exists. Thus, the feature is rejected as a County Geological Site.

The drained and much degraded fen at Ballyvogue.

Pigeon Rock

Though mentioned as a locality on the Irish Geological Heritage Master list for Cork, Pigeon Rock Glen is in the County Limerick portion of the Galtee Mountains. The locality was mentioned historically as an important locality for exposed Devonian Old Red Sandstone rocks, and a specific formation within the Old Red Sandstone sequence in Ireland is called the Pigeon Rock Formation, including lithic conglomerate and sandstone rocks.

The area on the southern side of the Galtee Mountains where the Pigeon Rock Formation crops out is not actually in Pigeon Rock Glen itself, but in its tributary valley hosting the Blackrock River to its' north. The bedrock is poorly exposed, and there is nothing spectacular about the outcrops, which in reality only occupy a scarp at the northern end of the valley. This area where the bedrock actually crops out is included in the Galtee Mountains County Geological Site anyway, so the area of exposure of the Pigeon Rock Formation is itself not included as a separate County Geological Site.

The glen hosting the Blackrock River, where bedrock of the Pigeon Rock Formation crops out.

Morgans South Turlough

Another site not mentioned as a locality on the Irish Geological Heritage Master list, the turlough at Morgans South just northwest of Askeaton has been included on Geological Survey Ireland's web viewer for Karst Data in Limerick. The turlough locality at Morgans South was visited, and the feature comprises only a very small, wet-based hollow, and floods shallowly in winter. Owing to the very restricted area of the feature, this site is rejected as a County Geological Site.

The tiny turlough at Morgans South.

Tomdeely South Turlough

A further site not mentioned as a locality on the Irish Geological Heritage Master list, the turlough at Tomdeely South northwest of Askeaton has been included on Geological Survey Ireland's web viewer for Karst Data in Limerick. The turlough locality at Tomdeely South was visited, and the feature comprises only a very small, shallow hollow. Owing to the very restricted area of the feature, this site is rejected as a County Geological Site.

The restricted turlough area at Tomdeely South.

Tomdeely North Turlough

The turlough site shown on Geological Survey Ireland's web viewer for Karst Data in Limerick at Tomdeely North was not mentioned as a locality on the Irish Geological Heritage Master list either. This turlough locality was visited, and the feature comprises only a very small, shallow hollow. Though unusual in that it so close to the Shannon Estuary, owing to the restricted area of the feature and the very subtle, almost-flat topography, this site is rejected as a County Geological Site.

The small, almost-flat turlough area at Tomdeely North.

Garryarthur Quarry

Garryarthur Quarry is not listed as a locality on the Irish Geological Heritage Master list, but as this is one of the few quarries cut into Silurian rocks in Limerick, the site was visited. The quarry is relatively restricted in extent and though exhibiting good exposures of well bedded greywackes, there is nothing unique or unusual about the structural geology, nor the rocks themselves, in the quarry. Thus, with few features of geological heritage interest visible on the whole the site is therefore rejected as a County Geological Site.

Garryarthur Quarry.

Deel River Section, Askeaton

Two sites, Mantlehill (Deel River Section) and the Deel River Section, Askeaton were listed as potential County Geological Site in the IGH Master List under the IGH8 Lower Carboniferous theme. Records for both sites related to 'river sections exposing the base of the complex and a good thickness of the underlying Basal part of Waulsortian complex on Ballysteen Formation'. The section at Mantlehill is well documented in published literature and this location was selected as the representative County Geological Site for this Deel River section.

Deel River section at Mantlehill.

Kilmeady Quarry

The IGH Master List records 'Kilmeady Quarry' under the IGH3 Carboniferous to Pliocence Palaeontology theme, and 'Kilmeedy' under the IGH8 Lower Carboniferous theme. The accompanying notes refer to the Ballyvergin Shales. The Kilmeady Quarry notes state that the site is the 'Council owned' quarry, and not the nearby private quarry. Therefore both sites are the same site (of the disused, roadside, 'Council owned' quarry), albeit both Master List sites have 'Kilmeedy' spelled differently. The sites are combined as one – as 'Kilmeedy', avoiding the use of the term quarry to avoid any confusion with the private quarry at Kilmeedy.

Small, 'Council owned' roadside quarry at the Kilmeedy County Geological Site.

Askeaton Quarry

The IGH Master List records 'Askeaton Quarry' under the IGH8 Lower Carboniferous theme for the presence of Lower Carboniferous Waulsortian bedrock in the locality. The Master Lists notes that the 'quarry has yielded an important conodont fauna together with a macrofauna'. The quarry is now flooded and off-limits. Because the features are not currently accessible or closely observable, the site is not considered suitable for CGS designation.

Flooded quarry at Askeaton.

Ballygowan

Given that Ballygowan are a well-known, national, spring water brand, and as their water source is from the Lower Carboniferous limestone of southwest Limerick, it was decided to investigate if the deep bored wells that supply the water had any interesting historical, hydrogeological or folklore aspects, that might have potential as a Geological Heritage Site. Despite a visit to the site, and repeated correspondence, a meeting could not be scheduled, so the site was therefore rejected.

Knockderk – Derk Hill

The Derk Hill site is cited in the IGH Master List as showing "the whole of the Limerick volcanic area in microcosm and [..] consequently of considerable interest".

On the geological map, the hill is mapped as a trachyte plug within basalt lava of the Knockroe Volcanic Formation, which is essentially the same geological setting as at Kilteely Hill, 3km to the west. Kilteely Hill has been recommended as a County Geological Site, and the exposures there are much better than on Derk Hill, and access is considerably easier. Moreover, at Kilteely Hill, the field relationships between volcanic plug and basalt lavas are particularly well displayed. As the Derk Hill site does not add to what is already better seen at Kilteely Hill it is recommended for rejection as a County Geological Site.

Derk Hill summit, view from west.

Trachyte outcrop on summit of Derk Hill.

Knockroe

Knockroe is cited in the IGH Master List for displaying "lava tubes". The grid reference supplied appears to be for the townland of Knockroe, and further information regarding the lava tubes, including a more precise location, could not be obtained during the course of the audit. Further investigation may yield a precise location, and enable definition of a new County Geological Site.

Ballinleeny Quarry

The IGH Master List records Ballinleeny Quarry under the IGH8 Lower Carboniferous theme.

The records note 'a transition up into Mellon House Beds and Ringmoylan Shales. Also columnar volcanics present with circa 1cm hexagonal columns present'. On inspection, the quarry was found to be an interesting site in terms of the clean and accessible quarry faces, but the columnar volcanics were not discovered. Furthermore, the aforementioned transition was not apparent either. The lack of recently published research literature relating to the site rendered identification of features of interest challenging. As a result, the site is not considered as a County Geological Site.

Ballinleeny Quarry, viewed looking east.

2. Limerick Council Policies regarding geology and geological heritage

The completion of this county geological heritage audit will ensure that the listing of Limerick's County Geological Sites is provided for inclusion in the County Development Plan (CDP) 2022-2028 with a robust selection of sites that are genuinely important in County Limerick.

Limerick CDP 2010 – 2016 Volume 1 (P. 7 - 6) states that '*While an area such as the Burren in County Clare has been regarded as the premier geological attraction in the Mid West Region, this is not to say that there are not several areas of geological interest within the County. In the northern part of County Limerick, immediately close to the estuary areas such as Barrigone, some of the same characteristics as the Burren are exhibited. Individual sites such as Linfield Quarry, close to Pallasgreen in the east of the County, are also important parts Limerick's geological heritage. Linfield is known for its basalt formations, which may well be unique in the country'*

A number of policies and objectives are outlined which consider the heritage and ecological value county's geological characteristics.

> **Policy EH P1:** Sustainable Management and Conservation
> It is the policy of the Council to ensure the sustainable management and conservation of areas of areas of natural and environmental and geological value within the county.
>
> **Objective EH 04: Conservation of Geological Sites in County Limerick**
> It is the objective of the Council to seek the conservation and protection of features of geological interest within the County, particularly those that would have been recognised in the past as Areas of Scientific Interest or by Geological Survey of Ireland as being of particular value.

As well as this, the County Development Plan pays special attention to peat land sites, as this is one of the habitats that is under the greatest threat in Limerick. This faces a range of threats, from afforestation, agricultural improvement and also the development of wind farms. Natural Heritage Areas, Special Areas of Conservation and Special Protection Areas in County Limerick are identified in Map Guides 7.1, 7.2 and 7.3 in Volume 2 of the County Development Plan. As well as this, there is specific mention of peat land sites that are not protected sites.

> **Objective EH O3: Conservation of Peat Land Sites which are not protected sites**
> (a) It is the objective of the Council to seek the conservation and protection of features of natural interest such as appropriate woodlands and hedgerows, wetlands and uplands and places of high bio-diversity interest.
> (b) It is the objective of the Council to co-operate with NPWS (National Parks and Wildlife Services) and other interested parties in order to develop a high level wind farm deployment zone map based on appropriately detailed ecological site assessment of the upland blanket bog and heath areas within the county.

Much of the general thrust of Section 7.2 'Heritage', particularly sub-section 7.2.3 'Limerick's Natural Environment' in the County Development Plan alludes to Geological Heritage, in many cases mentioning it in particular.

> **Objective EH O1: Nature Conservation Sites**
> It is the objective of the Council to:

a) Maintain the conservation value of those sites as defined in the Planning and Development Acts 2000 - 2010 (SPAs, SACs) or lands proposed for inclusion by the Department of Environment Heritage and Local Government, as well as any other sites that may be so designated during the lifetime of this plan.
b) Ensure that development projects and development plans likely to have significant effects on European Sites (either individually or in combination with other plans or projects) are subject to an appropriate assessment and will not be permitted under this plan unless they comply with article 6 of the Habitats Directive.
c) Maintain the conservation value of all Natural Heritage Areas and also Natural Heritage areas proposed for designation by the DEHLG as well as any other sites that may be so designated during the lifetime of the plan

Objective EH O2: Species Protection
It is the objective of the Council to seek to protect plant, animal and bird species that have been identified by the Habitats Directive, Birds Directive, Wildlife Act and the Flora Protection Order in line with national and EU legislation**.**

Policy EH P2: It is the policy of the Council to promote the distinctiveness and where necessary safeguard the sensitivity of Limerick's landscape types through the landscape characterisation process and also where possible to develop the means to successfully integrate differing kinds of development within them.

Objective EH O11: Lough Gur Landscape Character Area
It is the objective of the Council to:
(a) Safeguard the visual amenity of the area and to have regard to the views and prospects in and out of Lough Gur.
(b) Restrict development including residential development in the area of Special Development Control, shown on map 7.5 except in exceptional circumstances. Appropriate tourism development and extensions to existing properties, which respect the special character of Lough Gur will be considered.
(c) To have regard to the archaeological importance and richness of the area indicated in Map 7.5 as a zone of archaeological amenity. Any developments within the zone will be required to provide for an archaeological examination during the course of excavations or other ground disturbance.
(d) To safeguard the existence of Natural Heritage Areas and the Wildfowl sanctuary when assessing applications for development in the area.

Objective EH O15: Tory Hill Landscape Character Area
It is an objective of the Council that there is a presumption against development in this location. Tory Hill is an isolated locally prominent hill which is within 2km of the town of Croom and is visible from the Cork/Limerick road. It is an important feature in the surrounding countryside, and is of geologic importance as it is a limestone hill with deposits of gravel, which have been left since the last ice age. The hill supports areas of scrub and woodland as well as limestone grassland. The dominant nature of the hill, which rises from the surrounding flat landscape, magnifies the effect of development.

Objective EH O16: Western Uplands Landscape Character Area
It is an objective of the Council to: Volume 1 Environment and Heritage Limerick County Development Plan 2010 – 2016 November 2010 (as varied) 7 - 15
(a) Where housing is permitted encourage appropriate scale and high quality design for this landscape area coupled with sensitive site location and landscaping. Respect traditional scale particularly on elevated or locally prominent sites.
(b) Discourage the selection of locally prominent sites.
(c) Encourage the use of local landform and landscape features coupled with sensitive landscaping in order to screen development.
(d) Ensure that forestry that is subject to planning permission is confined to below 280m above sea level to protect intact remnants of peat land habitat.
(e) This area is open to consideration for wind energy development.
(f) Where wind farm development is permitted a random spacing layout shall be considered to limit the visual and landscape impact.

The Western Uplands is an upland area, which begins approximately 5km to the south west of Newcastle West with the Barnagh Hill area, which already has been designated as a scenic route in previous County Development Plans. This hill range dominates the surrounding landscape to the east and is clearly visible from Newcastle West.

With this report, the forthcoming County Development Plan 2022 – 2028 should be equipped to include more specific objectives relating to County Geological Sites and geological conservation, and to include a listing of County Geological Sites in an appendix or a map of their locations as provided herein.

Section 7.3.6 of the CDP (**Scenic views and prospects and Tourism,** P. 7 - 16) states the council's commitment to supporting geotourism initiatives in the region:

Objective EH O17: Scenic Views and Prospects
(a) It is the objective of the Council to safeguard the scenic views and prospects by integrating them into landscape character areas, which will ensure a more balanced approach towards landscape issues within the County.
(b) In areas where scenic views and prospects are listed in Map 7.6 there will be a presumption against development except that which is required in relation to farming and appropriate tourism and related activities, or a dwelling required by a long term land owner or his/her family that can be appropriately designed so that it can be integrated into the landscape.
(c) The Planning Authority will exercise a high level of control (layout design, siting, materials used, landscaping) on developments in these areas. In such areas site specific designs are required. It should be noted that in areas outside these delineated areas, high standards will also be required.

Groundwater
A Groundwater Protection Scheme has been completed for Limerick City and County Council by Geological Survey Ireland which gives land surface zoning objectives in terms of groundwater protection for every portion of Limerick's landmass. This scheme allows an assessment of the vulnerability of groundwater to pollution for any proposed development, and all proposed schemes must adhere to associated Groundwater Protection Responses.

This audit complements the Groundwater Protection Scheme, as it has examined and listed many vulnerable karst sites around the county, and defined boundaries to these sites, offering an extra element of protection as these sites will now be listed in the CDP.

Within the Development Plan specifically, section 7.4.1.3 covers Groundwater Protection. It is stated that:

> The Groundwater Protection Plan of the County is an essential tool in enabling Planning Authorities to take into account both geological and hydro-geological factors in locating potentially polluting developments so that the chances of ground water contamination is reduced to a minimum.
>
> **Objective EH O21: Septic Tanks & Proprietary Systems**
> It is the objective of the Council to ensure that septic tanks and proprietary treatment systems, or other waste water treatment and storage systems which are required as part of a development, comply with relevant guidelines and that they are constructed only where site conditions are appropriate. In respect of groundwater, it is a requirement that as part of the required site assessments the local groundwater conditions as identified in the groundwater protection scheme and the Shannon River Basin Management Plan are properly assessed in informing the Groundwater Protection Response

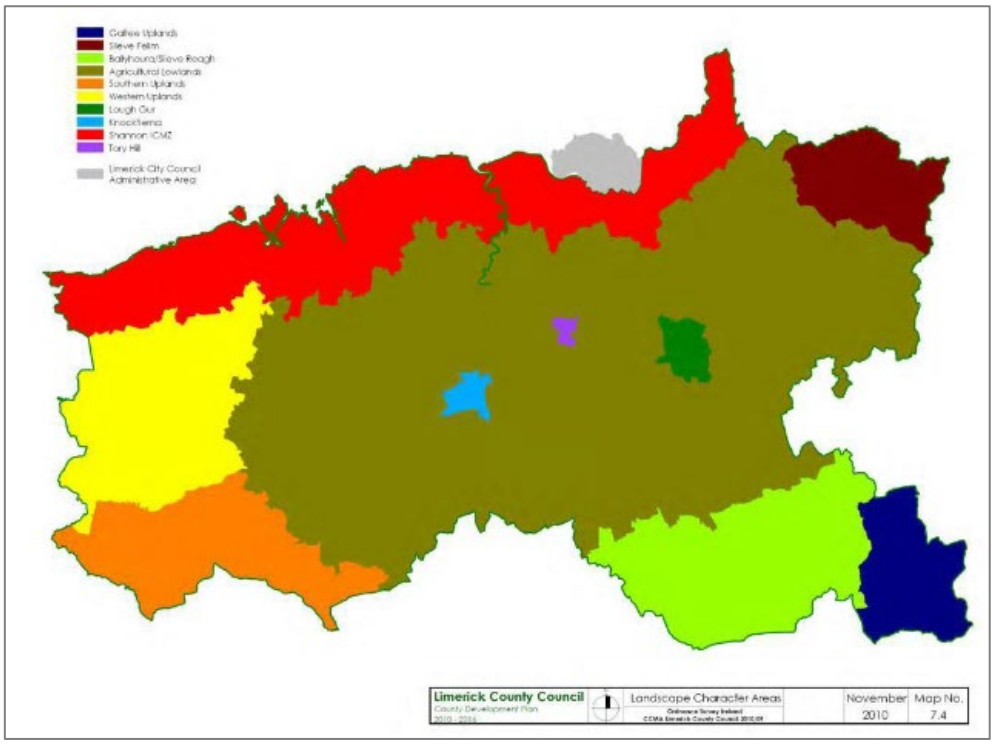
3. Geological conservation issues and site management

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 pNHA sites. In these areas, the geological heritage enhances and cements the value of these sites for nature conservation, and sometimes requires no additional designation of actual land areas, other than citation of the geological interest.

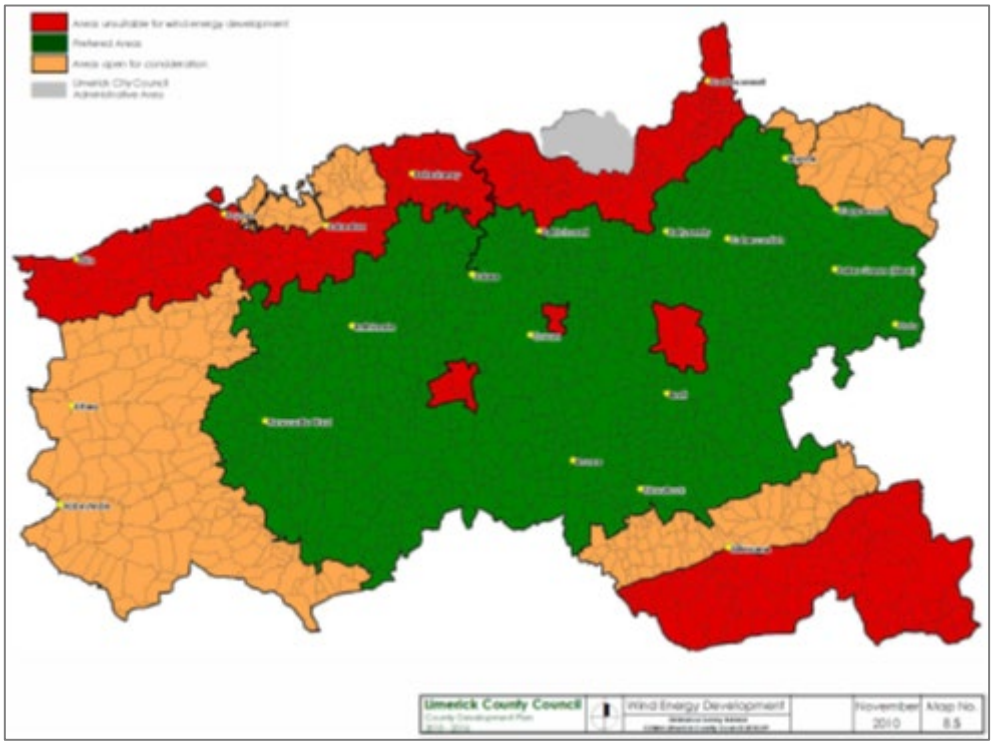
Broadly speaking, there are two types of site identified by the Geoheritage Programme (IGH Programme). The first, and most common, includes small and discrete sites. These may be old quarries, natural exposures on hilly ground, coastal cliff sections, or other natural cuttings into the subsurface, such 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 Limerick, these include the Galtee Mountains and the Ballyhoura Hills sites.

It is also important from a geological conservation perspective that planners understand the landscape importance of geomorphological features that may not in themselves warrant any formal site designation, but which are an integral part of the character of County Limerick. A lack of awareness in the past, has led to the loss of important geological sites and local character throughout the country. In County Limerick, a Landscape Characterisation Assessment was completed and incorporated into the County Development Plan 2010-2016, and carries through to the current, soon-to-be-adopted plan. This provides a tool for planners to help maintain the character of the County and informs things like wind energy strategy. However, it is a methodology that could be considered to place inadequate value on the underlying geodiversity in defining landscape character areas. The Strategic Environmental Assessment within the County Development Plan also provides tools. In addition, the now routine pattern of consultations with Geological Survey Ireland, 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. **It is important that the relevant planning department is aware of the county geological heritage sites and, more generally, that consultation with Geological Survey Ireland 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 data and sample collection at temporary exposures, or to influence planning design so that access to exposures of rock is maintained for the future, or in extreme cases to prevent a completely inappropriate development through presentation of a strong scientific case.



Landscape Character Areas (Map No. 7.4, Limerick County Development Plan 2010-2016).



Wind Energy Development Zonings (Map No. 8.5, Limerick County Development Plan 2010-2016).

In many counties, working quarries are listed as County Geological Sites because they are the best representative sections available of specific rock sequences in areas where exposure is otherwise limited. 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 Mungret Limestone Quarry in Limerick are now included as County Geological Sites. These issues are explored in a set of

Geological Heritage Guidelines for the Extractive Industry, published jointly by the Geological Survey Ireland 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. None of County Limerick's sites are really likely to require such an approach.

Waste dumping

An occasional problem throughout the country, County Limerick included, is fly-tipping and 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, disused gravel pits, or bare karst limestone, waste can leach into the groundwater table as the materials 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 Limerick was one of the first included in this national scheme for Groundwater Protection, in 1996, 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 Limerick.

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. One example considered in this audit is the Ballykeeffe N18 road cut, where Lower Carboniferous limestone strata are exposed in the cutting where the route passes beneath a minor road east of the Limerick Tunnel. 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 planning for other roads in the county likely to be significantly upgraded, the option should be borne in mind for all future road improvements.

Geoparks

The rapid growth and adoption of the UNSECO European and Global Geoparks concept over the past two decades represents an extremely interesting development in geological heritage and geological conservation. 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**. The initiative largely grew from the European Geoparks Network (EGN), expanding worldwide as the Global Geoparks Network (GGN) from 2004. The Geoparks programme 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. UNESCO Geopark branding helps promote the geological heritage resource so that the community can benefit from it. However, significant management support from local authorities has proven to be essential across the network.

In Ireland, there are three members of the UNESCO Geoparks Network. One is the cross-border Cuilcagh Lakelands UNESCO Global Geopark in Fermanagh and Cavan [see https://marblearchcaves.co.uk/ andhttps://cuilcaghlakelands.org/. The Copper Coast UNESCO Global Geopark in Waterford [www.coppercoastgeopark.com] also joined the Network in 2001. A now well-established addition has been the Burren and Cliffs of Moher UNESCO Global Geopark in County Clare [www.burrengeopark.ie]. Having submitted the application to UNESCO at the end of November 2021, the Joyce Country and Western Lakes region of counties Mayo and Galway is now an aspiring Geopark. (https://joycecountrygeoparkproject.ie/). In addition, there are aspirant Northern Ireland groups exploring the work and infrastructure required for applications in other areas such as the Mourne-Strangford area..

This audit will assist with the required geological appraisal and knowledge required for any potential future application or for discussion with potential Geopark management. A separate discussion of this idea is included below. There are also many other ways of using geoheritage to promote local geotourism initiatives without aspiring to full UNESCO Global Geopark status, and this can often be completed in collaboration with wider government agencies and supports.

3.1 Geological Heritage Theme - The Southern Irish End Moraine

Much confusion has existed in the past in Irish glacial literature about the exact positioning of glacial features. Whilst the interpretation of drumlins, eskers and glacial deposits is bound to vary over time and between different researchers, there has been remarkably little agreement on the nature and distribution of the actual landforms and deposits. This is problematic, as a 'glacial map' should form the basis of any reconstruction. Surely the exact position of the features should never be in doubt, as the process only involves their placement on a map!

However, systematic and consistent mapping at the ice sheet scale has only recently been achieved in Ireland. It is thus no surprise that the historical reconstructed behaviours differ greatly. Previous studies were conducted at different scales, with different authors working in the same area including some features and disregarding others. Hence the models built by each researcher were bound to differ, and it is difficult to compare these with each other as features seen as important by one researcher are disregarded by another.

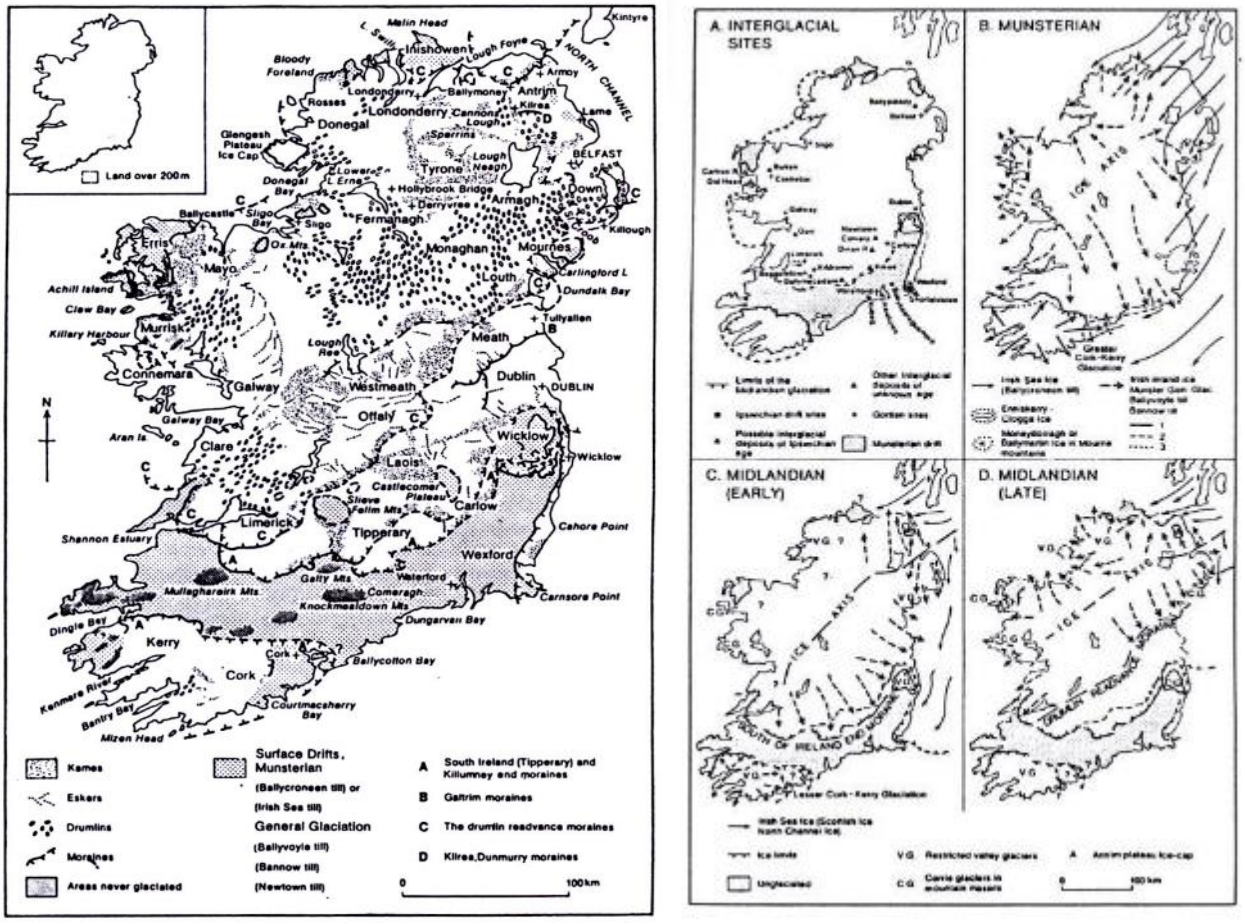


Figure 1 Left: General Quaternary geomorphology map of Ireland, as modelled pre-1990s. Right: Montage of General ice movements as interpreted during the 1960s and early 1970s. A) Interglacial sites B) Munsterian ice flows. C and D) Midlandian ice flows (all maps from Davies and Stephens, 1978). Note the 'Southern Irish End Moraine' stretching across the country from Limerick to Wicklow, through Tipperary.

Thus, before the 1990s, it had been assumed that the glacial landforms of Ireland were broadly grouped into two provenances associated with two Pleistocene cold phases, termed the Munsterian (older) and Midlandian (younger), which were separated by the 'Southern Irish End Moraine'. Further north, the 'Drumlin Readvance Moraine' separated the area comprising fresh, 'Midlandian' landforms into those formed by drumlin-moulding ice, and those not. Detailed field mapping in the 1990s showed that no such features existed on the ground and the features have since been rejected based on sedimentological evidence and on a stratigraphic basis.

It is now widely accepted that the entire island of Ireland was covered by an ice sheet during the last glacial cycle, with ice limits extending well offshore to the south and west.

3.2 Geological Heritage Theme - Lowland Karst Areas of North Central Limerick

Approximately 40% of the island of Ireland is underlain by Carboniferous limestone. Consequently, karst is a significant aspect of Irish geology. The karst of upland areas, such as the plateaux of the northwest in Sligo and Leitrim, and areas such as the Burren have long been the subject of research. However, little work has been done on the lowland karst, which forms a much more complex system as it interfingers with, influences and is in turn influenced by glacial and

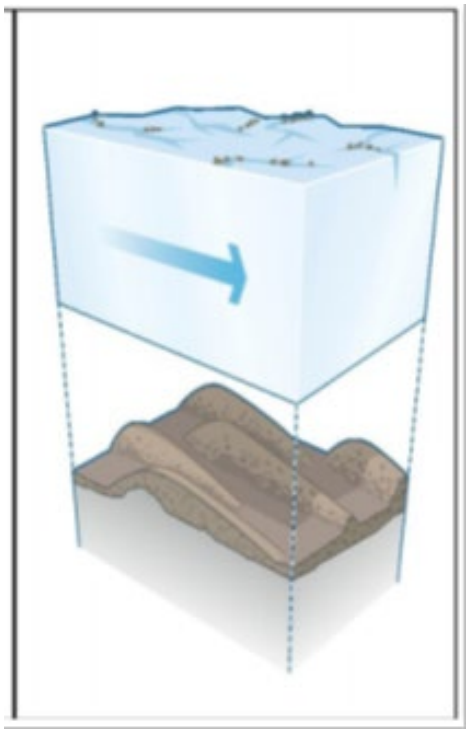
postglacial sediments of varying thicknesses. This system of buried karst underlies most of the lowland of north central Limerick.

Karstification involves the enlargement of rock fissures when groundwater dissolves the fissure walls as it flows through them. As a consequence, water disappears down vertical passages, rather than moving laterally as a surface stream. Fissures become master fissures and *swallow holes*, or sink-holes, are created. A swallow hole is basically an opening in the bed of a river that flows over limestone. At this opening the river takes its course underground and winds it's way under the ground surface. Some swallow holes develop into small-to-medium-sized closed depressions, or *dolines*; water moving laterally beneath the surface as underground rivers forms *caves* from fissures. Other karst features that develop include *dry valleys*, the beds of streams that once flowed at the surface and then disappeared underground; *springs*, where water reappears at the surface from underground fissures; and *estavelles*, which act as swallow holes during dry periods of the year and springs during wet. Low-lying spots close to springs and swallow holes may flood in winter, as *turloughs*. Karst features can even be recognized on what may seem the most bland rock outcrops, with many limestone surfaces pitted with hollows or runnels, collectively termed *karren*.

From reading this it can correctly be assumed that the lowlands of north central Limerick existed in the Palaeogene / Neogene Periods as merely an extensive karst basin, with sporadic hums (hills). The ice sheets of the Pleistocene would then have planated and smoothed the basin, causing the almost bowl-shaped lowland in existence today. The total area of the region is approximately 200km^2, bounded by the Maigue Estuary in the northeast, Adare in the southeast, Aughinish in the northwest and Creeves in the southwest. All of the area is underlain by pure, well bedded, karstified limestone, much of this is at or just below the surface. The majority of the area lies below 50m OD with the highest points being at Cloonagalleen near Kildimo (76m OD) and Gorteenamrock near Askeaton (68m OD).

3.3 Geological Heritage Theme - Subglacial bedforms

The ice sheets that covered County Limerick during the last Ice Age have had a profound influence on its present landscape. Most of the low ground in the county is underlain by deep deposits of glacial till, or 'boulder clay', obscuring the bedrock geology beneath. Over much of the county this till was moulded by the moving ice sheet into drumlins. The name "drumlin", used internationally, comes from the Irish 'dromnín' meaning 'low hill'. Drumlins are mounds of debris left behind by melting ice sheets and are typically streamlined in the direction of icesheet flow. The following illustrations show the formation of drumlins under a moving ice sheet. The ice sheet of the last glaciation flowed generally north to south across Limerick, a fact illustrated by the orientations of the drumlins, which are all generally aligned north-south.



3.4 Geological Heritage Theme – The Limerick Volcanics

Ireland's geological heritage stretches back almost two billion years and includes numerous traces of volcanic activity. Of most significance from a geoheritage perspective are those produced between the time of closure of one ocean, the Iapetus, and the opening of another, the Atlantic. Closure of the Iapetus along opposing subduction zones saw volcanic eruptions in the Ordovician period, with volcanic rocks preserved on both the southern side of the ocean (e.g. in Portrane, County Dublin and Avoca County Wicklow) and on the northern side (e.g. in the Longford-Down Inlier). The North Atlantic began opening around 200 million years ago and the ensuing period of crustal rifting eventually led, 65 million years ago, to the creation of the Palaeogene North Atlantic Igneous Province. Then, large volumes of magma were intruded into the crust or erupted through fissures. Traces of Palaeogene volcanism can be found as far south as Dingle in County Kerry but the most important examples are in County Antrim. The Giant's Causeway is the most spectacular example of thick basalt lava flows that covered much of the northern part of Ireland.

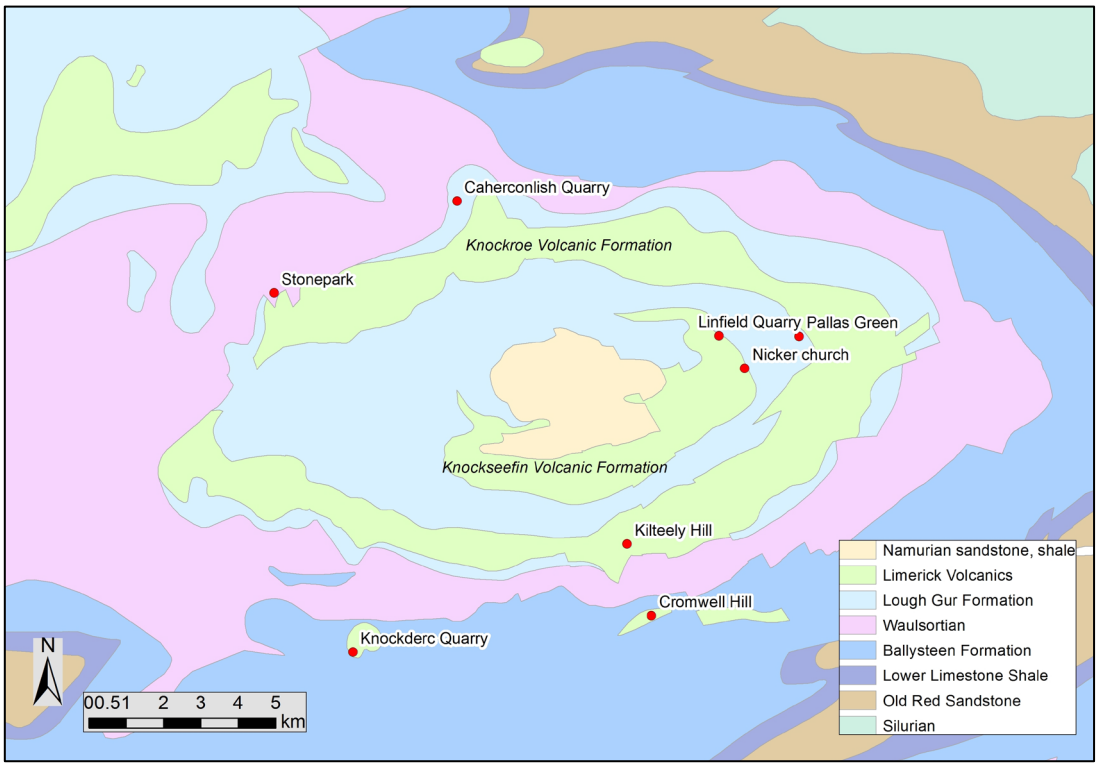
In between these episodes of ocean closure and opening, the deposition of sediments in the shallow tropical seas of the Carboniferous period was interrupted by a third phase of volcanism. The Limerick Volcanics are among the most significant examples of Carboniferous age volcanism in Ireland and Britain. After the Antrim lavas, they comprise possibly the most extensive and, in places, spectacular exposures of volcanic rocks in Ireland. The volcanic rocks include lavas, tuffs and intrusive rocks and range in composition from alkali basalt to trachyte.

The Limerick Volcanics are largely contained within the Limerick Syncline, a distinct oval-shaped basin in east Limerick. Two rock units, the older Knockroe Volcanic Formation and the Knockseefin Volcanic Formation, are interbedded with limestones of the Lough Gur and Herbertstown Limestone Formations. The earliest extrusions in the west were subsequently overlapped by later ones in the east, indicating a gradual eastward migration of the centre of volcanism through time.

The Knockroe Volcanic Formation was erupted onto limestone of the Lough Gur Formation. Initially, lithic and vitric tuffs were produced by explosive eruptions when seawater interacted with hot magma in seafloor vents. As the volcanoes developed and emerged from the sea subsequent eruptions were of basalt lava which flowed across the earlier volcanic deposits and onto the limestone seafloor. As individual waned the magma generally became more fractionated, the basalt lava evolving to a more intermediate trachyte. There are numerous occurrences of trachyte in Limerick. It typically forms dykes, filling a fracture or fault, as stocks or plugs, where it filled a former vent, or as sills, emplaced conformably within the limestone strata. At Caherconlish Quarry, the trachyte dyke displays well-developed columnar jointing, a common feature in the Limerick Volcanics. A good examples of a trachyte stock or plug can be seen at Kilteely Hill whereas at Cromwell Hill the hill-top consists of a sill sitting conformably on Ballysteen Formation limestone. At Knockderc Quarry, a syenite intrusion is a plutonic equivalent of the trachyte volcanic rocks. All of these localities have been designated County Geological Sites.

In recent decades, drilling undertaken for mineral exploration in the Stonepark area has demonstrated the presence of large diatremes, up to 500m in diameter and extending to depths in excess of 500m in boreholes. Diatremes are volcanic vents formed when magma rises through fractures and reacts with water, causing an explosion that leaves a shallow crater, typically filled with rock clasts produced by the explosion. In Limerick the diatremes are filled with clasts of Waulsortian limestone. Clasts of rocks that were originally part of the deep crust have been recognized in one diatreme.

The youngest volcanic sequence is the Knockseefin Volcanic Formation, which occurs in the eastern part of the syncline near Pallas Green. This unit appears to form a single volcanic centre. The rocks are similar to those of the Knockroe Formation, comprising basalt lavas and tuffs. At Nicker church (Knockseefin), a lava flow can be observed resting directly on limestone of the Herbertstown Limestone Formation. To the north, at Linfield Quarry, a spectacular example of radiating columnar jointing is on display. Both localities are also County Geological Sites.



4. Summary and Recommendations

4.1 Proposals and ideas for promotion of geological heritage in County Limerick

This section briefly examines the existing objectives in the County Limerick Heritage Plan (2017-2030) relating to geological heritage and provides specific suggestions as to how these may be implemented, supported or enhanced by the audit of geological heritage sites in the county. Limerick Heritage Plan 2020-2025 (P.13) states:

> *"The natural environment of Limerick takes many forms ranging from the estuaries in the north of the county, through the hedgerows and pastoral landscape of much of the centre of Limerick. The urban environment itself should not be forgotten as this provides many species with a home. The variety of habitats within a relatively confined space means that they are readily accessible to those that wish to do so. The common habitats that we take for granted are the home to the plants and wildlife of the county. Through actions in the plan it is hoped that the people of Limerick learn more about their natural surroundings and that during the life time of the plan that some practical actions to address biodiversity issues are implemented. The objectives below have been informed by the national policy including the National Biodiversity Plan and the recent National Pollinator Plan."*

There are several objectives in the plan that could loosely be related to the focus and outcome of this audit.

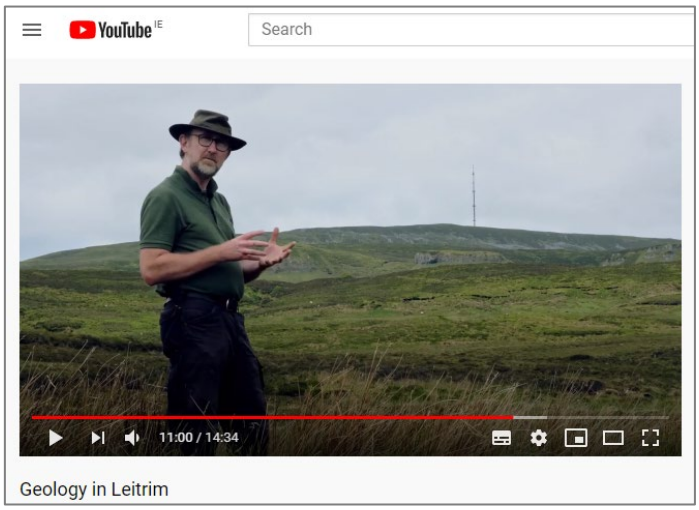
> **Objective**: Support distribution of information through digital media, information sessions, talks, including established Council events such as the Tidy towns programme, community initiatives, and national programmes such as Heritage Week, Tree week, Water Day Biodiversity Week, and the heritage in schools programme,
>
> **Objective**: Liaise with education providers to incorporate environmental heritage into their curriculum if feasible, and to promote the Heritage in Schools programme in the interest of local biodiversity,
>
> **Objective**: Investigate the feasibility of developing digital technology with educational agencies (third-level colleges, secondary school, transition year students, youth training scheme programmes) to increase awareness of Limerick's natural heritage and to consider where possible, innovative means of studying, promoting and recording natural heritage through digitalisation projects and modelling.
>
> **Objective**: Explore and develop further digital accessibility of natural heritage information for the benefit of the community and the tourist.
>
> **Objective**: Work with relevant agencies and individuals to promote opportunities for ecological rehabilitation of disturbed sites such as quarries, landfills, cutaway bogs, and forestry.
>
> **Objective**: Investigate the feasibility of developing digital technology with educational agencies (third-level colleges, secondary school, transition year students, youth training scheme programmes) to increase the awareness of Limerick's natural heritage.

4.2 Ideas for projects

Online Video and DVD projects

In 2020, Leitrim County Council's 'Connecting Through Heritage' Project (funded by the Heritage Council) produced a series of videos to celebrate the natural, built and cultural heritage of the area by interviewing heritage experts. One of the series of videos included a 15 minute video introducing the geological heritage of Leitrim, presented by Dr. Robbie Meehan. Online and publicly accessible productions such as the *'Connecting Through Heritage'* videos are a valuable means of showcasing geological heritage to a wide audience.
https://www.youtube.com/watch?v=hZvRy8rY5tE&t=411s

DVDs which focus on 3D animations and interactive of aspects of places such as the Limerick Volcanics geological landscape, and in particular sites such as Lough Gur, would be worthy additions to the geological education resource.

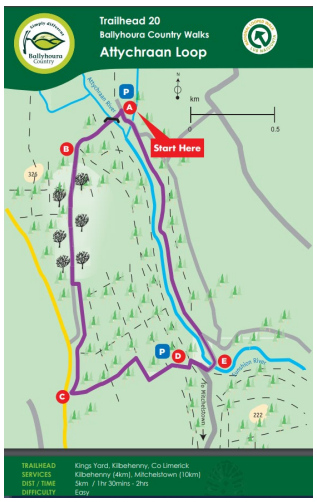


Screengrab of Geology in Leitrim 'Connecting through Heritage' Youtube video (2020).

Such videos could easily be produced regarding aspects of the geological heritage of Limerick.

Leaflets

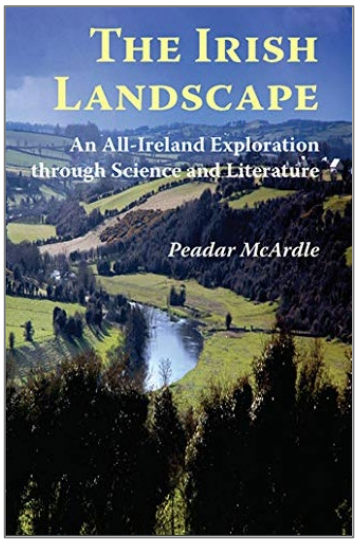
Few existing leaflets on the geological heritage of County Limerick are known, other than the Geoschol leaflet accompanying this report (Appendix 8). There is some potential for new leaflets to be published, and made available as PDF downloads on the Council's website to avoid printing costs and reduce paper usage. Such a format has been adapted by the 'Explore Ballyhoura' committee, whereby the booklet guides to sites in the Mountains can be downloaded from the Geoschol website. There are some funding schemes that are particularly suited to such publications when produced by local groups. The authors can advise any potential communities looking to create local leaflets or guides.



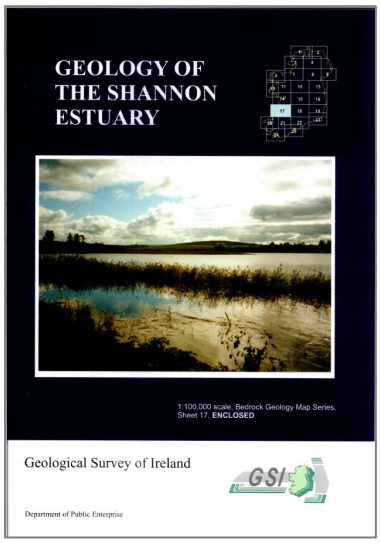
Guides

There is little coverage of Limerick in other fieldguides relating to the geology of Ireland. The Irish Quaternary Research Association (IQUA) published a specific guide to the Galtee Mountains in 1979, as a part of their annual field excursion. More recently IQUA published 'Limerick and the Shannon Estuary Region' (2014) and 'Quaternary Sites in the Shannon Estuary region and along the Wild Atlantic Way' (2019).

Several book publications and guides include chapters and sections on the geology of County Limerick. These include *Karst of Ireland* (Drew, 2018) and *The Irish Landscape An All-Ireland Exploration Through Science and Literature* (McArdle, 2015).



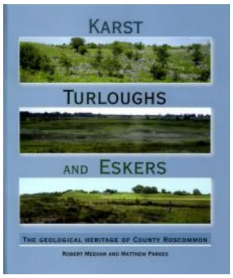
The Irish Landscape: An All Island Explosation through Science and Literature (McArdle 2015)

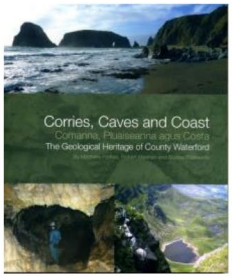


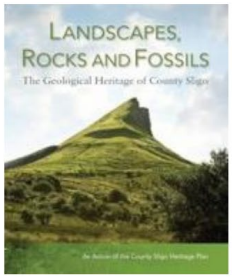
Geology of the Shannon Estuary: Bedrock Geology 1:100,000 Scale Map and Report on Sheet 17

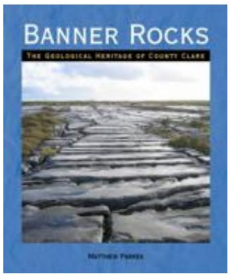
The 1:100,000 Scale Geological Survey Ireland map report for Sheets 17, 18, 21 and 22 cover County Limerick and are an essential resource.

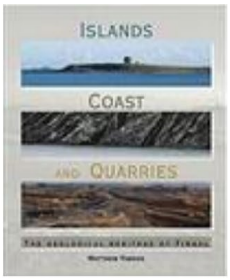
There is potential for guides to be published at varying levels of detail and accessibility for non-specialists and enthusiasts. A wide range of leaflets, booklets, books and other media are all feasible, but the research and production of appropriate text and images can prove challenging to achieve successfully, in the absence of appropriate experience, and adequate time and resources. It is suggested that **with modest editing and reorganisation the main content of this report an informative general guide to the geological heritage of County Limerick could be produced**, in a broadly similar style to those books produced for Sligo, Fingal, Mayo, Waterford, Roscommon, Clare, Longford, Wicklow and Leitrim following the completion of county geological audits in those counties.











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 one discrete place, such as those at the Galtee Mountains trailhead, is preferable 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 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 Limerick City and Council Offices, County Library branches or other venues. The model followed was that used for Carlow, Dun Laoghaire-Rathdown, Waterford, Wicklow, Longford etc. Images of those and other similar exhibitions can be seen on the Geological Heritage/Exhibitions section of the Geological Survey Ireland website [www.gsi.ie].

New media

There is a growing number of examples of new methods of promoting Geology and Earth Sciences via mobile apps, online video and podcast content and other electronic media. Examples of self-guiding apps on specific sites, such as those produced by Ingenious Ireland (www.ingeniousireland.ie) for Dublin city geology and the app for tourists in the Burren and Cliffs of Moher UNESCO Geopark. Plans for such products would require some considerable effort to produce and imaginative effort, to link sites in any coherent ways.

Geoschol

Geoschol is an educational project, now essentially represented by a website [http://www.geoschol.com/ireland.html] which was largely aimed at providing educational materials about geology for primary schools. A four page PDF **document** summarising the geology of County Limerick is available from Geoschol (see Appendix 8). Links to the Heritage section of the Limerick City and County Council website, as well as to other heritage websites, could be included on any revisions to the document.

County Geological Heritage Research Archive

A geological heritage research archive was produced for the Burren and Cliffs of Moher UNESCO Geopark, with public access to PDF publications, reports and academic papers. The reference lists provided in this audit report could form the foundation for such an initiative in Limerick City and County. The availability of technical references of direct relevance to County Limerick's geology

and geomorphology would assist many users and researchers into the future. The literature is extensive, and is specialist in nature, such that a geological heritage section with a select bibliography on the City and County Council Heritage web pages might suffice for most users with general interest in heritage. Placenames are the most obvious example of information that could be contained in such an archive.

Paper Maps

Hard-copy map publications produced by East-West Mapping (https://eastwestmapping.ie/) include geological data from Geological Survey Ireland. The inclusion of County Geological Sites as a feature layer in future publications of paper editions of 1:50,000 Discovery Series maps by the Ordnance Survey of Ireland would be a welcome initiative.

5. A summary of the Geology of County Limerick

5.1 Concise simple summary of the geology of County Limerick

County Limerick has five main episodes in its geological story. The first of these is represented by rocks of the Ballyhoura, Slieve Felim and Galtee Mountains. Here, Silurian marine rocks, around 440 million years old, are found where erosion of the uplands has stripped off the younger Devonian sandstones and conglomerates. The Devonian rocks, of sediments deposited by rivers, form the second stage. They surround the Silurian rocks in these mountain ranges, as well as forming most of the upland area of Corronoher and Knockfeerina Ridges. The Carboniferous Period began around 360 million years ago and forms the third episode. Its limestone forms the bedrock to the lowland plains.
These are limestones from open marine environments. Midway through this phase a period of volcanic activity saw basalt lava and other volcanic rocks deposited on the limestones
. In the fourth episode, the Upper Carboniferous, deep-water marine shales and deltaic sandstones were deposited and these now form the Mullaghereirk Mountains and the adjacent Abbeyfeale Plateau. However, the most significant force to shape the county as we see it today was the fifth major episode, the Ice Age, which ended about 11,500 years ago. Large ice sheets covered the entire region and county, and eroded the surface rocks. As the ice eventually melted away, the meltwaters reorganised the sediments into iconic landforms like eskers, also with outwash terraces of sand and gravel.

AGE (Million Years Ago)	ERA	PERIOD	EVENTS IN LIMERICK (non-italics)	IF THIS TIMESCALE WAS A DAY LONG...
2.58	Cenozoic	Quaternary	Several ice ages smothering Limerick, followed in the last 10,000 years by the spread of vegetation, growth of bogs and arrival of humans. Sculpting of corries in the Galtee Mountains. Deposition of (till) boulder clay in drumlins and till plains, as well as sands and gravels in outwash terraces and eskers. Dissolution of limestone beneath Quaternary sediments.	Ice ages would begin 38 seconds before midnight
23	Cenozoic	Neogene	Erosion, especially limestone. Turloughs, swallow holes, cavities, underground streams develop in lowlands of north and central Limerick.	Neogene period begins at 11.52 pm
66	Cenozoic	Palaeogene	Deposition of sediments and associated vegetative remains in cavities at Kildromin and Baggotstown.	Palaeogene period begins at 11.40 pm
145	Mesozoic	*Cretaceous*	*Erosion. No record of rocks of this age in Limerick.*	11.15 pm
201	Mesozoic	*Jurassic*	*Uplift and erosion. No record of rocks of this age in Limerick.*	Age of the dinosaurs, starting at 10.55 pm
252	Mesozoic	*Triassic*	*Desert conditions on land.* *No record of rocks of this age in Limerick.*	10.42 pm
299	Palaeozoic	*Permian*		10.30 pm
359	Palaeozoic	Carboniferous	Land became submerged, limestones with some shales and sandstones deposited in tropical seas across much of Limerick. Limestones remaining today are pure and unbedded in the majority, with smaller areas of muddier limestones at the edges. Eruption of volcanoes: lave flows and tuff deposited on limestones. Shales and sandstones deposited in the Mullaghereirk Mountains / Abbeyfeale Plateau.	Inundation of land by sea around 10.10 pm
419	Palaeozoic	Devonian	Caledonian mountain building. Sandstones deposited around the edges of the Ballyhouras, Galtees and Slieve Felim Mountains, and in the ridges at Corronoher and Knockfeerina.	'Old Red' Sandstone deposited at 9.52 pm
443	Palaeozoic	*Silurian*	Shallow seas following closure of Iapetus Ocean. Greywacke and shales deposited in the centre of the Ballyhouras, Galtees and Slieve Felim Mountains.	Starts at 9.42 pm
485	Palaeozoic	Ordovician	Iapetus Ocean divides Ireland into two. *No record of rocks of this age in Limerick.*	Begins at 9.28 pm
541	Palaeozoic	*Cambrian*	*Opening of the Iapetus Ocean.* *No record of rocks of this age in Limerick.*	Starts at 9.11 pm
2500	Proterozoic	*Precambrian*	*Some of Irelands oldest rocks deposited in Mayo and Sligo.*	Beginning 11.00 am
4000	Archaean	*Precambrian*	*Oldest known rocks on Earth.*	Beginning 3.00 am
4600	Archaean	*Precambrian*	*Age of the Earth.*	Beginning 1 second after midnight

The Geological Timescale and County Limerick.

5.2 More detailed summary of the geology of County Limerick

The scenic landscapes in the Limerick area formed over hundreds of millions of years by various geological processes, each one leaving its mark in the physical geography of the county. Careful examination of the rocks in the region can help unravel the mysteries surrounding their formation and thus shed light on the evolution of Limerick's terrain.

Rocks can be divided into three main groups, sedimentary, igneous and metamorphic. The first two of the three rock groups are exposed in Limerick. Sedimentary rocks are laid down in rivers, lakes or seas as particles of material such as sand or mud and then hardened by compaction and lithification into sandstones, siltstones, mudstones and limestones. Fossils, often preserved in these rocks, can give us an idea of when the rock formed and what the climate and environment were like at that time. Igneous rocks crystallise from magma originating deep beneath the Earth's surface and may be extrusive (i.e. lava flows at the Earth's surface) or intrusive (emplaced within the Earth's crust, below the surface). Metamorphic rocks are sedimentary or igneous rocks that have been altered by changes in temperature and/or pressure – this latter rock type is not present at any point beneath Limerick's landscape.

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

The landscape of County Limerick is a mix of lowland and upland terrain. The core portions of the Ballyhoura Mountains, Slieve Felim Mountains and the Galtees, are formed of the oldest rocks in the county. These older rocks crop out in several areas towards the centre of these mountain ranges where erosion has stripped away the younger rocks. These grey mudstones, siltstones and sandstones are Silurian in age, around 440 million years old, and were deposited on a deep ocean floor.

Surrounding these, and also forming the Corronoher and Knockfeerina Ridges, are conglomerates and sandstones of Devonian age, laid down by flash floods in a poorly vegetated river environment. Both Silurian and Devonian rocks are partly preserved because they were lifted up by Earth movements in both the Caledonain and Variscan orogenies, 490 to 390 and 380 and 290 million years ago.

Soon after the start of the Carboniferous Period, sea levels rose to flood across the low plains of Limerick. 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 million years ago, are much darker in colour and were deposited in considerably deeper water. Although the limestones mostly form low ground across the centre and east of the county, they are well exposed in various working and disused quarries and on some of the low hills in both the centre and south of the county also.

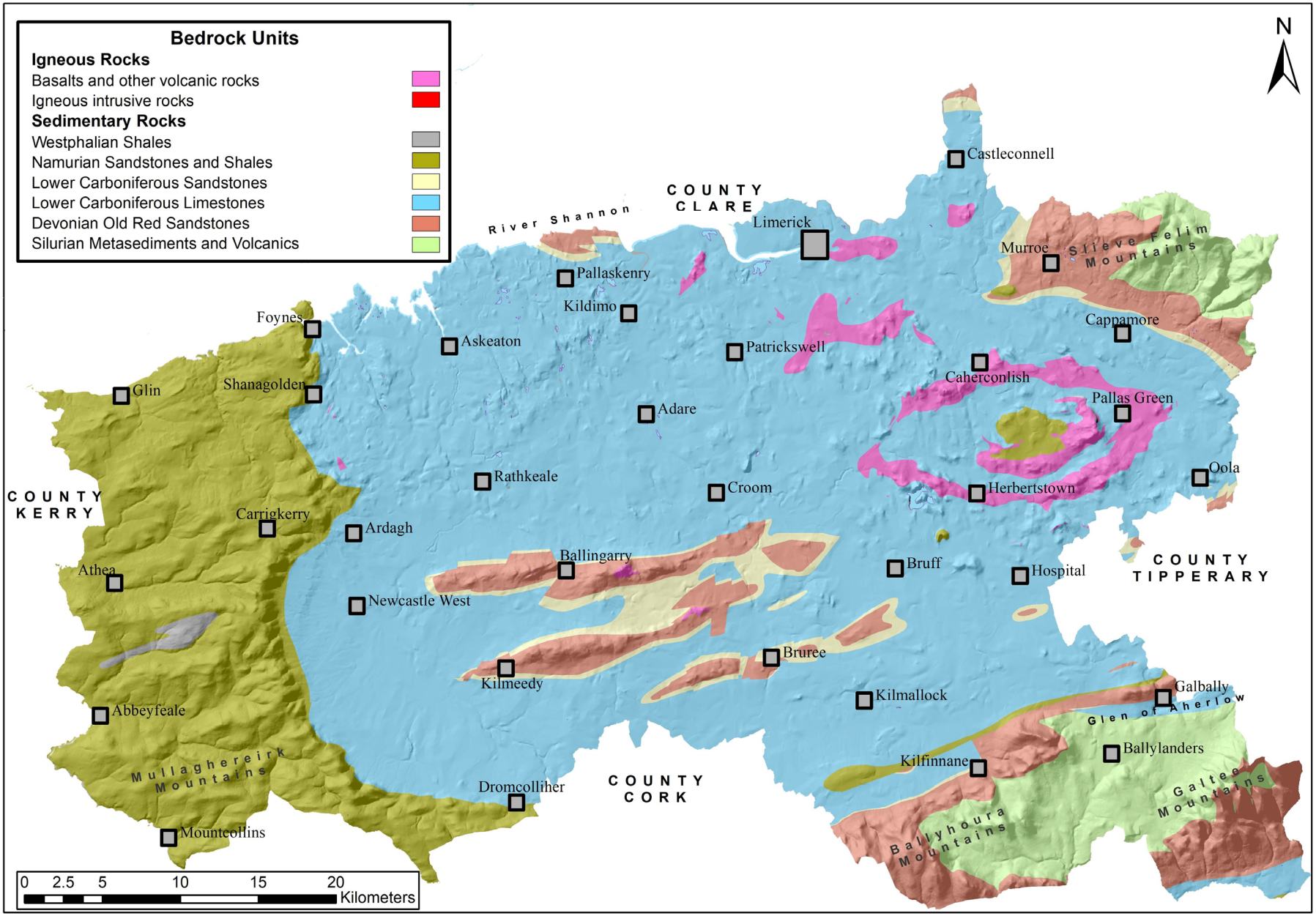
Although the Carboniferous Period was dominated by warm-water sedimentation on the continental shelf, it also saw a series of volcanic eruptions. Thick flows of basalt and beds of tuff were deposited on the sea floor and today form layers on and between the limestone strata. Thick basalt lava flows form the huge rock outcrop upon which Carrigogunnell Castle stands, near Mungret. Most of the Carboniferous volcanic rocks occur in the area between Pallas Green and Fedamore, as lava flows and tuff layers interbedded with limestone. The volcanic magma was also intruded as dykes along faults or fractures and as fillings or plugs to volcanic vents. These intrusions, typically composed of resistant trachyte, now form small, sharp peaks, such as those at Knockderk and Kilteely. Apart from the Antrim Basalts, which include the Giant's Causeway, the Limerick Volcanics constitute the most extensive and best-preserved example of a volcanic episode in Ireland.

Only in and around the Mullaghereirk Mountains and the adjacent Abbeyfeale Plateau are there younger rocks, from the Upper Carboniferous Period, when the shallow sea was filled with deltas and swamps. The delta deposits solidified to form sandstone and the vegetation in the swamps eventually matured into coal.

The land surface was then uplifted and over a period of nearly 300 million years many of the rocks formed in the preceding 200 million years were eroded away, and the land surface reduced down to its present level.

The most significant force to shape the form of the county as we see it today was the Ice Age which ended about 11,500 years ago. Large ice sheets several hundred metres in thickness covered the county for tens of thousands of years and eroded the rocks beneath. Only the highest points in the Galtee Mountains, and Black Rock and Seefin Mountains in the Ballyhouras, poked up above the ice as nunataks. As the ice eventually melted away, the meltwaters reorganised the sediments into iconic landforms like drumlins, eskers and moraines. Drumlins occur in the northcentral part of Limerick, and eskers were formed by sub-glacial rivers, that is, they flowed in tunnels at the base of the ice sheets. Some eskers are small and local within Limerick, such as the Carrigkerry Esker, but the majority that traverse the county form extended networks and cross several counties. Other iconic landforms created by the ice sheet in Limerick include the crag and tail at Tory Hill, and the deep meltwater channels at Galbally and the Clare Glens.

Since the Ice Age, much of the exposed limestone in Limerick has developed into what is termed karstified bedrock. Water solution of the rock formed underground cavities linked to the surface by swallow holes. Geological processes continue to modify the landscape today, as manifested by events such as seasonal flooding of the Shannon and many of Limerick's other major rivers.



A simplified geology map of County Limerick outlining the main geological units.

6. Acknowledgements

The authors gratefully acknowledge the assistance of Tom O'Neill, Heritage Officer from Limerick City and County Council in the development of this project. Funding from the Heritage Council and Limerick City and County Council is also acknowledged. We also acknowledge the many members of the Geoheritage (IGH) Programme Expert Panels who originally helped define the sites that were considered for County Geological Site status.

The authors especially thank all the landowners and others who have provided information and help in the field visits to sites, but for their assistance and generosity, we especially thank the following people:

The staff at Irish Cement in Mungret, particularly Emmet Clarke
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Ann Cribbin of Tomdeely North, Askeaton
Costelloe's Quarry, Ballinleeny
Declan Flynn, Knocksouna
Harry Tobin of Tobins Quarry, Eyon, Murroe
Teresa English, Caherconlish Quarry

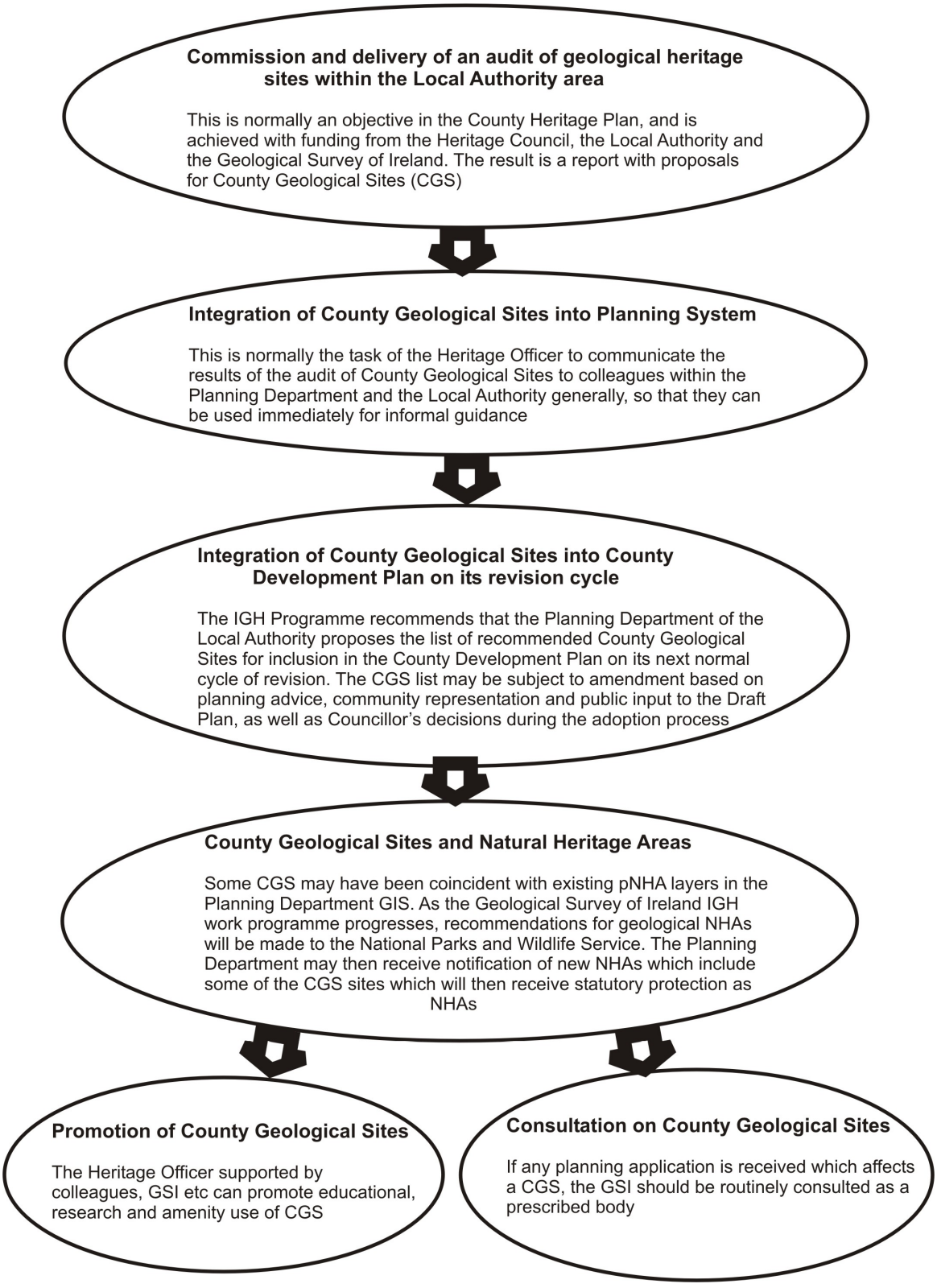
Appendix 1 – Geological heritage audits and the planning process

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 Geological Survey Ireland 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 Geoheritage (Irish Geological Heritage) Programme in Geological Survey Ireland, over the course of numerous county audits since 2004.

County Geological Sites - a step by step guide



Appendix 2 - Bibliography – Geology of County Limerick

Shortlist of Key Geological References

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

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Appendix 3 - Bibliography – Quaternary Geology of County Limerick

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Appendix 4 – Geological heritage versus geological hazards

Ireland is generally considered to have a very low level of risk in terms of major geological hazards: there are no active or dormant volcanoes in Ireland, the island is located on stable tectonic plates which means earthquakes are rare, and disastrous landslides, mudflows, flood events or other geological catastrophes are rare throughout recorded history. This section considers the specific record and nature of geological hazards in County Limerick and the relationship of County Geological Sites to those hazards.

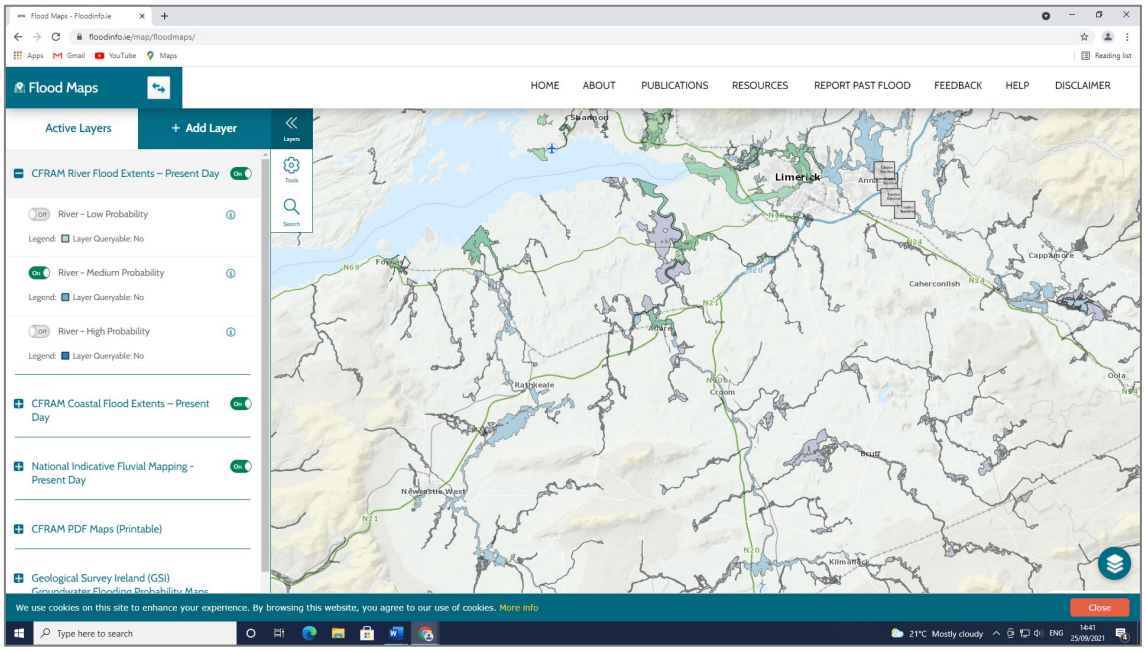
The difference between human timescales and geological timescales can be difficult to comprehend but, for many geological processes, there are periods of sudden activity encompassing major events, followed by long, quiet periods in between. The County Geological Sites in this audit represent evidence of past geological environments and processes, such as the building of high mountain chains, ice sheets covering the land surface and so on. Presently in County Limerick there are relatively few sites representing the active geomorphological or land-forming processes of today.

Landslides and bog flows

Geological Survey Ireland has been compiling national data on landslides in the past decade. There are over five events recorded in County Limerick. A landslide at Castlegarde, near Cappamore, in 1708, was exceptionally destructive, causing 21 deaths. The bog slide there broke through bridges and eventually flowed into Lough Coolpish, several kilometres away. For more information see Geological Survey Ireland Geohazards Programme webpage (https://www.gsi.ie/).

Flooding

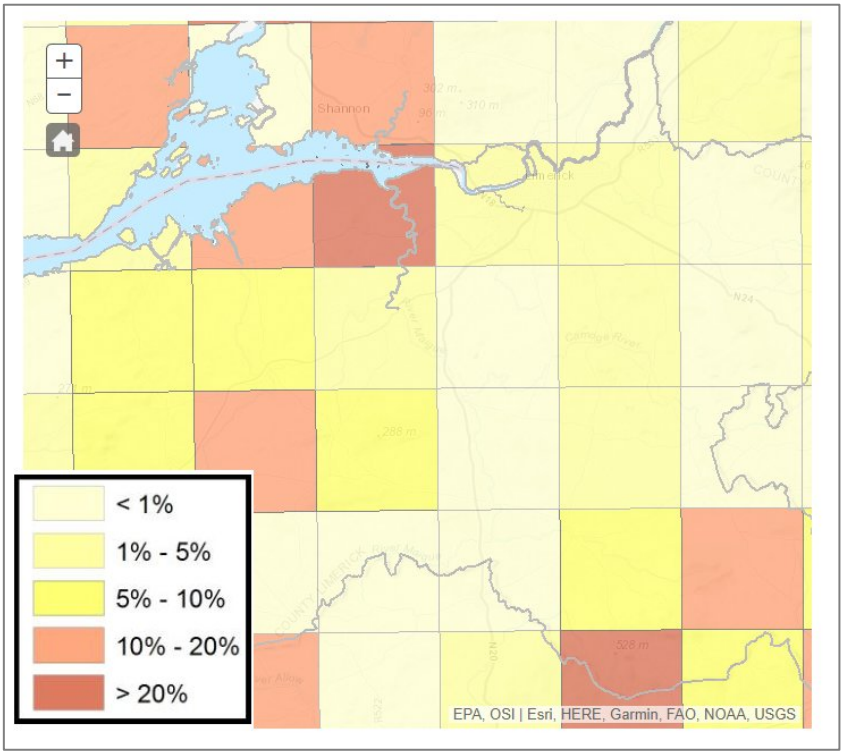
There are two types of flooding which need consideration. River flooding occurs inland when rainfall exceeds the capacity of the ground to absorb moisture, and the river channels cannot adequately discharge it to the sea. The Office of Public Works website (www.flooding.ie) can be consulted for details of individual flood events in County Limerick. Karstic flooding can occur when underground passages are unable to absorb high rainfall events.



Screengrab of OPW Flooding Probability Map showing County Limerick

Radon

Radioactive minerals and gases at high concentrations can be carcinogenic. Radon 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 viewed on the Environmental Protection Agency (EPA) website (www.epa.ie).



Screengrab of EPA Radon Map showing County Limerick (https://www.epa.ie/)

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. County Limerick is 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 Limerick

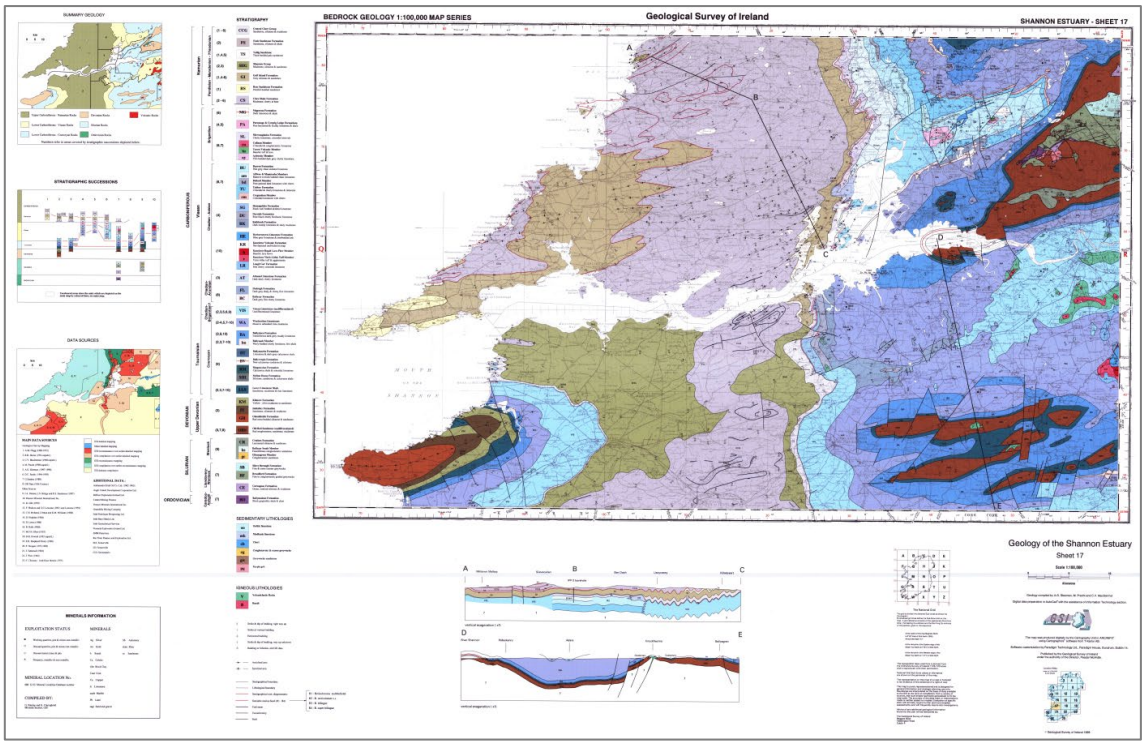
This section is a brief summary of publicly available Geological Survey Ireland data and services, to assist with any enquiry concerning geology. Geological Survey Ireland has a vast library of data accumulated since it began mapping Ireland's geology in 1845. A Document Management System called GOLDMINE is freely available online, and hosts almost digital 500,000 documents and maps. All GOLDMINE data is publicly available free of charge. Key datasets include:

GOLDMINE

Goldmine (**G**SI **O**n**L**ine **D**ocument **M**aps and **I**nformatio**N** **E**xplorer) is Geological Survey Ireland's online digital archive database. The service provides public access to reports, publications and maps in PDF or high resolution TIFF image formats. The library consists of scanned documents and maps which include Geological Survey Ireland principal datasets, Mineral Exploration Reports, Geotechnical Reports, boreholes and test data, historic 6" and 1" scale geological maps, official Geological Survey Ireland publications, bulletins, published and unpublished reports, groundwater well hydrographs, airborne geophysical maps, mineral locality reports and mine records. https://secure.decc.gov.ie/goldmine/index.html (or search online for GSI Goldmine).

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. Map Report Sheets 17, 18, 21 and 22 cover all of County Limerick.



Geological Survey Ireland Sheet 17 showing Counties Limerick, Kerry and Clare

19th Century Six inches to One mile (1:10,560) Field Sheets

The 6" scale field sheet series provides an important historical and current resource with very detailed observations of the geology of the entire country. Produced in the mid-18th century, these sheets are digitally available the public via Geological Survey Ireland's Interactive Web Data Delivery System (IWDDS) and GOLDMINE service.

- https://jetstream.gsi.ie/iwdds/map.jsp
- https://secure.decc.gov.ie/goldmine/index.html

Geological Survey Ireland 6 Inch Field Sheet Limerick 32a–1 showing the Lough Gur area, County Limerick

19th Century One Inch to One Mile (1:63,360) Maps and Memoirs

Information from the detailed 19th century mapping was distilled into one inch to the mile maps, of which parts of parts of Sheets 142, 143, 144, 153 and 164 cover County Limerick. Each sheet is accompanied by a memoir describing the geology of the area. The maps and memoirs provide valuable records of observations, though some interpretations may have changed since publication with better geological understanding.

Memoirs are publically available in scanned PDF format on the Geological Survey Ireland GOLDMINE website.

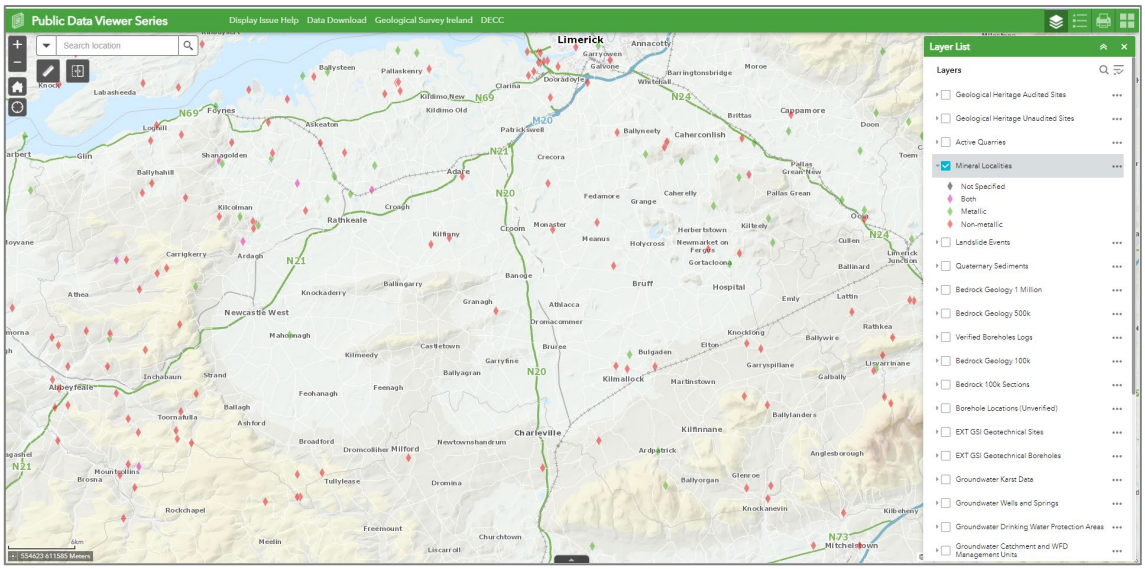
Maps and memoirs are publicly available in on the Irish Historical Geological Maps website of the British Geological Survey, Geological Survey of Northern Ireland and Geological Survey Ireland.

Open File Data

Each Mineral Prospecting Licence issued by the Geoscience Regulation Office (GSRO), of the Department of Environment, Climate and Communications, carries an obligation on licence holders to submit exploration reports and data on the works carried out under a prospecting licence. Reports and data are held confidentially for 6 years or until licence surrender, whichever is the sooner. After 6 years or upon surrender of the licence, the data is released publicly via the GSRO interactive map viewer and a searchable database. Records include geological interpretations, borehole logs, geophysical and geochemical surveys. Licences relate to numbered prospecting areas and are available on a map from GSRO (www.mineralsireland.ie)

MinLocs Data

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



Screengrab of Geological Survey Ireland Public Data Viewer displaying Mineral localities in Co Limerick

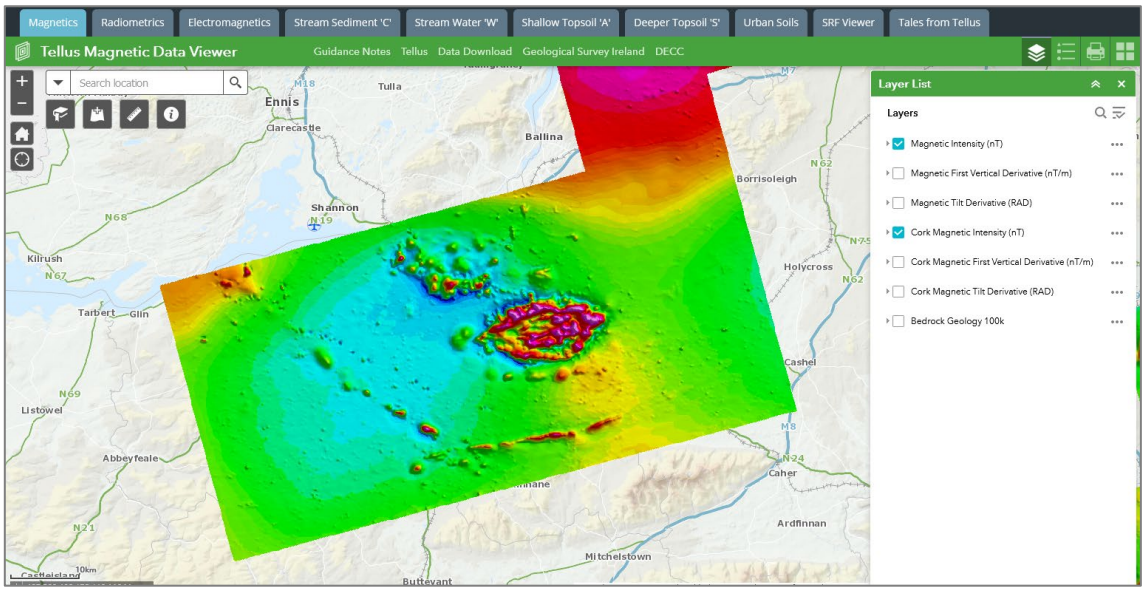
Subsoils and Quaternary Mapping

In 2012, Geological Survey Ireland completed the final county-scale Groundwater Protection Schemes (GWPSs), in partnership with Local Authorities, and there is now national coverage of GWPS mapping. Subsoil and bedrock mapping provides a significant resource for groundwater protection, as well as for other purposes. Detailed compilation of glacial geology and geomorphology datasets, including a revision published by Geological Survey Ireland in 2014, has amplified data pertaining to groundwater and the Quaternary history of Ireland. Digital mapping of many different datasets is now available via the Geological Survey Ireland public data viewer (see www.gsi.ie).

Tellus Mapping

Tellus is an island-wide mapping project, combining airborne geophysical and geochemical surveys to provide geoscientific information for the island of Ireland. Tellus surveying was completed in the border region of Ireland in 2013, and has since moved southwards, including (as of October 2021) almost complete airborne geophysical coverage of County Limerick. All data from Tellus is available free of charge online. The Tellus surveys support mineral exploration, environmental management, agriculture and research activity. See www.gsi.ie/tellus.

Data are freely available at https://www.gsi.ie/en-ie/programmes-and-projects/tellus/Pages/Data-and-Maps.aspx



Screengrab of Geological Survey Ireland Tellus Data Viewer displaying Magnetic Intensity in County Limerick

Historic Mine Records in Geological Survey Ireland

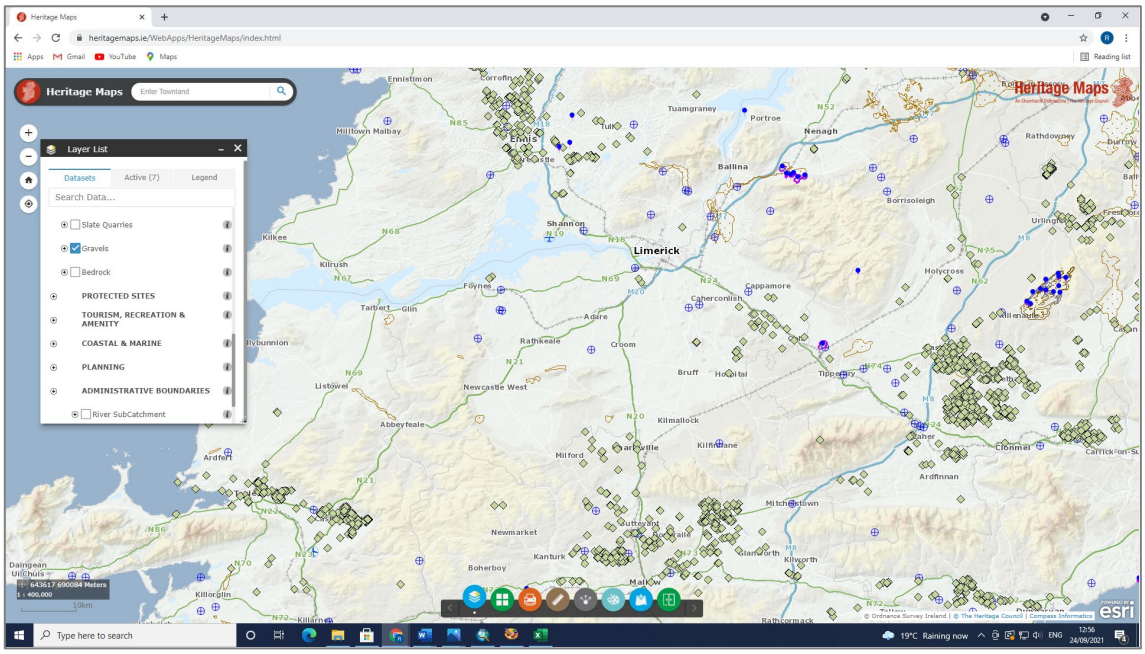
Abandonment plans and varied other material exist for the various mining ventures in the country and are stored in Geological Survey Ireland. The range of data varies from single items for some historical mine sites, to immensely detailed series of plans for more modern mine sites. Virtually all of these are scanned and available on GOLDMINE (see above) but additional material, e.g. photographs, may be stored in the paper records, held in Geological Survey Ireland archives. Additionally, scanned material does not include some very historic or rare plans and documents that are stored in a separate Geological Survey Ireland archive, part of the National Archive.

Ordnance Survey Geohive

The Ordnance Survey Ireland online mapping website Geohive (https://www.geohive.ie/) offers a superb resource with OSI maps at different scales, colour and black & white air photos, and a varied range of datasets available to view online. Geological Survey Ireland data (e.g. bedrock geology, Quaternary geology, minerals, groundwater and county geological heritage sites) is available on the map service, along with NPWS and other protected site data. Boundary data for County Geological Sites are available as a data layer on the online mapping service. http://map.geohive.ie/mapviewer.html

Heritage Council Heritage Viewer

HeritageMaps.ie is a web-based spatial data viewer, co-ordinated by the Heritage Council, and working with the Local Authority Heritage Officer network, which focuses on the built, cultural and natural heritage around Ireland and off shore. The viewer allows users to look at a wide range of built and natural heritage data sets online. The outlines of and data on each individual County Geological Site in Limerick should be made visible on the HeritageMaps.ie viewer once the audit is completed. http://heritagemaps.ie/



Screengrab of Heritage Maps Data Viewer displaying County Limerick (Oct. 2021)

Appendix 6 – Further sources of information and contacts

Geoheritage Programme staff at Geological Survey Ireland can be contacted in relation to any aspect of this report. Tom O'Neill, Limerick City and County Heritage Officer, is the primary local contact in County Limerick for further information in relation to this report. Other contacts include National Parks and Wildlife Service Conservation Rangers of the, currently in the Department of Lousing, Local Government and Heritage. See www.npws.ie for contact details.

Websites of interest

www.gsi.ie - general geological resources. Geological Survey Ireland is the national earth science agency and is a division of the Department of the Environment, Climate and Communications. We provide independent geological information and advice and gather various data for that purpose.

https://secure.decc.gov.ie/goldmine/index.html - GOLDMINE. Geological Survey Ireland online data archive database.

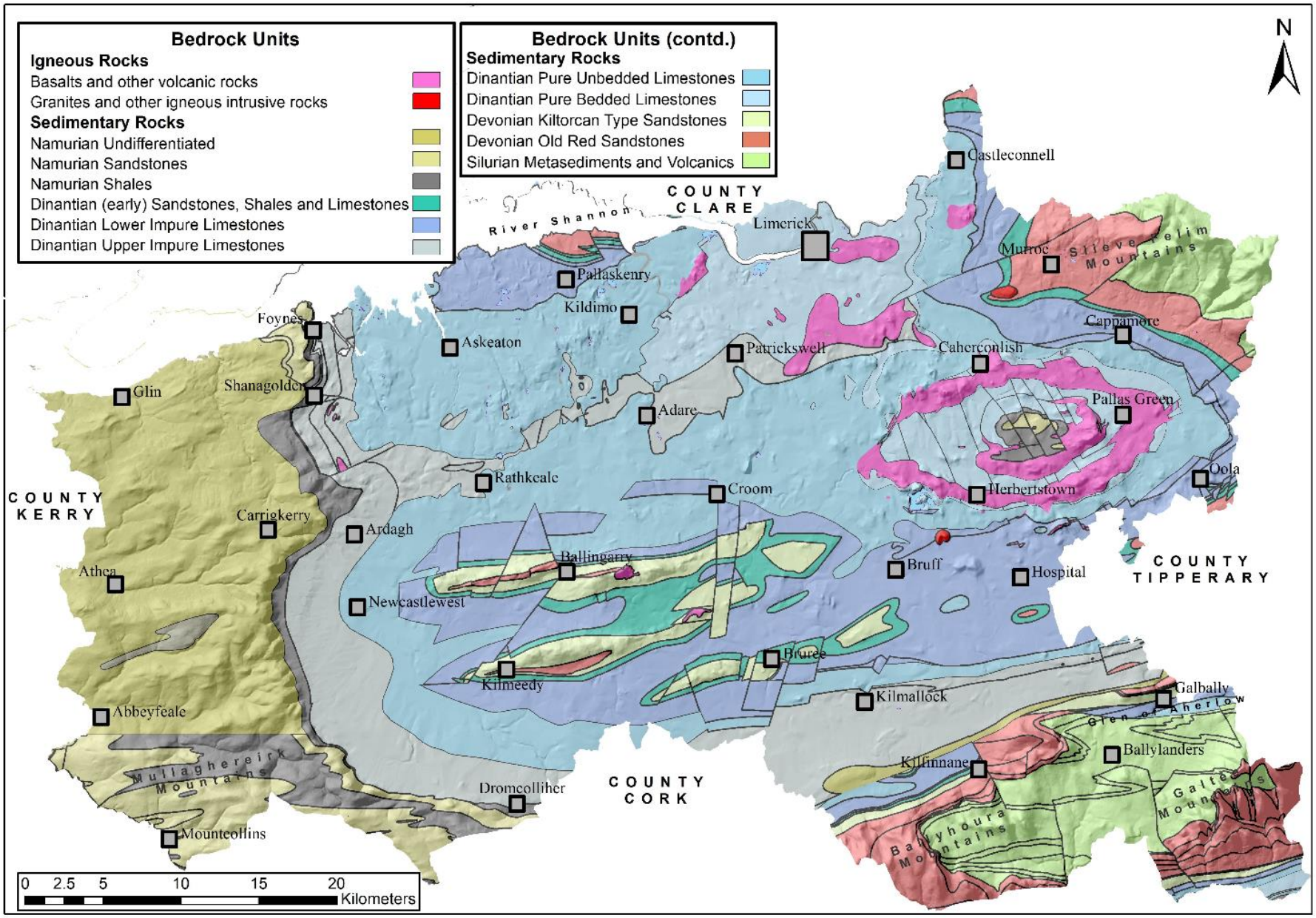
www.geologicalmaps.net/ - historical geological maps.

www.geology.ie –website of the Irish Geological Association who run fieldtrips and lectures for members, including many amateur enthusiasts.

http://www.iqua.ie - for information, fieldtrips, lectures etc in relation to Ireland's Ice Age history.

http://www.progeo.ngo/ - for information about ProGEO the European Association for the Conservation of Geological Heritage.

Appendix 7 – Detailed geological map of County Limerick



Appendix 8 – Geoschol leaflet on the geology of County Limerick

LIMERICK

AREA OF COUNTY: 2,686 square kilometres or 1,037 square miles

COUNTY TOWN: Limerick

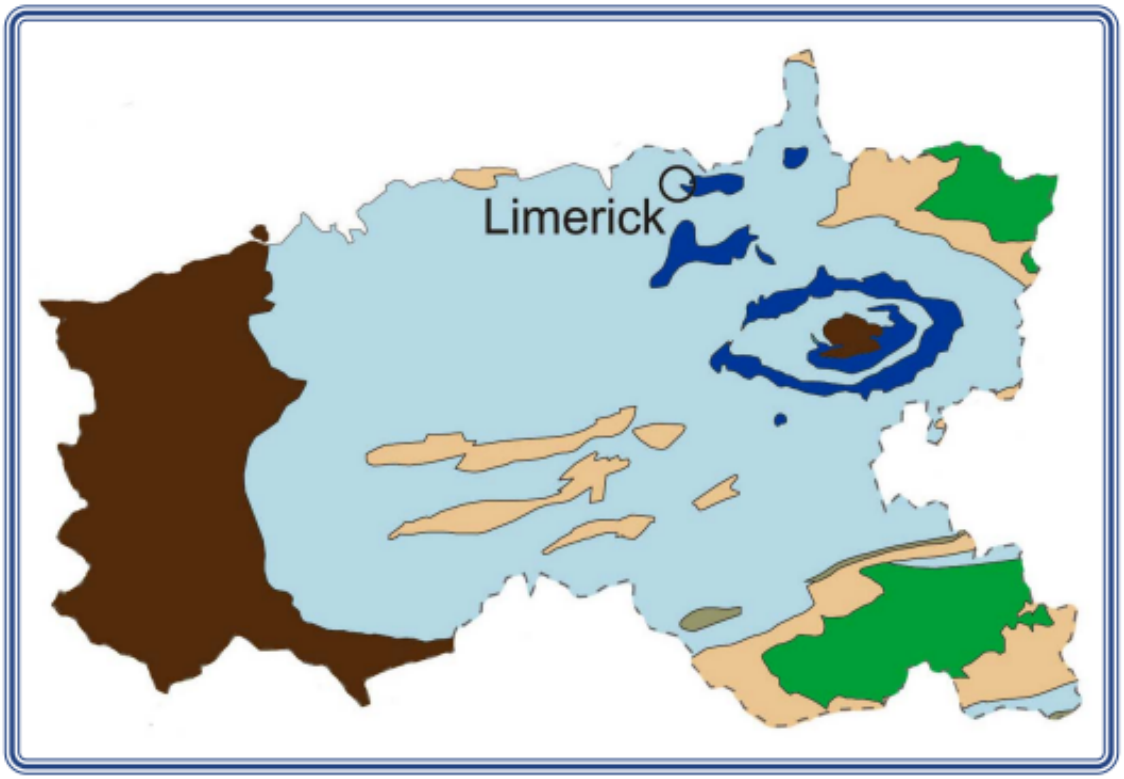
OTHER TOWNS: Askeaton, Kilmallock, Newcastlewest, Rathkeale

GEOLOGY HIGHLIGHTS: Giant Irish Deer, Lower Carboniferous limestones and volcanic rocks

AGE OF ROCKS: Silurian to Carboniferous

Carrigogunnell Castle, Co. Limerick

This ruined 13th to 16th century Norman castle is perched on top of a crag of Lower Carboniferous volcanic rocks



Geological Map of County Limerick

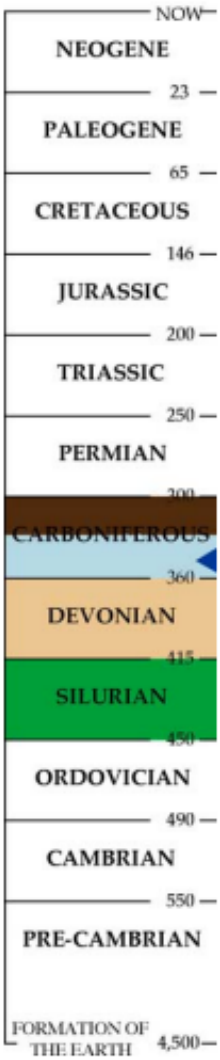
Green: Silurian sediments; **Beige:** Devonian sandstones and conglomerates; **Light blue:** Lower Carboniferous limestone; **Brown:** Upper Carboniferous shales; **Dark blue:** Carboniferous volcanic rocks.

Geological history

The geology of Co. Limerick comprises rocks that are between 450 and 300 million years old [Ma]. The Silurian rocks are the oldest and are mudstones and sandstones deposited in an ocean that separated Ireland into two. This ocean, at that time, had nearly closed as the continents on either side moved together. These oldest rocks now make up the Slievefelim Mountains. At the start of the Devonian period (415 Ma) the landscape had changed significantly. No longer was Ireland split into two, but it consisted of one large continent. The climate was dry and the land desert-like because of a lack of plants. It contained many sand dunes of wind-blown sand but also temporary rivers which occasionally flooded and as they did so coarse pebbly sediments and sands were deposited. These were eventually cemented to form conglomerate and sandstones which make up part of the Slievefelim range. The area became flooded by a shallow tropical ocean at the beginning of the Lower

Giant Irish Deer (male) from Lough Gur now at Trinity College, Dublin

Carboniferous (360 Ma). Life in the oceans was plentiful and is now seen as fossils in the pale grey limestone. Small mudmounds developed in the oceans. Today in the Pallas Green district can be found some volcanic lavas and other rocks surrounded by limestone. Some zinc was also found locally. In Ireland such Carboniferous volcanic rocks are rare. During the Upper Carboniferous (330-300 Ma) rivers carried a great deal of sediment southwestwards across the continent and it was dumped at the mouth of these rivers in the form of deltas that grew out into a deepening ocean. These formed the shales that make up the higher ground just west of Newcastlewest.



Geological timescale showing age of rocks in Limerick

Megaloceras giganteus – the Giant Irish Deer

During the last 2 million years Ireland was subjected to a number of ice advances and ice retreats which collectively are known as the Ice Age. Various animals lived here during the warmer periods, and included bears, hippopotamus, mammoth, hyaenas, and Giant Irish Deer. This deer was a spectacular animal with the male carrying impressive antlers over 2 metres wide. These had to be grown every year. During summer the deer lived and fed on higher ground but in the colder winters they came down to lowland valleys to rest and feed. Fossils of these animals have been found at Lough Gur where it is thought that when they died they became washed into the lake. Overtime vegetation in-filled the lake and formed a raised bog. When this was excavated the fossils were located.

Cement

Cement in Ireland is manufactured at three locations in Ireland: Platin, Co. Meath, Edenderry, Co. Kildare and at Castlemungret, Co. Limerick. The Limerick Cement Works opened in 1938 and the plant was expanded in the 1950s. Cement is produced by combining crushed Lower Carboniferous limestone that is quarried locally with Silurian shale, a deep-water, fine-grained dark sedimentary rock. The mixture is then heated to 1500 degrees Centigrade and forms clinker, which is then powdered. Finally a small amount of the mineral Gypsum is added, and the process is complete.

Limestone quarry at Mungret with Limerick Cement Works in the background

Norman Castles

The Normans came to Limerick in the late 1100s and rapidly began to build castles across the county to enforce their rule. Many of these castles were constructed of local stone – Lower Carboniferous limestone – as it was readily available from the immediate surroundings, and it was easy for the stone masons to work it and to cut it into blocks when required. The castles are largely Tower Houses with a square plan and several floors. Many of these are built on small limestone mudmounds as they would be drier than the surrounding areas and gave the occupiers a better viewpoint if attacked. These mudmounds developed on the Lower Carboniferous seafloor 350 Ma when corals and bryozoans all helped to trap a lot of lime mud and build small mounds that grew higher than the adjacent layers of lime mud that later became well-bedded limestone.

Map adapted with permission from Geological Survey of Ireland 1:1,000,000 map 2003.
Image credits: Geological Museum, Trinity College, Dublin 3; Geological Survey of Ireland 4.

Appendix 9

Glossary of geological terms

Geological term	Definition
Adit	a horizontal or only gently inclined mine tunnel dug to access coal or mineral ore, or to drain, ventilate or further develop a mine
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.
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.
Breccia	igneous or sedimentary rock comprising of large angular fragments within finer grained material.
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.
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).
Cyclothem	alternating layers of marine and non-marine sediments, indicative of cyclic depositional regimes; often interbedded with coal seams
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.
Glacial striae	markings left on the surface of pebbles / boulders / bedrock by moving ice sheets.
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).
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.
Impermeable rock	rock through which water cannot flow
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.
Karst	a landscape with distinctive hydrology and bedrock landforms that arise when the underlying rock is soluble.
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.
Meltwater channel	a channel cut by glacial meltwater, either under, along or in front of an ice margin.
Mississippian	earlier (first) of the two subdivisions of the Carboniferous Period, lasting from 358.9 to 323.2 million years ago.
Moraine	any glacially formed accumulation of unconsolidated debris, in glaciated regions, such as during an ice age.
Mudmound	Waulsortian limestone of Carboniferous age is characterised by forming as massive mounds or ridges or sheets of carbonate mud on the seafloor of the time. Mudmound is a general term to describe the varieties of forms.
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.
Mississippian	later (second) of the two subdivisions of the Carboniferous Period, lasting from 323.2 million to 298.9 million years ago
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.
Transgression	an incursion of the sea over land area
Type section	the designated exposure of a named layered stratigraphic unit or of a stratigraphic boundary that serves as the standard of reference
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	Mississippian (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.

Section 2 - Site Reports

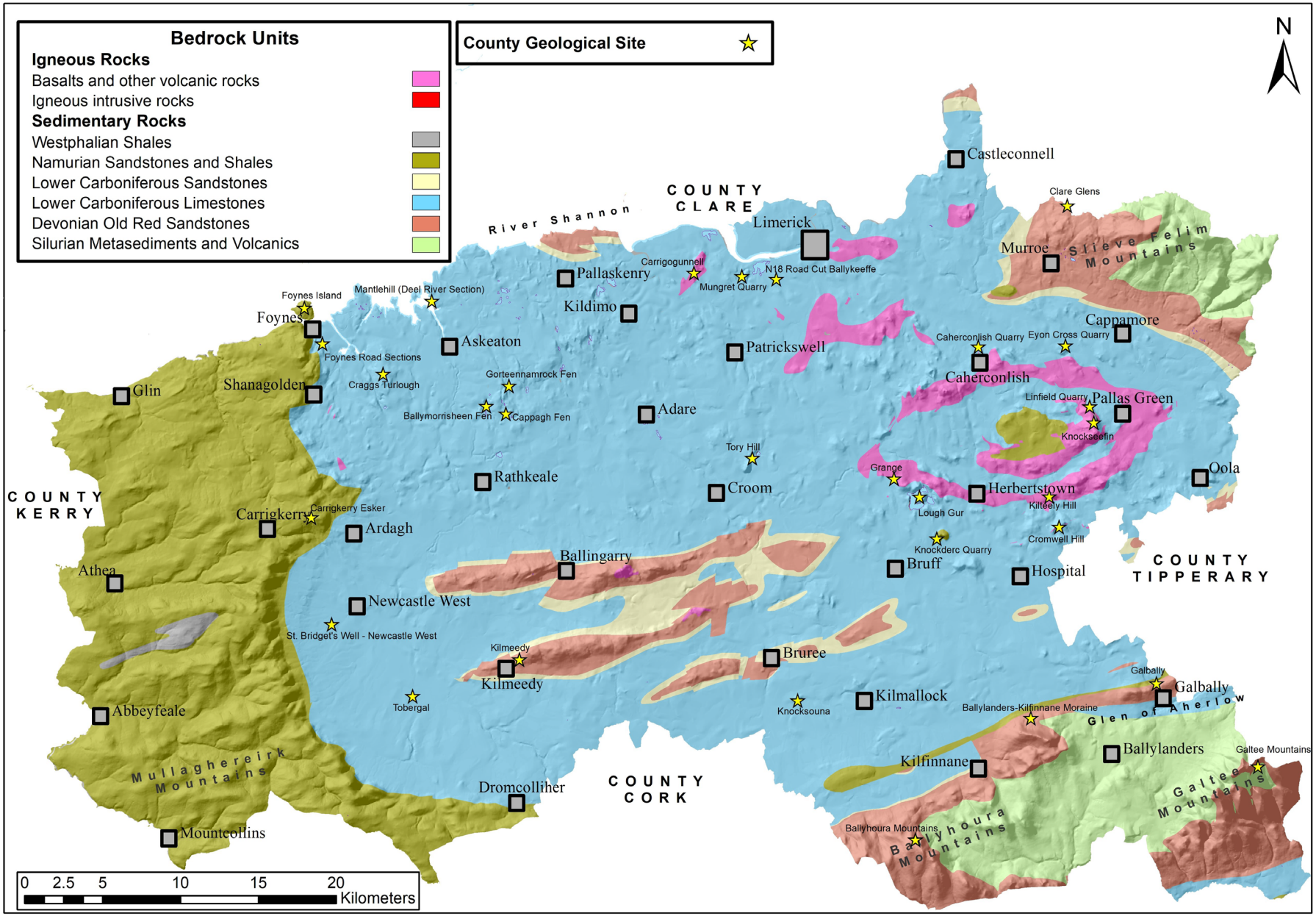
Site reports – general points
The following site reports are brief non-technical summaries of the proposed County Geological Sites for County Limerick. These have been specially prepared for this report with the objective of making the information accessible to planners and others without geological training. Further sites may become relevant as Geoheritage Programme and County Geological Site initiative develops in the future.

Each County Geological Site report has primary location information, a description of the main rock types and age, and a summary of the key aspects of scientific interest at the site. A section outlining any particular management or other issues specific to the site is included, along with several low-resolution photographs exemplifying the site. **A CD accompanying this report will include further pictures of most sites at higher resolution, should they be required for a publication or information leaflet**. Grid coordinate references are given for a central point in the site generated from the GIS mapping (ESRI Shapefile) of the site boundary. Grid coordinates are indicative of the general site location. Two six-digit Irish Transverse Mercator (ITM) grid coordinates (X and Y) are presented for all site localities in the site reports. Irish Transverse Mercator (ITM) is the standard coordinate system for Ireland, and is used in updated OSI Discovery series maps.

The site boundary extent is best shown on the included maps, and is also published on the Geological Survey Ireland Public Data Viewer mapping service. **It is important to note that these boundaries have no legal or definitive basis. They are indicative only of the limits of exposure or of geological interest, and not based on detailed field and boundary surveys, which were outside the scope of this contract.** Boundaries are drawn to include the geological or geomorphological interest of the site, but are extended to the nearest mappable boundary, such as a field boundary, stream, road or edge of forestry. On a few sites, such as in open mountain terrain, it is impractical to find a boundary within a reasonable distance and an arbitrary line may be defined. County Geological Sites are non-statutory and so this is not problematic. If any County Geological Site is fully assessed for NHA status in the future, such a boundary may require small revisions.

For sites that have already, or which will be recommended for NHA designation, detailed site boundary maps will become available to the Local Authority through NPWS as the designation process is undertaken. Some areas may already be available if they are proposed NHAs (pNHA), under the Wildlife (Amendment) Act 2000. Sites, which are situated in a designated Special Areas of Conservation (SAC) under European Habitats Directive will also have statutory boundaries already determined. The geological interest may be included within these wider areas of nature conservation.

In terms of any geological heritage site designation as NHA, due process of site reporting, boundary survey and very importantly, consultation with landowners where they can be readily identified, will take place before Geological Survey Ireland finalises recommendations with NPWS on the most important sites to be designated. Any landowner within areas or sites identified in this report with concerns over any aspect of this project is encouraged to contact the Head of the Geoheritage Programme, Geological Survey Ireland, Block 1, Booterstown Hall Booterstown, Blackrock, Co Dublin, A94 N2R6. Phone 01-6782837. Email: clare.glanville@gsi.ie.



Simplified Geological Map of County Limerick with county geological site locations indicated.