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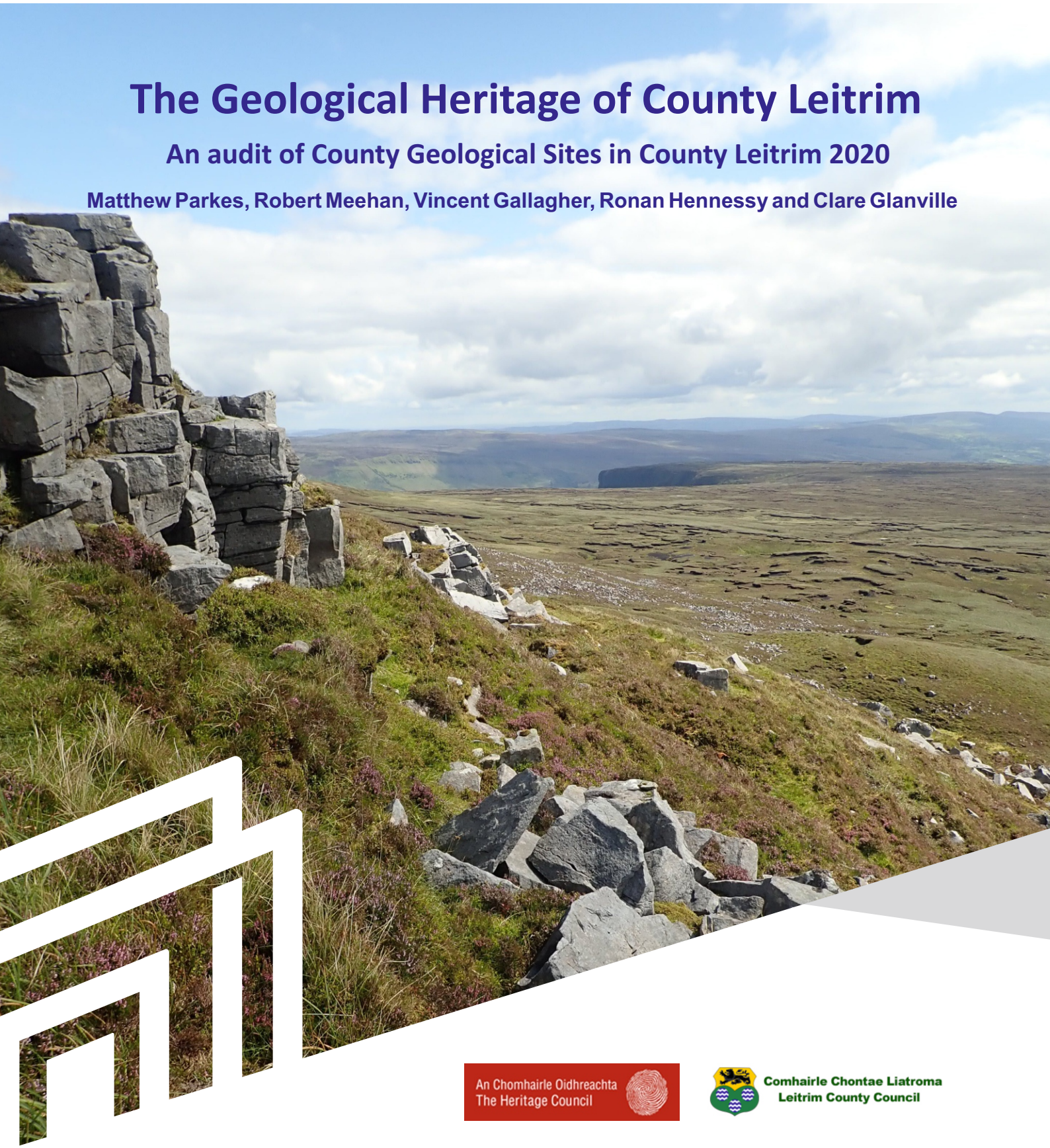
The Geological Heritage of County Leitrim

An audit of County Geological Sites in County Leitrim 2020

Matthew Parkes, Robert Meehan, Vincent Gallagher, Ronan Hennessy and Clare Glanville



An Chomhairle Oidhreachta
The Heritage Council

Comhairle Chontae Liatroma
Leitrim County Council

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

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2020

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Comhairle Chontae Liatroma
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Dedication

This audit is dedicated to the memory our colleague and friend, Matthew Parkes, who passed away suddenly in the days prior to completion of the audit's work.

Matthew was an exceptional geologist with a keen eye for detail and an expertise in numerous sub-disciplines of geology. He was inquiring in the field, had huge output in terms of peer reviewed papers, and gave tirelessly to students of geology, of any age, with diligence, care, and passion.

Matthew was probably **the** driving force behind Geoheritage in Ireland, having initially worked in the mid-1990's on the then-blossoming Irish Geological Heritage Programme in Geological Survey Ireland, and latterly as curator in the Natural History Museum.

Matthew worked on and co-authored every one of the reports for the twenty four County Geological Heritage Audits completed thus far in Ireland.

This Geological Heritage Audit was funded by the Heritage Council and Leitrim County Council.

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Not represented in County Leitrim

Executive Summary

County Leitrim 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 Leitrim has an extensive and diverse range of geological heritage sites. Many of them represent the primary geological foundation of uplands composed of Carboniferous age limestone and sandstone rocks. Associated with the upland areas are coal and iron deposits and extensive development of caves and other karstic landscape features. The County Council's support for this audit is critical in raising the profile of geological heritage in County Leitrim 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 Leitrim. 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 listing based on desk study that was previously adopted (List is Appendix C) in the current 2015-2021 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, many of the sites fall within existing pNHAs and SACs where the ecological interest is actually founded upon the underlying geodiversity.

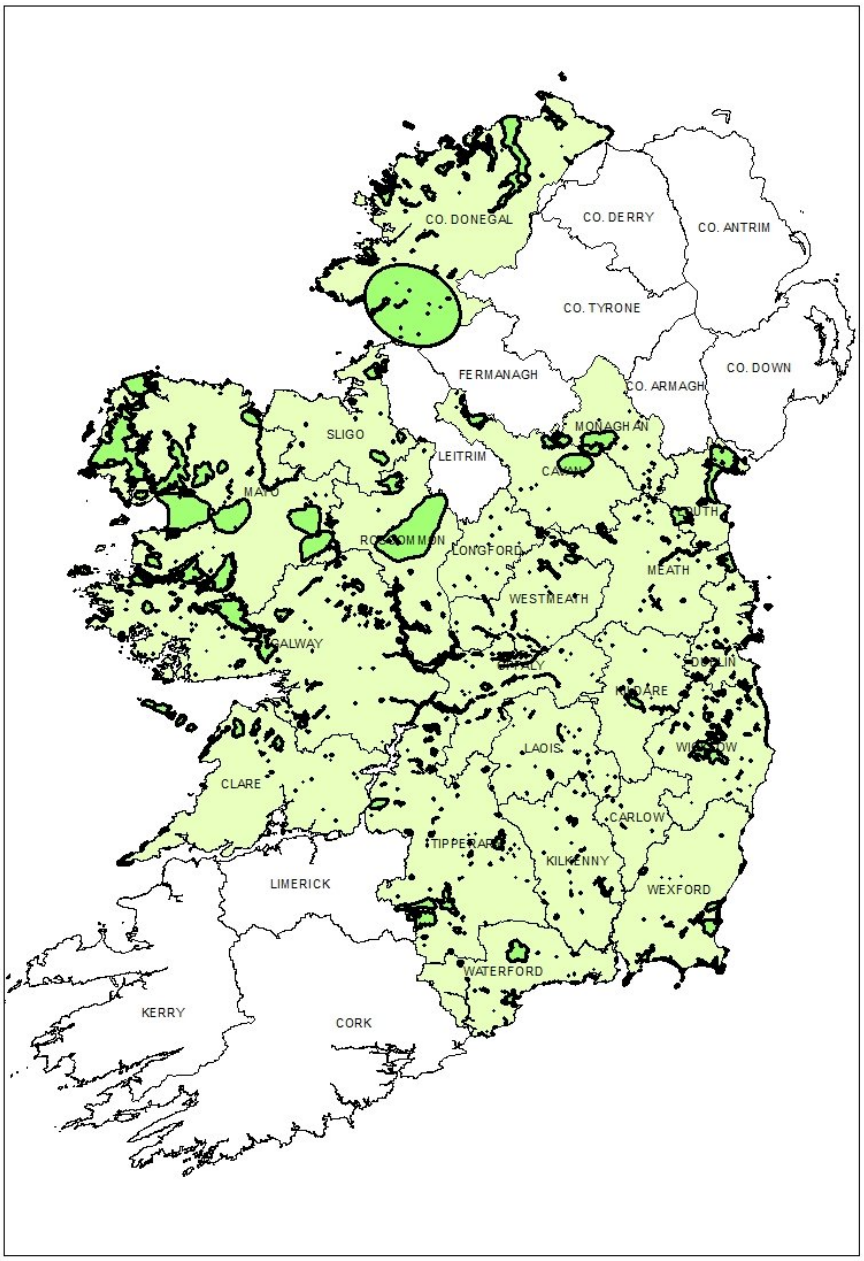
The commission of this audit and adoption of the sites within the CDP ensure that County Leitrim follows a now established and effective methodology for ensuring that geological heritage is not ignored in the absence of progress with designation of geological NHAs at national level. It brings County Leitrim 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 and the Planning Department of Leitrim County Council. It should also be made available via the County Council website for the people of County Leitrim. A chapter of the report includes recommendations on how to best present and promote the geological heritage of County Leitrim to the people of the county. It will also inform the work of the 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 Leitrim, if the funding can be found to produce them.

1. County Leitrim in the context of Irish Geological Heritage

This report brings County Leitrim 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 Leitrim 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 real statutory protection where it is required, although the statutory County Development Plan provides capacity to preserve sites where necessary.



Counties shown as olive have been audited prior to 2020. County Geological Sites in dark 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 assessing Ireland's geodiversity. Geodiversity is the foundation of the biodiversity addressed under European Directives on habitats and species by the designations of Special Areas of Conservation (SAC) and 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 County Leitrim 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 2020, 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 done along with a Theme Report. Due to various factors, none have yet been formally designated. In County Leitrim, some karst sites like Largy and The Doons were so far considered to be of national importance and had been put forward as Natural Heritage Areas (NHA) for the IGH1 Karst Theme. Therefore, inclusion of all sites as County Geological Sites in County Leitrim's planning system will ensure that they 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. It does not exclude other sites being identified later, or directly promoted by the Council itself, or by local communities wishing to draw attention to important sites for amenity or education with an intrinsic geological interest. New excavations, such as major road cuttings or new quarries, can themselves be significant and potential additions to this selection.

It was not possible within the scope of this study to identify landowners except in a few sites, but it is emphasised that CGS listing here is not a statutory designation, and carries no specific implications or responsibilities for landowners. It is primarily a planning tool, designed to record the scientific importance of specific features, and to provide awareness of them in any 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 Leitrim County Geological Sites

Site Name	Designation	IGH Primary	IGH Secondary	IGH Third	GIS Code
Aghagrania stream section	County Geological Site	IGH8			LM001
Arroo Mountain Caves	County Geological Site	IGH1			LM002
Benbo	County Geological Site	IGH5	IGH11		LM003
Bencroy	County Geological Site	IGH9	IGH15		LM004
Carrickbaun Quarry	County Geological Site	IGH8			LM005
Corry Shore	County Geological Site	IGH3	IGH8		LM006
County River Natural Bridge	County Geological Site	IGH1			LM007
Creevelea	County Geological Site	IGH15	IGH6		LM008
Dough Mountain	County Geological Site; recommended for Geological NHA	IGH1	IGH14	IGH7	LM009
Eagle's Rock	County Geological Site	IGH7			LM010
Finnalaghta Quarry	County Geological Site	IGH4			LM011
Fowley's Falls	County Geological Site	IGH14			LM012
Glenade Cliffs	County Geological Site	IGH8	IGH7		LM013
Glenboy Cave	County Geological Site	IGH1	IGH14		LM014
Glencar Waterfall	County Geological Site	IGH7	IGH14	IGH1	LM015
Good Friday Cave	County Geological Site	IGH1			LM016
Keshcarrigan Quarries	County Geological Site	IGH8			LM017
Lackagh Sandstone Quarry	County Geological Site	IGH9	IGH15		LM018
Largy - Gorteenaguinnell	County Geological Site; recommended for Geological NHA	IGH1			LM019
Larkfield and Meenymore	County Geological Site	IGH8			LM020
Leitrim Coast	County Geological Site	IGH8	IGH7		LM021
Lough Rinn Drumlins	County Geological Site	IGH7			LM022
O'Donnell's Rock	County Geological Site	IGH8	IGH1		LM023
Peakadaw landslips	County Geological Site	IGH1	IGH7		LM024
Poll na mBéar	County Geological Site	IGH7	IGH1		LM025
Polticoghlan	County Geological Site	IGH1			LM026
Stony River	County Geological Site; recommended for Geological NHA	IGH9	IGH3	IGH15	LM027
Teampall Shetric	County Geological Site	IGH1			LM028
The Doons	County Geological Site; recommended for Geological NHA	IGH1			LM029
Thur Mountain	County Geological Site	IGH9	IGH7		LM030
Truskmore	County Geological Site; recommended for Geological NHA	IGH7			LM031
Twigspark	County Geological Site	IGH15			LM032

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 Leitrim's geology, especially in the upland karst areas. Here caving groups have in recent years, documented significant caves and other 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 spec during fieldwork. It should be noted that in a number of cases in Leitrim, along with other counties, the original expert panel process of developing a Master Site List 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.

Aghnamona Bog

Aghnamona Bog is situated approximately 2 km east of Roosky, County Roscommon, with the vast majority of the site in southern County Leitrim. The site is designated a Natural Heritage Area (NHA sitecode 000422) based on the presence of some intact high bog and cutover bog. A site visit revealed that the site is small and relatively inaccessible, and as the diagnostic features for which it has been designated a NHA are no longer well-demonstrated owing to excessive peat harvesting in recent years, is therefore not included as a County Geological Site.

The highest portion of high bog at Aghnamona Bog, which has been recently drained.

Arroo Mountain Dolerite

Two dolerite intrusions of probable Tertiary (Palaeogene) age were mentioned on the Geoschol leaflet by Mike Simms (see Appendix 8), a well-known scholar of limestone terrain in Ireland and

curator of the Ulster Museum. Given the rarity of rocks of this age in Leitrim it was decided to assess both site localities to see if they should be included as County Geological Sites, as representatives of an important geological period, when the Atlantic Ocean started to open around 65 million years ago.

While there is some evidence visible to an experienced field geologist to suggest a dolerite body may be present where it is mapped on the Geological Survey Ireland 1:100,000 geological map, there is no exposure and therefore nothing of geological heritage interest. The terrain mapped as underlying the igneous intrusion is covered by a raised bog rather than blanket bog which dominates the rest of this upland. There are some cobbles in the stream bed that are probably dolerite, and some underwater exposures that look like they have weathered in a typical form for igneous bodies. We are unaware of any published work investigating the body, such as a radiometric date. Thus there is no site to be defined as a County Geological Site in this instance.

Metagabbro exposure in psammitic gneiss, Benbo.

Barnameenagh

Barnameenagh townland includes two former coal mine sites, one in the east of the townland, known as Barnameenagh mine or Geoghegan's mine, and the other on the southwest side of Slieve Anierin, known as Wynne's Adit. Barnemeenagh mine was last worked in the 1950s but both it and Wynne's adit were the subject of renewed exploration in the late 1980s. The visible remains on each site largely reflect this later phase of exploration. At Barnemeenagh mine, in the cliff face below Slieve Anierin summit, the main adit is obscured but coal-rich waste forms a partially grassed heap on the slope below it. There is good exposure of the sandstone beds overlying the coal seam but the seam itself was not observed. At Wynne's adit, the adit was cleared and a trench was excavated to expose the coal seam. The seam, overlain by thinly-bedded sandstone, is still visible to the south of the adit. While the exposure of coal at Wynne's adit is of interest the other extant mine features in Barnameenagh townland are not particularly impressive. The CGS site at Bencroy demonstrates a wider range of coal mine features in a more accessible site. Neither of the Barnemeenagh townland sites is of comparable interest and thus are recommended for rejection.

Wynnes's adit, coal seam exposure.

Barnameenagh mine, cliff face above adit.

Benbo 1 – Landscape view

During the Breifne Project between 2000 and 2004, Geological Survey Ireland collated existing natural and cultural heritage information (ecology, geology, archaeology and ethnology or folklore) into a web-based GIS database that formed the basis for an information/educational resource for project stakeholders, tourists and local interests. As part of this, a number of 'landscape views' were listed as being important localities, across County Leitrim, many for the geological features visible from their locality. A view point at the top of Benbo Mountain in north Leitrim had been listed thus, and this was visited as part of this project. The locality itself is designated as the 'Benbo' site (see Section 2), and thus will be merged with this owing to its geological interests. The view alone does not give the basis to rank the locality as a County Geological Site. The authors consider that a view locality should be ranked a County Geological Site only if there exists any geological specialism at that exact locality. An argument could be made that every good view point in Ireland could be ranked as a County Geological Site if this were the basis upon which sites were ranked.

Benbulben - Gleniff - Glenade complex

The Gleniff Loop is a well-known tourist driving route in northwest Ireland. This site was listed in the Geological Survey Ireland's Leitrim Irish Geological Heritage Master List. Upon visiting the locality, it was seen that the entirety of the loop lies in County Sligo, hence this site is rejected as a County Leitrim County Geological Site.

View westwards from the western flanks of Truskmore, across the Benbulben - Gleniff – Glenade Complex, County Sligo.

Benbo 3

The site consists of several outcrops of metagabbro within psammitic gneisses of the Precambrian Slishwood Division on the southern flank of Benbo Mountain, at the northeastern end of the Ox Mountains. The outcrops are on and beside the old paved path that runs up the southern side of mountain from the forest road near its base. While well exposed, the outcrops do not contain any features of outstanding interest or rarity. Numerous metagabbro and dolerite pods within the Slishwood Division are present at the main Benbo site on the summit where exposure is of a much better quality.

Metagabbro exposure in psammitic gneiss, Benbo.

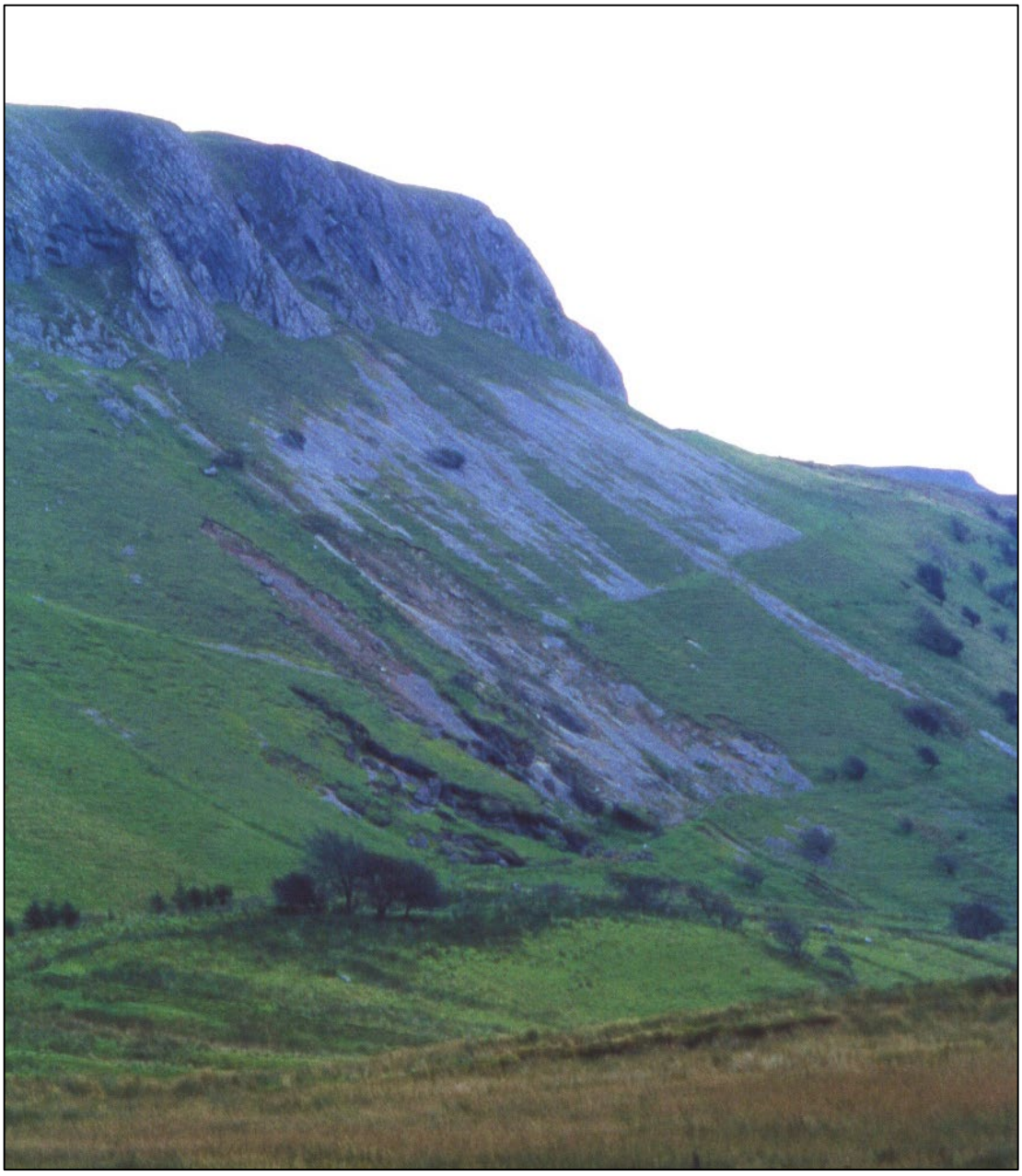
Creevy 'channel' soil type site

Much of County Leitrim has heavily gleyed and waterlogged soils, with a specific type of gleyed soil known as 'channel' being particularly common across the central tract of the county. This soil type, which has been mapped spatially as belonging to the 'Garvagh Series' by Teagasc, hosts a compact layer, 8 to 30 cm thick, of angular chert gravel beneath the sod at ground level, known locally as "channel". The 'type site' for this soil type occurs in the townland of Creevy, just outside Ballinamore. Historically, this soil was well exposed at Creevy. However, a visit to the locality revealed that there are no extant exposures. The locality is therefore rejected as being of geological significance.

The gleyed soil landscape of the Garvagh Series at Creevy.

Curraghan Screes

Previous exploration for caves on Leean Mountain and surrounds had encountered some limestone screes that had been cemented by lime to create new rock strata, but which had then begun to be eroded and were breaking down, with some blocks several metres in size. On researching the locality, it was identified as actually being just inside County Sligo and so has not been visited or assessed further in this audit. It is recommended however that is should be assessed in a future revision of County Sligo's County Geological Sites.



Screes on Leean Mountain.

Drumduff dolerite dyke

Two dolerite intrusions of probable Tertiary (Palaeogene) age were mentioned on the Geoschol leaflet by Mike Simms (see Appendix 8). Given the rarity of rocks of this age in Leitrim, it was decided to assess both occurrences to see if they should be included as County Geological Sites, as representatives of an important geological period, when the Atlantic Ocean started to open around

65 million years ago. Geological mapping of the Drumduff dolerite intrusion indicates a wide body nearly 1 km long. However, ground investigation confirmed that there is a low ridge of ground along the line of the intrusion but there is almost no exposure. Heavy forestry obscures much of the area underlain by the intrusion, with no surface indications, but in some stretches large blocks of dolerite are seen in walls and gathered on the spine of the ridge. Despite the definite indications of the existence of this dolerite intrusion, the lack of any clear exposures of bedrock in situ make it difficult to argue for inclusion of the Drumduff dolerite dyke as a County Geological Site.

Some large blocks, not in situ, are the best exposure of this dolerite.

Glenade Esker

Though not mentioned as a locality on the Irish Geological Heritage Master list, it was known that one esker exists in north Leitrim, adjacent to Glenade Lough. The esker locality was visited, and the feature observed to be very low, short and narrow. It is difficult to discern it as a discrete landform and to separate it out from surrounding hills. As well as this, owing to the high rainfall of the locality, the soils on the esker are relatively poorly drained, and do not seem to promote the diversity of unusual flora that most eskers in Ireland do. Hence, this site is rejected as a County Geological Site.

The short and low Glenade Esker.

Glenaniff Valley view point

During the Breifne Project, a view point at the Glenaniff Valley in north Leitrim had been listed as an important geological site, and this was visited as part of this audit. Though the locality has views of some nice limestone cliffs, and extensive blanket bog, visible, this does not give the basis to rank the locality as a County Geological Site. As above, the authors consider that a view locality should be ranked a County Geological Site only if there exists any geological specialism at that exact locality. An argument could be made that every good view point in Ireland could be ranked as a County Geological Site if this were the basis upon which sites were ranked. Glenaniff Valley view point is rejected on this basis.

The Glenaniff Valley view point.

Greaghnaglogh Landslide locality

The locality at Greaghnaglogh, just north of Lough Allen, suffered a significant landslide event on June 29th 2020. After several months of very dry weather and one intense rainfall event, thousands of tonnes of peat slid down the mountainside to become impounded by the Dawn of Hope Bridge. The site was visited to assess if there were significant geomorphological features that would persist on the mountainside into the future, marking the landslide as a scar on the landscape. However, the peat flow is low angle and comprised mostly of liquefied peat which slid down a low angle

valley, hence it will just re-colonise with vegetation and become invisible within a few years. The site is therefore not deemed worthy of ranking as a County Geological Site.

The peat slide up-gradient of the Dawn of Hope Bridge at Greaghnaglogh.

Kilroosk

The Giant's Rock Tonalite is in County Sligo and is exposed over a strike length of 10 km. The entry in the Irish Geological Master List refers to "Giants Rock Tonalite, Kilroosk". At Kilroosk, in County Leitrim, a very minor tonalite body, in a 10 m long exposure, has been described and it appears that these two bodies were confused at the time of the master list compilation. The Kilroosk area was visited but the four-figure grid reference available from the published work was not precise enough to allow discovery of the minor tonalite occurrence. As it seems that it was the Giant's Rock Tonalite that was intended for inclusion in the list, this site in County Leitrim is recommended for rejection.

Lough Melvin view point

Similar to the aforementioned Glenaniff Valley view point, a view point at Lough Melvin in north Leitrim was listed as an important view as part of the Breifne Project. This locality was visited as part of this county geological audit. The locality has a spectacular view of the north Leitrim lowlands but this is not deemed of sufficient heritage value to rank the view point locality as a County Geological Site. Thus, the Lough Melvin view point is rejected.

Lough Melvin view point.

Manorhamilton / Manorhamilton Zion Hill

A research paper included a site in Manorhamilton village, among c. 40 other sites, as a source of minerals that were successfully dated, providing an estimated Ordovician age (470-440 Ma) for the Grampian orogeny in the Ox Mountains region. The site in Manorhamilton was suggested for inclusion in the master list as having parallels with the Slishwood Division mineral assemblage at Zion Hill in county Sligo (hence the reference to "Manorhamilton c.f. Zion Hill") where excellent exposures of metamorphic minerals kyanite, staurolite and almandine can be observed. Thus there is just one site in Manorhamilton. It is described in the master list as under threat and its location would suggest it may potentially be developed in the future. The site is entirely overgrown and no outcrop was observed. It is therefore recommended for rejection.

Manorhamilton site, view towards east.

Mohill area

The Mohill area was listed as being important by the IGH7 Quaternary Theme Panel owing to the abundance of spindle-shaped drumlins adjacent to the village, an unusual occurrence in that general area. It was discovered during field survey that the majority of the best examples of these features occur around Lough Rinn, already a proposed Natural Heritage Area. Thus, the site has been renamed 'Lough Rinn Drumlins' and includes both the proposed Natural Heritage Area (which concentrates on the lake itself) and the drumlins surrounding it.

Pollboy Copper Mine

There are no surface features remaining at Pollboy, a small copper mine that was apparently in operation in the 1840s. An uneven ground surface, visible on aerial photos, may reflect the old excavations but this site has long been returned to farmland.

Site of Pollboy Copper Mine, as shown on 6-inch (Cassini) map and on recent aerial photo.

Slieve Anierin Iron Mines

There do not appear to have been any iron mines as such on Slieve Anierin. Iron occurs here in the form of iron nodules within shale beds that are part of the Namurian succession. On Slieve Anierin, the nodules were apparently removed from outcrops and rolled down the hillside to the road where they were loaded on carts for transport to a smelter in Drumshanbo. One of the main sources of nodules appears to have been the exposed shale beds in the Stony River, on the western flank of the mountain. The Stony River is included as a County Geological Site and proposed NHA.

Iron nodule in shale bed, Barnameenagh, Slieve Anierin. 2 Euro coin for scale.

Spion Kop (Altagowlan)

Spion Kop was added to the list of sites during this audit as it includes numerous 19th and 20th century collieries on Corry Mountain, west of Lough Allen. Spion Kop was an old miners' name for the area. Collieries were operated here in the townlands of Altagowlan, Tullymurray, Knockateean, Tullycorka, Seltannaskeagh, Liscuillew Upper, Seltannasaggart and in Glackaunadarragh, with the latter the last to close in the 1980s. There are large waste heaps here, including some relatively rich in coal waste, collapsed adits and mine water discharge courses. There are several large-scale wind farms on the mountain. However, none are of particular interest and there are no outcrops of coal or of the coal-bearing strata to provide geological interest. The site at Bencroy, east of Lough Allen, is, in contrast, an excellent County Geological Site with numerous mine features and well exposed geology and will serve as a good example of a coal mine in County Leitrim. Accordingly, Spion Kop is recommended for rejection.

Waste heaps at Glackaunadarragh, Spion Kop.

Swiss Valley

The Swiss Valley is a hidden valley at the western end of Glencar. The locality was listed in Geological Survey Ireland's Leitrim Irish Geological Heritage Master List. Upon surveying the locality, it is seen that the entirety of the valley lies in County Sligo, hence this site is rejected as being a County Geological Site in County Leitrim.

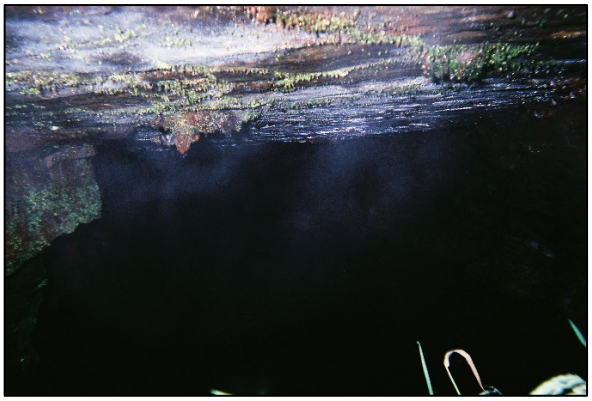
View westwards across the Swiss Valley, County Sligo.

Tullynamoyle Mine

Tullynamoyle Mine was a small iron mine approximately 1.5 km north-northwest of Creevelea. It was investigated as a potential County Geological Site as part of the Audit. There is very limited information available – it is not recorded in Cole's 1922 *Memoir of Metalliferous Mines and Mineral Localities of Economic Importance*. In preparation for Mining Heritage Trust of Ireland field trips Alastair Lings researched this mine and provided information. The site is recorded on Ordnance Survey Ireland 1:10,560 scale maps as 'Iron Mine disused'.

Attempts to locate the mine to assess its interest were abandoned since the mine was located in or beside a deep gorge within very dense over-mature forestry that was wind-fallen and jumbled. The information available suggests that the mine itself was relatively modest with an adit about 1000 feet long (c. 300 m) with some cross cuts.

If the mine had been located it is perhaps likely, on simple practical concerns, that it would have been unsuitable as a County Geological Site, but it is possible it would make a good representative County Geological Site for underground iron mining in the district as a whole. It is recommended here, that should there be wholesale forestry clearance that made the mine site accessible, then an audit review of the site should be carried out.




The sandstone roof and the exterior of what Alastair Lings located as the main level.

The rotten fallen trees in the steep sided gorge at Tullynamoyle iron mine.

Tullyoran Quarry

Tullyoran Quarry a locality on the Irish Geological Heritage Master list, for having a Waulsortian mudmound exposed in a quarry. Upon mapping and thorough examination of the quarry itself and outcrop extent, the exposure was seen to be poor and although some extant faces do exist, these are low and have few features of interest. As well as this, most of the quarry is flooded. With few features of geological heritage interest visible on the whole the site is therefore rejected as a County Geological Site.

Tullyoran Quarry.

Tullyskehenry Cave

In the course of the audit, a newly discovered cave near Kiltyclogher was investigated. From assessment of the site in a Geological Survey Ireland report and photographs and from discussions with caver Robert Mulraney, who has surveyed the cave and is very familiar with others in Leitrim, it was determined that this is simply a new, modest cave, but not one meriting inclusion as a County Geological Site.

2. Leitrim Council Policies regarding geology and geological heritage

The completion of this county geological heritage audit will ensure that the listing of Leitrim'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 Leitrim.

Leitrim CDP 2015 – 2021 Volume 1 (P.151) states that '*geology is now recognised as a fundamental component of natural heritage and as such the conservation of geological heritage features is considered an important aspect of conserving the natural heritage… Geological heritage is part of Leitrim's natural heritage and its uniqueness is a reflection of the county's geological makeup.'*

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

> **Policy 82:** It is the Policy of the Council to recognise the need to identify sites of geological interest in the County and to protect these sites in the interest of protecting our geological heritage.
>
> **Objective 71:** It is an objective of the Council to protect from inappropriate development County Geological Sites, as outlined in Appendix C (Volume 2) of this Plan.
>
> **Objective 72:** It is an objective of the Council to protect geological NHAs as they become designated during the lifetime of this Plan.
>
> **Objective 73:** It is an objective of the Council to conduct an audit of County Geological Sites, in partnership with the Geological Survey of Ireland and the Heritage Council, as per the National Heritage Plan; subject to the necessary resources becoming available.
>
> **Objective 73:** The Council is aware of the importance of a number of peatlands, or bogs as they are more commonly known, in the County and recognise that they are an irreplaceable resource that act as a carbon sink and are of significant ecological value.
>
> **Objective 74:** It is an objective of the Council to conserve peatlands and protect peatland landscapes within the County.

Leitrim's Draft CDP for 2022-2028 has an Environmental Report on the Strategic Environmental Assessment, and lists *Landscapes/Geology* as one of the ten environmental themes that require specific attention in the CDP. Whilst some CGSs from this report have been suggested as candidates for NHA designation in the future, when geological NHAs become established, many new CGS that are purely of county-wide importance have been added to IGH Master List as a result of this audit. Equally, some sites have been rejected following the field auditing.

The CDP 2015 – 2021 indicates *that 'the Council is also aware of the environmental impacts associated with windfarms and the public concerns raised in respect to such developments'* and recognises *'areas of Geological Importance including those established under the Irish Geological Heritage (IGH) Programme'* as environmentally sensitive areas identified in the CDP.

The Development Management and Design Standards chapter (CDP 2015 – 2021, P. 223) states that, *'assessment of quarries shall be in accordance with Quarries and Ancillary Activities, Guidelines for Planning Authorities, as published in 2004 by the Department of the Environment, Heritage and Local Government; the 'Environmental Management Guidelines - Environmental Management in the Extractive Industry', as published by the Environmental Protection Agency in 2006; 'Archaeological Code of Practice' between the DoEHLG and the Irish Concrete Federation, 2009; 'Geological Heritage Guidelines for the Extractive Industry', 2008 and 'Wildlife, Habitats and the Extractive Industry-Guidelines for the Protection of biodiversity within the Extractive Industry NPWS 2009*.'

The CDP 2015 - 2021 has detailed policies relating to mineral extraction and quarries in Section 4 (P. 137). The council states that *'the aggregates and concrete products industries have a particularly sensitive role in relation to the environment and as such any development of aggregate extraction, processing, delivery and associated concrete production must be carried out in a manner which minimises adverse effects on the environment and the local community'.*

Policies relating to mineral, oil and gas extraction, quarries includes:

> **Policy 72:** It is the policy of the Council to facilitate the further development of the industry by permitting the continuation and extension of existing quarries and the development of new quarries, where such development does not adversely impact on; human or animal health, the environment, existing infrastructure and the amenity value of neighbouring lands.
> **Policy 73:** It is the policy of the Council to promote the mineral, gas and oil extractive industries where such development does not adversely impact on; human or animal health, the environment, existing infrastructure and the amenity value of neighbouring lands.
> **Policy 74:** It is the policy of the Council that transportation of extracted material from the source be carried out without causing nuisance to other road users.

The role of geological heritage in the promotion and development of tourism is included in the Section 4.10 Recreation, Sports and Amenity (P.185), where the council states it *'is aware that the tourism potential of its amenities has not yet been fully developed and will facilitate, and where necessary become directly involved in, the promotion and development of amenities such as… the development of the GeoPark through its extension into Leitrim'.*

With this report the forthcoming CDP 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 2.3 of the CDP (**Strategic Development Framework,** P. 47) states the council's commitment to supporting geotourism initiatives in the region:

> *'Support Cross-Border Regional projects supported and funded through the Special European Union Programme Body (SEUPB), for example, the Border Upland Project linking the Geo Tourism of the Marble Arch Caves for Counties Leitrim, Sligo, Cavan and Fermanagh.'*

Groundwater

A Groundwater Protection Scheme has been completed for Leitrim County Council by Geological Survey Ireland, which gives land surface zoning objectives in terms of groundwater protection for every portion of Leitrim'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.

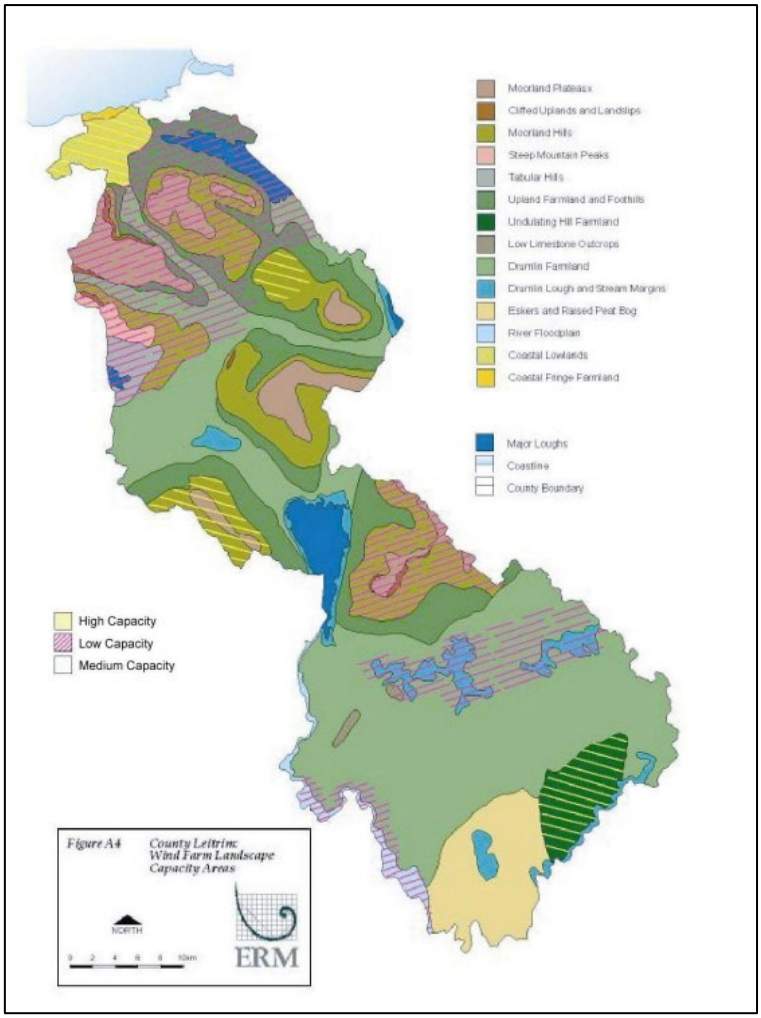
This audit complements the Groundwater Protection Scheme, as it has examined and listed many vulnerable karst sites around the county, and defined boundaries to these sites, offering an extra element of protection as these sites will now be listed in the CDP.

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 Leitrim, these include Largy - Gorteenaguinnell, Dough Mountain, Thur Mountain, and the Lough Rinn Drumlins 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 Leitrim. A lack of awareness in the past, has led to the loss of important geological sites and local character throughout the country. In County Leitrim, a Landscape Characterisation Assessment was completed and incorporated into the County Development Plan 2003-2009, and carried through to the current 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.



Windfarm Landscape Capacity Areas (P. 69 Leitrim County Development Plan 2003-2009).

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 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.

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 Lackagh Sandstone Quarry in Leitrim are now included as County Geological Sites in County Leitrim. 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. Few, or none of County Leitrim's sites are really likely to require such an approach.

Waste dumping

An occasional problem throughout the country, County Leitrim 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 Leitrim was included in a national scheme for Groundwater Protection in 2012, thus ranking the county land surface into vulnerability categories of 'Extreme', 'High', 'Moderate' and 'Low', and helping planners to assess which developments are suitable or not in some areas of County Leitrim.

New exposures in development

One less obvious area where the Local Authority can play a key role in the promotion and protection of geology is in the case of new roads. **Wherever major new carriageways are to be built,** or in other major infrastructural work, it should be a policy within the Planning Department, that **where new rock exposures are created, they be left open and exposed** unless geotechnical safety issues arise (such as where bedding dips are prone to rock failure). The grading and grassing over of slopes in cuttings is largely a civil engineering convenience and a mindset which is difficult to change. However, it leads to sterile and uninteresting roads that look the same throughout the country. Leaving rock outcrops exposed where they are intersected along the road, improves the character and interest of the route, by reflecting the geology and landscape of the locality. Sympathetic tree or shrub planting can still be done, but leaving bare rocks, especially where they show interesting features, not only assists the geological profession, but creates new local landmarks to replace those removed in the construction of the roadway. This can also potentially save money on the construction costs. It may also contribute to road safety by providing diversity of surroundings to maintain drivers' attention. In 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 Marble Arch Caves Global Geopark in Fermanagh and Cavan [see www.marblearchcaves.net and www.cavancoco.ie/marble-arch-caves-unesco-global-geopark.htm]. It is understood that a complementary action in the Heritage Plan to the completion of this audit is to explore the possibility of an extension of this Geopark into Leitrim. This audit will assist with the required geological appraisal and knowledge required for a possible future application or for discussion with the Geopark management. A separate discussion of this idea is included below.

The Copper Coast 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 in County Clare [www.burrengeopark.ie]. In addition, there are aspirant groups elsewhere in the Republic, as well as in Northern Ireland, exploring the work and infrastructure required for applications in other areas such as the Mourne-Strangford area. The most advanced in this respect is probably the Joyce Country and Western Lakes Geopark Project, envisaged in Mayo and Galway (https://joycecountrygeoparkproject.ie/).

3.1 Upland Karst Areas of North Leitrim

The largest area of upland karst in Ireland is located between the towns of Sligo, Drumshanbo, Enniskillen and Manorhamilton. The total area is approximately 1,800 km^2, of which 63% is underlain by Lower Carboniferous limestone and the remainder by Namurian sandstones and shales.

Limestone crops out over the western part of the plateau and as a narrow rim around the margins of the Namurian strata further east and north. Much of the plateau lies above 400 m O.D. with the highest points being Truskmore (647 m OD) in the west and Cuilcagh (666 m OD) in the east.

Annual rainfall exceeds 2,000 mm over much of the upland. Unlike the other upland karst areas of Ireland, exposures of the limestone are uncommon and blanket bog is widespread, often underlain by up to 2 m of rubbly, insoluble residue from decalcified limestone. The Dartry Limestone Formation comprises massive (reef) limestones in its upper part with bedded chert-rich limestone below. Beneath is the Glencar Limestone Formation with thinner bedding, shale layers and closer jointing. At the base of the Glencar Limestone Formation are the relatively impermeable Glencar shales, the boundary commonly marked by an abrupt break of slope.

The plateau has been dissected in varying degrees by glacial and, to a lesser extent, fluvial erosion that presumably continued throughout the Pleistocene and seems to have been particularly intense in this area, in comparison with other upland karsts such as the Burren. The last ice advance was from southeast to northwest across the north Leitrim area. This is reflected in erosional features such as the Glenade, Glenaniff and Glencar Valleys, which are glacial troughs, and the deep, oriented drumlins on the lowlands. These deep valleys have compartmentalised the plateau into long ridges such as the Crockauns-Keelogyboy-Leean-Benbo upland south of Glencar and, in turn, these ridges are decaying into isolated clusters of limestone hills or mounds such as in The Doons area north of Lough Gill. Extensive fragments of the formerly continuous plateau occur at greater distances from the main massif, in the Bricklieve Hills (25 km^2 in area), Kesh and Knocknarea, all in County Sligo.

An integrated approach to management of the uplands in Leitrim should be adopted by Leitrim County Council, in collaboration with the Irish Upland Forum, National Parks and Wildlife Service, the Irish Peatland Conservation Council, Inland Fisheries Ireland, the Environmental Protection Agency, the Forest Service, Geological Survey Ireland, Teagasc, Coillte, and other relevant bodies.

3.2 Potholes and karst features

County Leitrim lies within two of the six karst regions in Ireland. The northwest half of the county is within the karst plateau of the Northwest Region, whilst the southeast half of the county is in the Eastern Lowlands karst region.

Upland karst and associated pothole and cave systems are well-developed in areas north of Dromahair, where the upland areas are often dissected by cliff-edged, glacially deepened valleys. Most of the karst features occur around the edges of the mountain terrane and on the sides of valleys. These features include some of the best representations of karst landforms in Ireland. The Largy–Gorteenaguinnell County Geological Site is the most extensive area of enclosed depressions formed on plateau karst in Ireland. The area arguably has the densest and most extensive development of enclosed depressions, or dolines, and pothole type shafts in the country. Numerous potholes have been mapped by cavers but countless more shallow dolines that do not lead into potholes have only been mapped in recent years. The northeast section of Arroo Mountain also has a high concentration of karstic landforms, including sinking streams and potholes, as well as many enclosed depressions and limestone pavements. The Doons are isolated, steep-sided limestone hills that are interpreted as relict, glacially-modified tower karst. They are considered the best example of a group of such hills in Ireland, with better exposure and less blanketing glacial sediments than in some other comparable sites. Originally, prior to glacial modification, they may have been similar to the classic tower karst of the Guilin area in China.

The development of most caves in Leitrim was very strongly controlled by the relative hardness of the different geological layers, including the high proportions of chert layers in the Dartry Limestone Formation. The impermeable layers of chert led to cave development that is predominantly vertical, controlled by joints and faults in the rock rather than bedding planes, which is more common in many karst areas. Thus, most caves in Leitrim are vertical or sub-vertical potholes. In contrast, Teampall Shetric, one of the larger caves in the Glencar area, is unusual in that it was largely formed under phreatic conditions, i.e. the cave passages were water-filled, with significant resultant horizontal cave passage development. Glenboy cave is a 37 m long remnant of

what was formerly a more extensive cave system and is an excellent example of the natural process of erosion and unroofing of shallow river caves to create gorges.

In contrast, the southern half of the county is less well-endowed with karst landforms. The main area of karst here occurs on the south side of Slieve Anierin. A large cave and County Geological Site, Polticoghlan cave, is this region's finest example of a cave. The site is a good example of where a stream flowing over impermeable rocks immediately sinks underground when it reaches permeable carbonate (limestone) bedrock.

3.3 Sliabh an Iarainn: Iron and Coal

Sliabh an Iarainn ("Mountain of iron") draws its name from the many iron nodules that occur abundantly within the Namurian shale beds that form much of the bedrock around Lough Allen. In the early 17th century Sir Charles Coote, who became a major landowner as a result of the Plantation, brought in English and Dutch miners to exploit these iron deposits and established a smelter at **Creevelea.** The best ore occurred on Sliabh an Iarainn where nodules, washed down in streams to the lakeshore, were gathered by local people and carted to furnaces. This was essentially a local industry, conducted on the same small scale that was common throughout Europe, with timber from local forests providing the fuel to smelt the iron.

Iron nodule, Stony River, Sliabh an Iarainn.

However, by the mid-18th century the intense development of agriculture in Ireland, and the land clearances that went with it, led to the rapid disappearance of forests. In England, too, for the same reasons, the iron industry was in serious decline around the same time. But there, Alexander Darby made steady progress in developing the use of coal to smelt iron, overcoming the problems caused by sulphur impurities. Britain's vast deposits of coal could now be used to fuel the iron industry, resulting in a major expansion of the iron trade that helped lead to the British Industrial Revolution in the second half of the 18th century.

In Ireland, a similar revolution seemed possible, as the geology of the Lough Allen area is similar to that of British coal-producing regions. Four key elements underpinned the iron industry in Britain: (i) iron ore, (ii) coal for fuel, (iii) sandstone for use as a refractory lining in furnaces and (iv) limestone for use as a flux. All occur together around Lough Allen, so production costs could have been minimized. In 1765, the year in which the last wood-fuelled smelter in the region was

extinguished at **Drumshanbo**, the main coal seam was discovered in the hills above **Arigna**, west of Lough Allen in nearby County Roscommon. Sandstone and limestone were readily available locally, and there was a persistent belief in the "inexhaustible" nature and the good quality of the iron ore.

Coal seam, Bencroy colliery.

Remains of Creevelea iron smelter.

Several key factors stood in the way of Leitrim and its neighbouring counties becoming the cockpit of an Irish industrial revolution: (i) its remoteness, (ii) competition from English iron and (iii) the poor quality of the coal. The remoteness of the area from any potential markets was probably the principal factor inhibiting development of the iron and coal industry in Leitrim and neighbouring counties. The lack of good transport routes was never adequately addressed in the two centuries following discovery of coal in the region, with the narrow-gauge railway spur from Belturbet being the most striking if wholly inadequate attempt to improve matters. Secondly, despite various operations producing good-quality iron and periodically making good profits, they could not compete with low-cost iron produced on a huge scale in England. The smelter at Creevelea was making good profits in 1866 but the price of iron fell and by 1872 the works were abandoned, effectively ending iron mining in Leitrim for good. Thirdly, the coal seams on Sliabh an Iarainn and around Arigna were very thin by comparison with those exploited so successfully in Britain, with coalfaces as low as 30 cm being mined under exceedingly cramped conditions. Moreover, of the five seams in the district, three were relatively low-grade (high-ash content) "Crow" coal.

Despite this there were more orders from cities around Ireland than could be met – enough coal was mined but, for lack of transport, it could be left deteriorating in bad weather on the hillsides. If the coal could not be brought to market then, eventually, the market was brought to the coal. In 1958 the state electricity company, the ESB, opened a coal-fired power station at Arigna. It was essentially a means of preserving the mining jobs in the district. At its peak it took 85% of coal produced and when the power station closed in the late 1980s, two centuries of coal mining came to an end. The last coal mines closed in 1990.

3.4 Landslides in Leitrim

The term "landslide" describes a wide variety of processes that result in the downward and outward movement of materials under the force of gravity. The materials involved in such processes include rock, debris, earth, mud or peat, or a combination of these. Ireland's location, terrain and climate mean that landslides occur mainly in peat-covered areas with steep slopes

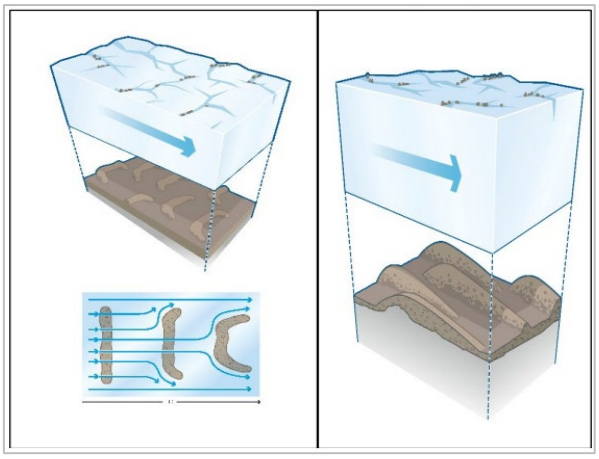
where bedrock is close to the surface. As Leitrim has many upland areas, which are often capped with blanket bogs, landslides are therefore particularly common in Leitrim.

Landslides have the potential to cause great havoc and have done so all around the world. They have resulted in large loss of life and damage to infrastructure, including roads, railways, canal embankments and even dams. They can destroy or severely damage buildings of all types – housing, commercial or industrial property. Rivers can become blocked or diverted by sediment or rock displaced by landslides. The consequences of this can include flooding, pollution of watercourses and the killing of fish stocks. Agricultural land can be sterilised in the short to medium term. It does not require spectacularly huge landslide events to cause serious disruption or loss of life. Relatively small landslides, i.e. in terms of the volume of material displaced, can damage bridges and roads, and also cause injury and death. These potential impacts of landslides, irrespective of their size, mean that the scale of the problem for Ireland in the past and in the future needs serious attention so that the susceptibility of the Irish landscape to slope instability can be properly assessed. Ireland is fortunate that in general it is not at extreme high risk to major geohazards. Indeed, in comparison to many other countries, Ireland may be regarded as a relatively benign environment in terms of landslide hazard.

Leitrim has suffered many landslides historically and during the course of this audit, in June 2020, a severe peat landslide happened at Greaghnoglogh, a few kilometres north of Lough Allen. As climate changes and drier summers and more intense rainfall events become more common, the unfortunate fact is that in future the risk of landslides occurring in Leitrim and elsewhere in Ireland will remain high.

3.5 Subglacial bedforms

The ice sheets that covered County Leitrim 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 'drumlinised' ribbed moraines. Ribbed moraines are large ridges formed perpendicular to ice flow. Ribbed moraines are effectively large ‘chains’ of drumlins, which are oriented transverse to ice flow. They are particularly large in County Leitrim. The name “drumlin”, used internationally, comes from the Irish 'dromnin' 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 ribbed moraines (left) and drumlins (right) under a moving ice sheet. The ice sheet of the last glaciation flowed generally either northwest to southeast (in the south of the county) or southeast to northwest (in the north) across Leitrim, a fact illustrated by the orientations of the ribbed moraines and drumlins, which are all generally aligned northwest-southeast.



4. Summary and Recommendations

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

This section briefly examines the existing objectives in the County Leitrim Heritage Plan (2020-2025) 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. Leitrim Heritage Plan 2020-2025 (P.13) states:

> *"The geology and topography of Leitrim varies significantly, from the table-like mountains and glacial glens in the northern half of the county to the undulating drumlin landscape in the southern lowlands. This varied topography and the extensive river systems and loughs across the county have resulted in a mosaic of natural and man-made habitats and have influenced where people have chosen to settle and where our rich and well preserved archaeological heritage can now be found."*

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

Objective: Support the Conservation and Recording of Leitrim's Heritage
Action*:*

- *Undertake a Geological Heritage Audit of the County and explore UNESCO Global Geopark designation.*

Objective: Raise Awareness of Leitrim's Heritage
Action:

- *Develop an online resource for heritage in the County*
- *Develop themed literature resources on the heritage of the County.*
- *Develop themed literature resources on the heritage of the County.*
- *Raise awareness of built and natural heritage assets among landowners and promote best practice.*

Objective: Support Sustainable Heritage Tourism in Leitrim
Action:

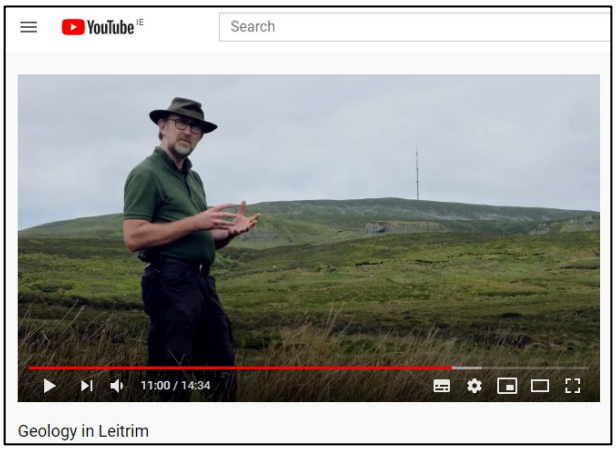
- *Identify key heritage sites in the County and develop site specific interpretation strategies.*
- *Promote best practice for heritage interpretation panels in the County.*
- *Produce a map of accessible heritage sites in the County*.

4.2 Ideas for projects

Online Video and DVD projects

In 2020, the Leitrim County Council '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



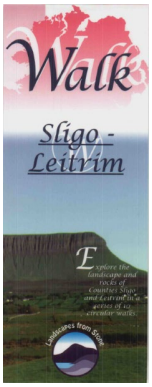
Screengrab of Geology in Leitrim 'Connecting through Heritage' Youtube video (2020).

Leaflets

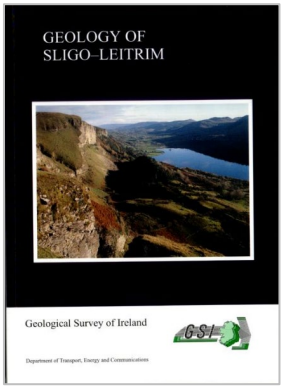
The production of leaflets in PDF format for public download on Leitrim County Council's website would be a cost effective methods of widespread distribution and avoid large costs of printing and paper use. Examples include the Geoschol (https://www.geoschol.com/) publication included in the appendix.

Guides

Several book publications and guides include chapters and sections on the geology of County Leitrim. These include *Landscapes in Stone: Sligo–Leitrim* (McKeever, 2000) and *The Irish Landscape An All-Ireland Exploration Through Science and Literature* (McArdle, 2015)



Landscapes from Stone: Sligo – Leitrim (McKeever 2000)



Geology Of Sligo-Leitrim: Bedrock Geology 1:100,000 Scale Map and Report on Sheet 7

The 1:100,000 Scale Geological Survey Ireland map report for Sheets 7 and 12 cover County Leitrim and are an essential resource.

There is scope for guides at different levels of detail and accessibility to non-specialists. A wide range of leaflets, booklets, books and other media are all feasible, but the research and production of appropriate text and images is a difficult task to do well without appropriate experience, and adequate time and resources. It is suggested that **with only modest editing and reorganisation the main content of this report would distil into a good general guide to the geological heritage of County Leitrim**, in a broadly similar style to those books produced for Sligo, Fingal, Mayo, Waterford, Roscommon, Clare and Longford following 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 a place is preferred to single interest panels. It is important to consult with potential partners in the planning stage so that duplication does not occur.

The successful integration of text and graphics on information panels is a fine art, and the Geoheritage 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 Leitrim 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 ones can be seen on the Geological Heritage/Exhibitions section of the Geological Survey Ireland website [www.gsi.ie].

New media

There are increasing 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 [www.geoschol.com], which was largely aimed at producing educational materials on geology for primary schools. A four page pdf summarising the geology and some highlights of County Leitrim is already part of the available material (see Appendix 6). Links to the Heritage section of the Leitrim County Council website, as well as to other heritage websites, should be established.

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 Co. Leitrim. The availability of technical references of direct relevance to Co. Leitrim geology and geomorphology would assist many users and researchers into the future. The literature is extensive, and is specialist in nature, such that that a geological heritage section with a select bibliography on the County Council Heritage web pages might suffice for most users with general interest in heritage.

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 Leitrim

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

Rocks can be divided into three main groups, sedimentary, igneous and metamorphic. All three groups are exposed in Leitrim. 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. New minerals grow in response to these changes and their composition depends on the composition of the original rock, and the temperatures and pressures that affect it.

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 oldest rocks in County Leitrim are exposed in the northeast Ox Mountains around Manorhamilton. Where they do not reach the surface they underlie younger rocks and extend deep into the Earth's crust. These rocks, belonging to the Slishwood Division, are thought to have originated as sedimentary rocks during Precambrian times. Their exact age is a subject of debate amongst researchers with some suggesting that deposition took place between 750 and 700 million years ago and others proposing a depositional age of 1,700 million years. Since their deposition they have been repeatedly folded and metamorphosed deep within the Earth's crust producing the banded gneisses that we see today at localities such as Benbo. Mountain building episodes more than 600 million years ago and 460 million years ago were responsible for this intense deformation and metamorphism (the timing of the first event is uncertain). Mountains are formed when continents collide, increasing the thickness of the crust. The first phase of mountain building pushed the Slishwood Division rocks so deep beneath the Earth's surface (approximately 47km) that they interleaved with mantle material. This mantle material, or peridotite, was subsequently metamorphosed to serpentinite, a sliver of which is exposed near Dromahair.

In contact with the Slishwood Division rocks are the slightly younger Dalradian rocks. The contact between the two is everywhere tectonic (i.e. bounded by faults). Both rock units are thought to have experienced different depositional and deformational histories until some time between 500-430 million years ago when crustal movement brought them side-by-side. This crustal movement (the Grampian orogeny) resulted in the deformation and metamorphism of the Dalradian rocks. These sediments were converted to metamorphic schists as a result. Analysis of some of the metamorphic minerals within the Dalradian Group show that they were subjected to depths no

greater than 27 km beneath the Earth's surface. Had they been buried more deeply different metamorphic minerals would have grown. Dalradian rocks are exposed in a number of locations in Leitrim most notably near Manorhamilton.

The southernmost part of the county hosts Ordovician metamorphic and volcanic rocks, which are the remnants of a former ocean floor and the roots of a long since vanished mountain chain. Devonian conglomerates and sandstones occur to the south of Drumshambo. These sandstones and gravels were deposited by flash floods in a poorly vegetated environment.

The dominant rock types in Leitrim belong to the Carboniferous System (359 – 299 million years). These rocks have only been mildly affected by folding and metamorphism and as such retain many of their original sedimentary and depositional structures. Analysis of these features can help us to understand the changing depositional environments or landscapes of this time. Carboniferous rocks in Ireland are extremely important economically as they host many valuable mineral deposits. Some minor examples of such mineral deposits are found in the Leitrim area, e.g. at Twigspark.

Carboniferous limestones are often easily dissolved by surface water and/or groundwater. This characteristic has resulted in the development of many cave systems and karsts in the Leitrim area (like those seen at Teampall Shetric, Polticoghlan and Poll na mBear). At the beginning of the Carboniferous, some time after the continental collision that saw the juxtaposition of the Slishwood Division and the Dalradian rocks, sea level began to rise. The shoreline gradually moved northwards, flooding the land as it passed. This Carboniferous marine transgression resulted in the deposition of shallow marine sandstones in the Leitrim area. During this time Ireland had a latitude of 10º and experienced a tropical climate. The Ballyshannon Limestone Formation was then deposited in a clean, shallow, tranquil sea, teeming with life. Limestone deposition was interrupted when a major river delta built out into the tropical sea from a landmass to the north. The northern landmass was the result of uplift associated with fault movements beneath the Carboniferous rocks. This event saw the deposition of the Bundoran Shale formation followed by the Mullaghmore Sandstone Formation, as exposed along the Leitrim coast.

As the delta retreated the Benbulben Shale Formation (named after its type area at Benbulben) was deposited. Deposition of the Glencar Limestone Formation marked the return to shallow sea conditions. The succeeding period saw the maximum extent of the Carboniferous sea. Continued fault-movement deepened the sea floor in places leading to unfavourable conditions for many forms of marine life. The dark coloured, largely fossil-free limestones and shales of the Dartry Formation (also exposed at Cloontypruglsih) reflect these deep-water conditions. Upstanding features like reefs developed within the deeper water. A fine example of these mudmounds or mudbanks is found At Carrickbaun Quarry. Lime mud was deposited above these upright structures. The Bricklieve Limestone Formation was deposited in shallower water over other parts of Leitrim at this time. As its name suggests this formation is best exposed on the Bricklieve Mountains. Sea level began to fall as the landmass to the north was uplifted again. The shallow sea deposits of the Meenymore Sandstone Formation marks the beginning of this changing environment. As the shoreline moved southwards again (a regression) the Glenade Sandstone Formation was deposited in a deltaic environment. This deltaic episode left behind a flat landscape over which the sea transgressed and regressed a number of times depositing the sediments of the Bellavally Formation.

Glenade sandstone and Meenymore evaporites are well exposed on the summit of Truskmore. The succeeding Carraun and Dergvone Shale Formations represent marine depositional environments. The succeeding Briscloonagh Sandstone, Gowlaun Shale and Lackagh Sandstone Formations (at Thur Mountain, Dough Mountain and Slieve Anierin) reflect deltaic, marine and deltaic conditions respectively. The Lackagh Sandstone Formation contains a number of cyclothems, sequences of sandstone, shale and coal formed under deltaic conditions, These coal seams comprise the Connacht Coalfield, one of Ireland's three historic coal-producing regions. At the end of the Carboniferous, the rocks were deformed by the Variscan orogeny. Deformation and metamorphism associated with this mountain building event was very mild in the north of the country. For much of the 300 million years following the Carboniferous, Ireland was mostly land, dominated by erosion rather than sedimentation. This geologically quiet period was interrupted approximately 75 million years ago when Ireland may have been covered by the sea (although no record of this is found in the Leitrim area) and again 60 million years ago as Europe and North America split apart producing the North Atlantic Ocean. Hot magma rose up along fractures and cracks that formed in the limestone, in response to this event, cooling to form dykes like those seen near Lough Melvin.

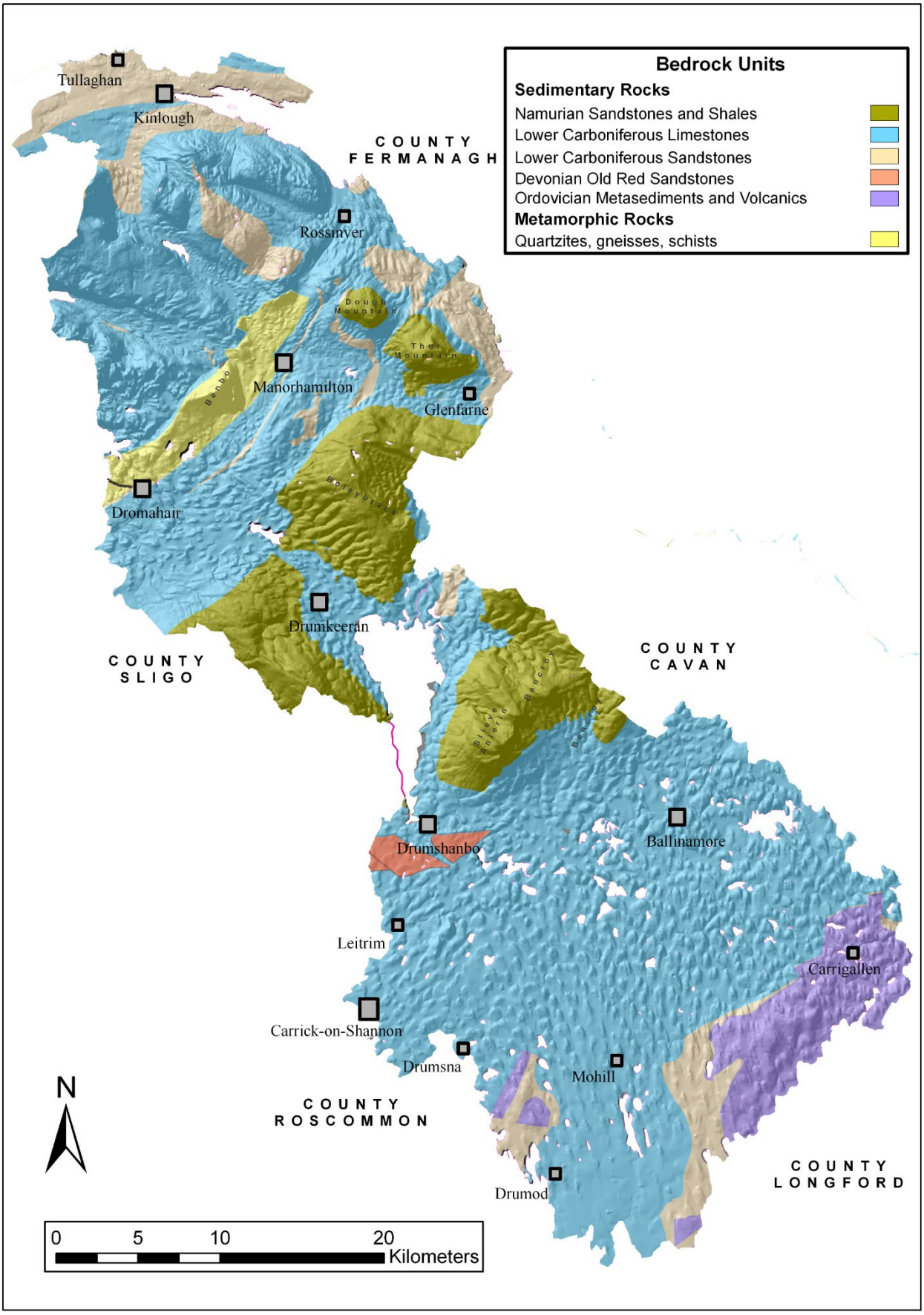
For the last 1.6 million years Ireland's climate has oscillated between arctic and temperate conditions. A large sheet of ice deposited glacial sediments in Leitrim during the last Glaciation (the Midlandian), which ended 10,000 years ago. At the maximum extent of the Midlandian Glaciation ice covered the entire county of Leitrim, reaching thicknesses of up to 650m in places. Earlier glacial and interglacial deposits were either buried by the Midlandian deposits or removed by the large sheet of ice. As the ice moved over the ground, loose debris was incorporated into it producing an abrasive base to the ice sheet, resulting in an ice-sculpted mountain landscape. The ice also carried large boulders, or erratics, far from their source area.

Large valleys were further sculpted by the ice producing classic U-shaped valleys such as Glenade and Glencar. Towards the end of the last glaciation, as the ice melted, oversteepened valley walls, once supported by the ice, collapsed as large-scale landslips like those seen today at Peakadaw and Eagle's Rock in Glenade. Glacial deposits are thinner in upland areas and thicker in lowland areas. Drumlins, ribbed moraines and crag-and-tails are common glacial features in the Leitrim area. Drumlins are low, smoothly rounded elongate hills, which formed beneath the sheet of ice. Largely composed of till, their long axis is parallel to the direction of ice flow (e.g. the area around Lough Rinn, near Mohill). Periglacial features such as those seen on Truskmore record the intense freeze-thaw conditions that shattered and moved the local bedrock towards the end of the last glaciation.

As the climate oscillated so too did sea level. Glacial periods saw the development of large sheets of ice, locking up available water and thus lowering the sea level. Warmer periods melted the ice allowing water back into the oceans causing sea level to rise. Wave cut platforms like those along the Leitrim coast record a post-glacial phase where sea level was different to what it is today. Peat bogs spread across both uplands and lowlands during the most recent warm and wet post-glacial phase.

AGE (Million Years Ago)	*ERA*	*PERIOD*	*EVENTS IN LEITRIM (non-italics)*	*IF THIS TIMESCALE WAS A DAY LONG...*
2.58	Cenozoic	Quaternary	Several ice ages smothering Leitrim, followed in the last 10,000 years by the spread of vegetation, growth of bogs and arrival of humans. Deep glacial valleys sculpted at Glencar and Glenade. Deposition of (till) boulder clay in ribbed moraines and drumlins, and moulding of crag-and-tails. Dissolution of limestone beneath Quaternary sediments.	Ice ages would begin 38 seconds before midnight
23		Neogene	Erosion, especially limestone. Caves, swallow holes, cavities, underground streams develop in uplands of north and central Leitrim. Intrusion of volcanic dykes near Lough Melvin, Lough Macnean and Manorhamilton.	Neogene period begins at 11.52 pm
66		Palaeogene		Palaeogene period begins at 11.40 pm
145	Mesozoic	*Cretaceous*	*Erosion. No record of rocks of this age in Leitrim.*	11.15 pm
201		*Jurassic*	*Uplift &erosion. No record of rocks of this age in Leitrim.*	Age of the dinosaurs, starting at 10.55 pm
252		*Triassic*	*Desert conditions on land.* *No record of rocks of this age in Leitrim.*	10.42 pm
299	Palaeozoic	*Permian*		10.30 pm
359		Carboniferous	Land became submerged, limestones with some shales and sandstones deposited in tropical seas around much of County Leitrim. Limestones remaining today are pure and unbedded in the majority, with smaller areas of muddier limestones at the edges. Shales and sandstones, with some coal seams, deposited in the Bencroy district.	Inundation of land by sea around 10.10 pm
419		Devonian	Caledonian mountain building. Sandstones deposited to south of Drumshanbo.	'Old Red' Sandstone deposited at 9.52 pm
443		*Silurian*	*Shallow seas following closure of Iapetus Ocean.* *No record of rocks of this age in Leitrim.*	Starts at 9.42 pm
485		Ordovician	Iapetus Ocean divides Ireland into two. Greywackes, shales, argillites and volcanic rocks form around and southeast of Carrigallen, and southwest of Mohill.	Begins at 9.28 pm
541		*Cambrian*	*Opening of the Iapetus Ocean.* *No record of rocks of this age in Leitrim.*	Starts at 9.11 pm
2500	Proterozoic	Precambrian	Some of Irelands oldest rocks deposited in northwest Ireland. Quartzites, gneisses and schists of this age present in a wide, crescentic band between Dromahair and Manorhamilton.	Beginning 11.00 am
4000	Archaean		*Oldest known rocks on Earth.*	Beginning 3.00 am
4600			*Age of the Earth.*	Beginning 1 second after midnight

The Geological Timescale and County Leitrim.



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

6. Acknowledgements

The authors gratefully acknowledge the assistance of Sarah Malone, Heritage Officer from Leitrim County Council in the development of this project. Funding from the Heritage Council and Leitrim 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.

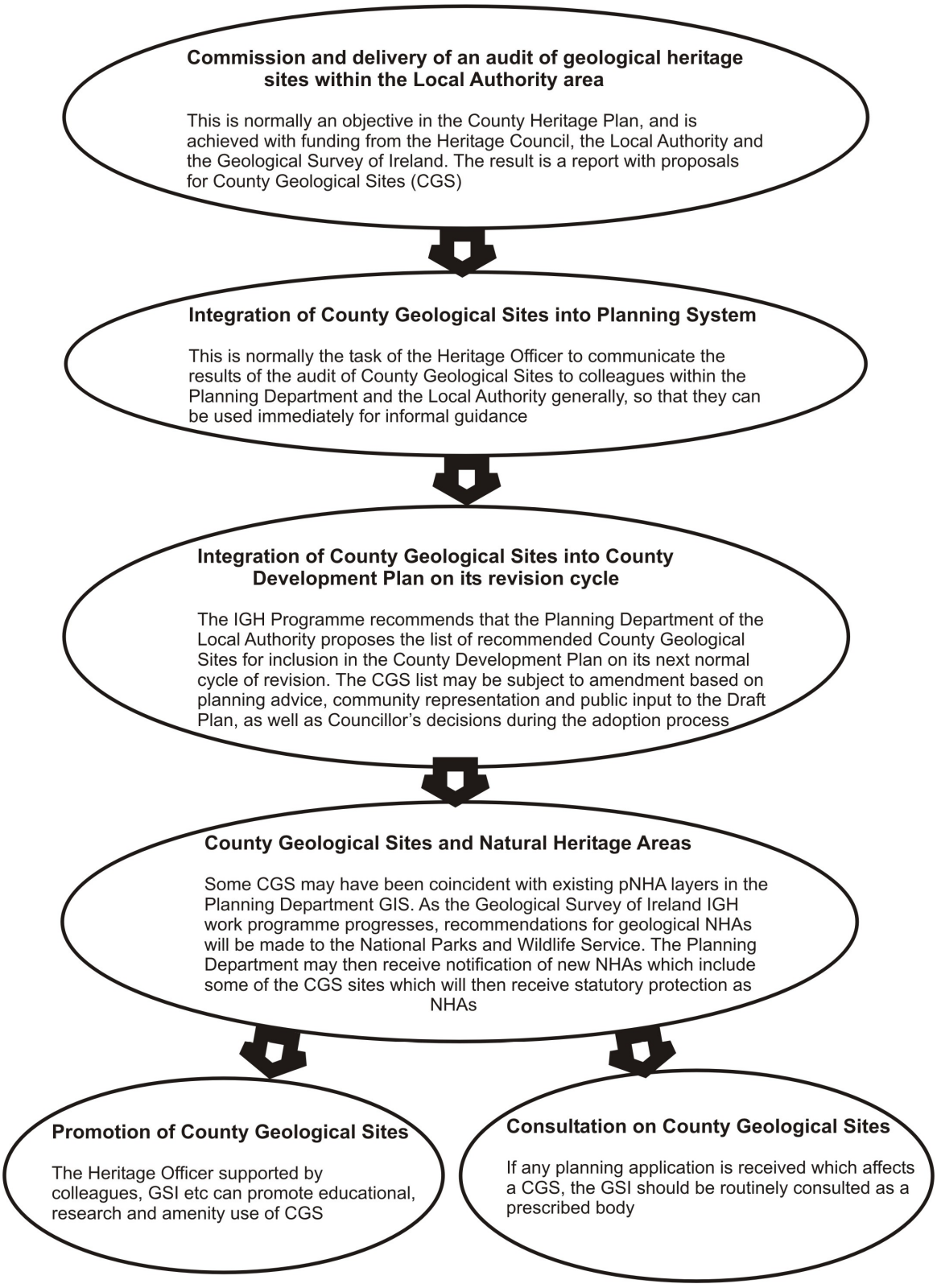
Appendix 1 – Geological heritage audits and the planning process

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 Leitrim

Shortlist of Key Geological References

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

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Full Geological references

Appendix 2 provides an extensive reference list of research papers, reports, books, articles and unpublished reports etc. relating to the geology and geomorphology of County Leitrim and the wider region. Some papers that refer to regional geology may or may not be specifically relevant to County Leitrim.

Quaternary References

Appendix 3 provides an extensive reference list of research papers relating to enormous body of literature on the Quaternary, or Ice Age geology of Ireland, and Co. Leitrim. They are split into references specifically covering sites or features in County Leitrim, and a section of national or regional papers which have some data from or on County Leitrim included.

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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 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 Leitrim and the relationship of County Geological Sites to those hazards.

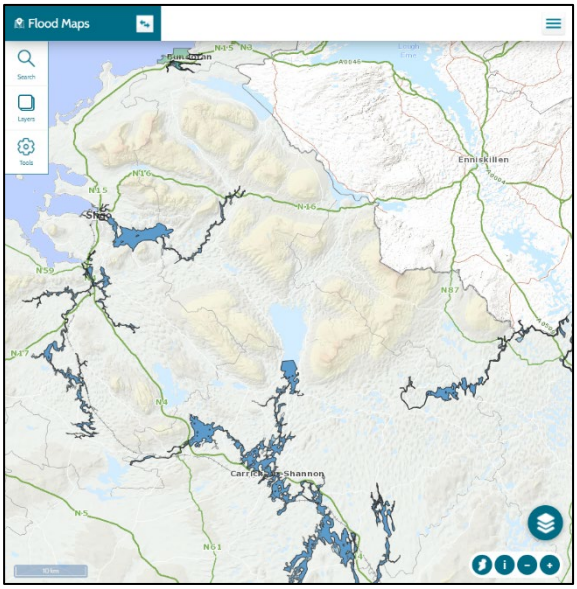
The difference between human timescales and geological timescales can be difficult to comprehend but, for many geological processes, there are periods of sudden activity encompassing major events, followed by long, quiet periods in between. The County Geological Sites in this audit represent evidence 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 Leitrim there are relatively few sites representing the active geomorphological or land-forming processes of today.

Landslides and bog flows

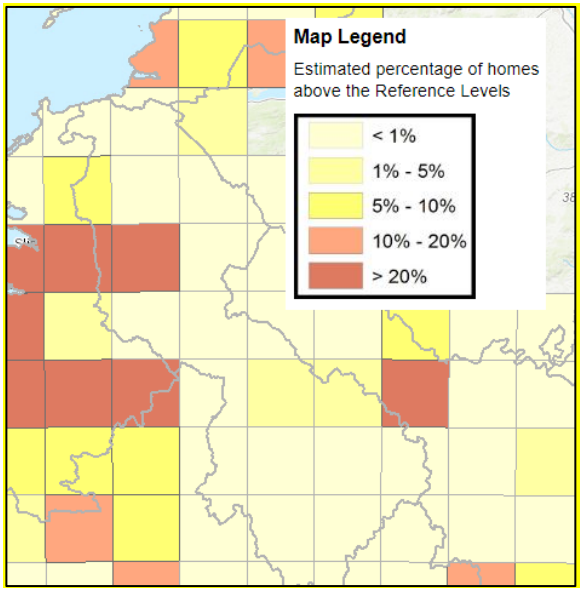
Geological Survey Ireland has been compiling national data on landslides in the past decade. There were over 75 events recorded in Leitrim. A landslide at Drumkeeran (Shass Mountain) in June 2020, illustrated the destructive forces associated with such events. See https://www.gsi.ie/en-ie/programmes-and-projects/geohazards/activities/Pages/Landslides-in-Ireland.aspx

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 Leitrim. Karstic flooding can occur when underground passages are unable to absorb high rainfall events.



Screengrab of OPW Flooding Probability Map showing Co. Leitrim



Screengrab of EPA Radon Map showing Co. Leitrim

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).

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 Leitrim 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 Leitrim

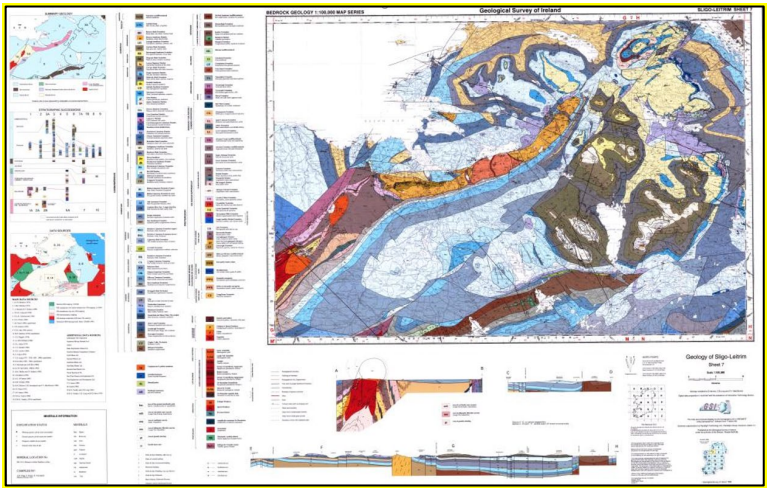
This section is a brief summary of publically available Geological Survey Ireland data and services, to assist with any enquiry concerning geology. The Geological Survey Ireland has a vast library of data accumulated since it began mapping Ireland's geology in 1845. A Document Management System called GOLDMINE is freely available online, and hosts almost digital 500,000 documents and maps. All GOLDMINE data is publically 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 the Geological Survey Ireland online digital archive database. The service provides public access to reports, publications and maps in PDF or high resolution TIFF image format. 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.dccae.gov.ie/goldmine/index.html (or search online for Geological Survey Ireland Goldmine)

1:100,000 Map Report Series

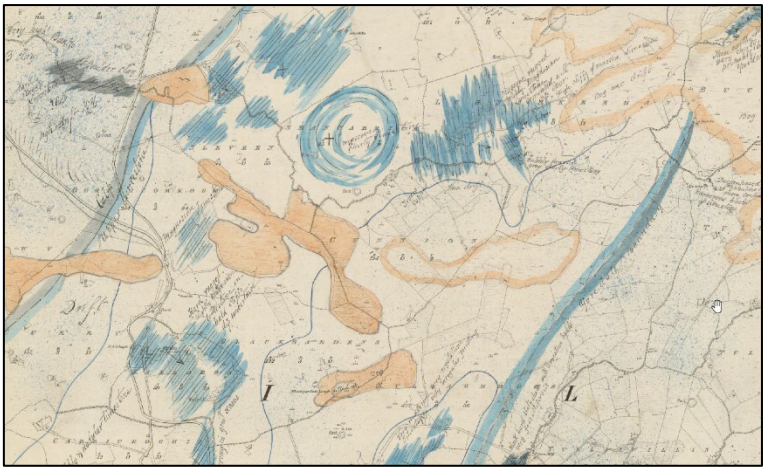
All historical, modern and other mapping has been compiled into very useful maps and reports that describe the geology of the entire country. Map Report Sheets 7 and 12 cover all of County Leitrim.



Geological Survey Ireland Sheet 7 showing Sligo and Leitrim

19th Century 6 inches to One mile (1:10,560) Fieldsheets

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 the Interactive Web Data Delivery System (IWDDS). https://jetstream.gsi.ie/iwdds/map.jsp



Geological Survey Ireland Field Sheet 15 showing Killargue area, Co. Leitrim

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 31, 43, 44, 55, 56, 67, 68, 78 and 79 cover County Leitrim. 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.
https://secure.dccae.gov.ie/goldmine/index.html

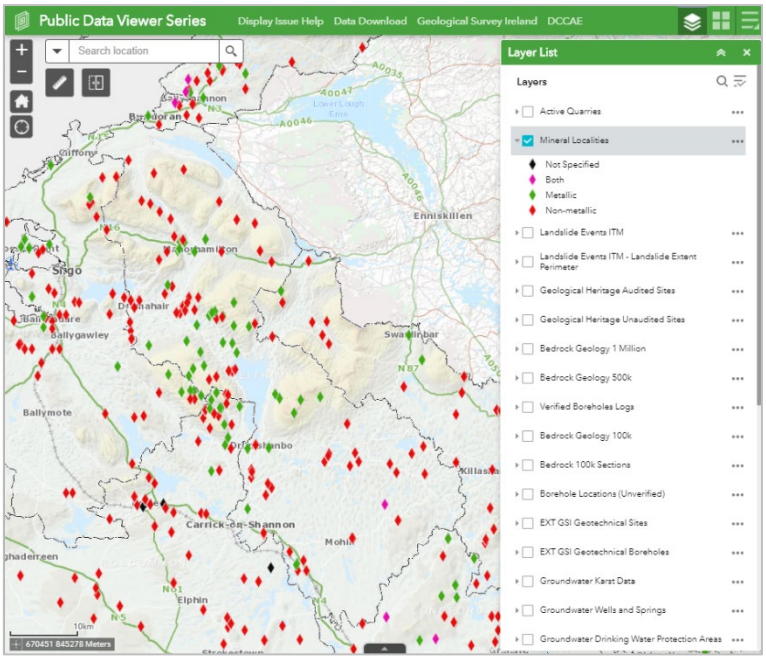
Maps and memoirs are publicly available on the BGS/GSNI/GSI Irish Historical Geological Maps website.
http://www.geologicalmaps.net/irishhistmaps/history.cfm

Open File Data

Each Mineral Prospecting Licence issued by the former Exploration and Mining Division (EMD), now Geoscience Regulatory Office (GSRO), of the Department of the 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 EMD interactive map viewer and a searchable database. Records include geological interpretations, borehole logs, geophysical and geochemical surveys. Licences relate to numbered prospecting areas, and these are available on a map from EMD/GSRO. See 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. Leitrim

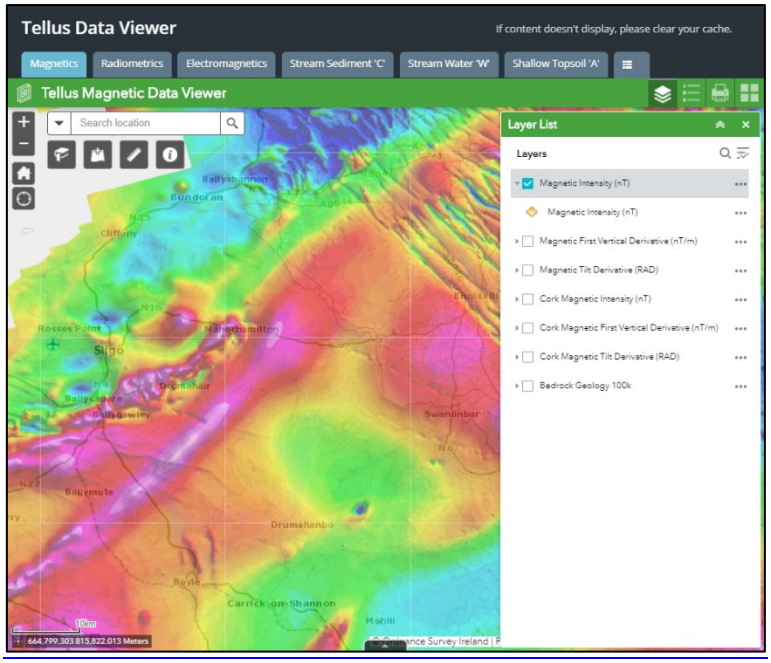
Subsoils Mapping

In 2012, Geological Survey Ireland completed 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 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 quaternary mapping. 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 included full coverage of County Leitrim. Geophysical and geochemical surveying has been carried out over most of County Leitrim. Tellus Border was an EU INTERREG IVA-funded regional mapping project and was a cross-border initiative between the Geological Survey of Northern Ireland, the Geological Survey of Ireland, Queen's University Belfast and Dundalk Institute of Technology. All data from Tellus is made available free of charge online. As of 2019, the Tellus airborne geophysical survey has mapped 75% of the country. The Tellus surveys support mineral exploration, environmental management, agriculture and research activity. See www.tellusborder.eu/.

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 Co. Leitrim

Breifne Project

The Bréifne Project was a collaborative initiative between Geological Survey Ireland (GSI) and Northern Ireland (GSNI), the Academy of Irish Cultural Heritages at the University of Ulster (Magee), and the local authorities of five counties: Sligo, Leitrim, Roscommon, Cavan and Fermanagh. The Special EU Programmes Body (SEUPB) funded the project, under the Programme for Peace and Reconciliation 2000-2004, with an overall aim to promote sustainable economic development within the region, particularly within the tourism sector. The project was thus an innovative tourism venture which sought to develop a new, branded tourism destination "*Bréifne*", covering these five counties.

The project area covered approximately 3,000km^2, delineated by the Sligo Coast to the west, Lough Key to the south and Lough Erne to the north and east, with the principal focus on an "upland core" encompassing the Dartry, Arigna, Sliabh an Iarainn, Cuilcagh and Bricklieve Mountains. A key task of the Bréifne initiative was to collate existing natural and cultural heritage information (ecology, geology, archaeology and ethnology or folklore) into a web-based GIS database that formed the basis for an information/educational resource for project stakeholders, tourists and local interests. The first product was a Landscape Characterisation of the area, as a report and GIS.

The Bréifne team based at Geological Survey Ireland carried out development work on a customised web-mapping interface and 3D visualisation, as methods of delivering and explaining the heritage of the region. Outputs from the project also included a Bréifne region DVD pack and booklet on the region, as well as a suite of road and tourist information signage.

Data are freely available at https://hub.arcgis.com/datasets/8a34a5b5d3f249068dca6ed6c10210be

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 in Leitrim, to immensely detailed series of plans for more modern mine sites such as those of the Connacht Coalfield, which straddled Counties Leitrim, Roscommon and Sligo. 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 (map.geohive.ie) offers a superb resource with OSI maps at different scales, colour and black & white air photos, and an 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 map viewer allows users to look at a wide range of built and natural heritage data sets online. Boundary data for County Geological Sites are available as a data layer on the online mapping service. http://heritagemaps.ie/

Earth Science Ireland Group and magazine [www.earthscienceireland.org]
Earth Science Ireland was an all-Ireland group promoting awareness of Earth sciences and supporting educational provision in the subject. A main vehicle for the efforts was the twice a year magazine Earth Science Ireland. Unfortunately, this organisation has ceased operating but the magazines remain available online, and include various articles relating to Co. Leitrim.

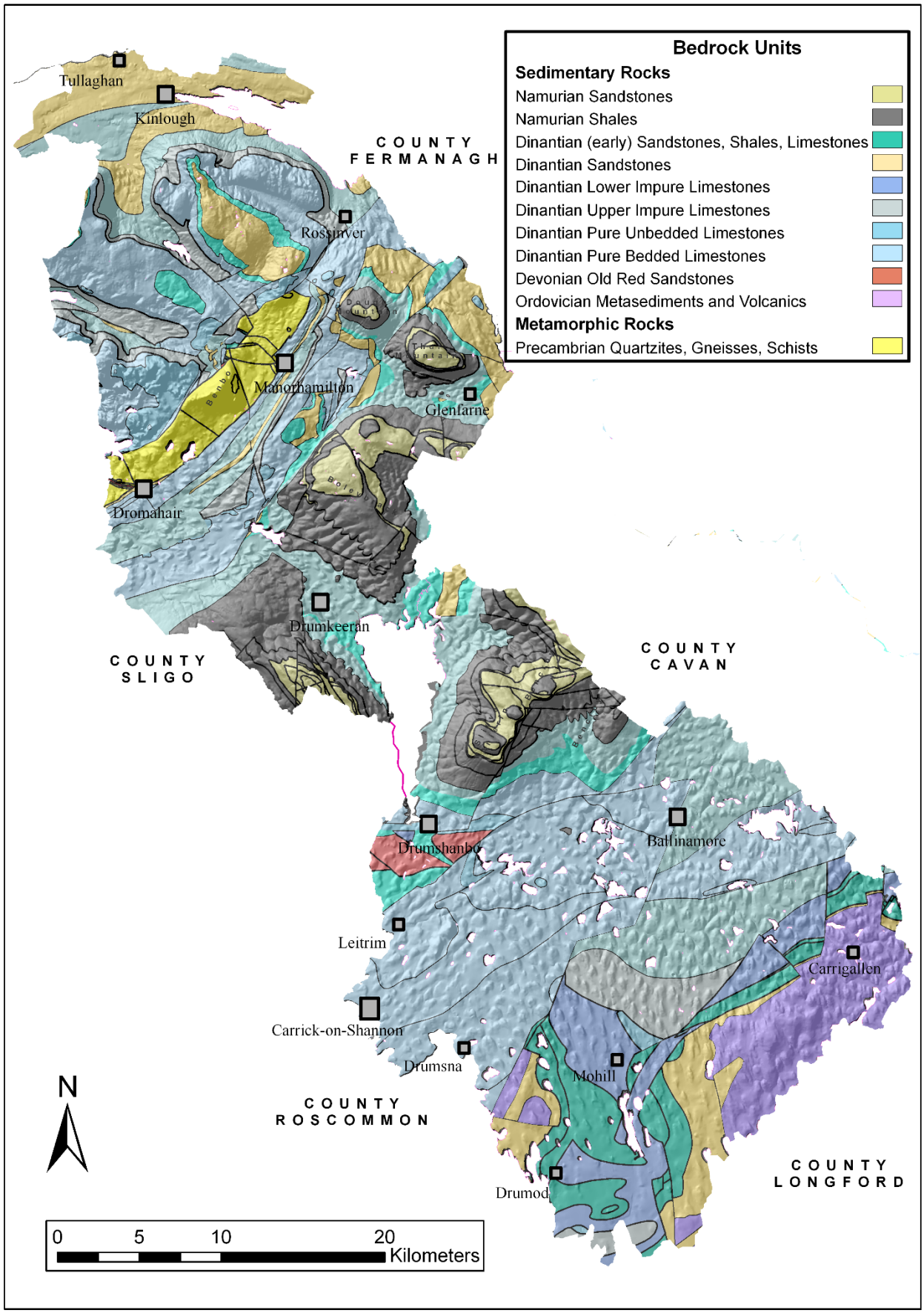
Appendix 6 – Further sources of information and contacts

Geoheritage Programme staff at Geological Survey of Ireland can be contacted in relation to any aspect of this report. Sarah Malone, Leitrim County Heritage Officer is the primary local contact in Co. Leitrim 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 Culture, Heritage and the Gaeltacht. See www.npws.ie for contact details.

Websites of interest

www.gsi.ie - general geological resources
https://secure.dccae.gov.ie/goldmine/index.html - Geological Survey of 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 Leitrim



Appendix 8 – Geoschol leaflet on the geology of County Leitrim

LEITRIM

AREA OF COUNTY: 1,588 square kilometres or 613 square miles

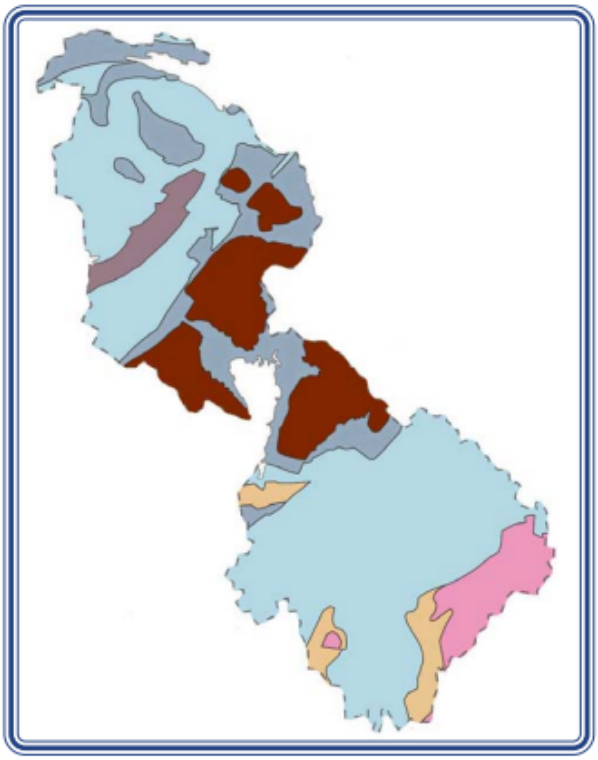
COUNTY TOWN: Carrick-on-Shannon

OTHER TOWNS: Ballinamore, Drumshambo, Dromahair, Manorhamilton

GEOLOGY HIGHLIGHTS: Carboniferous limestone cliffs, glacially deepened valleys, landslips, Precambrian gneiss, Arigna coalfield

AGE OF ROCKS: Precambrian, Devonian, Carboniferous, Paleogene, Pleistocene

Carboniferous limestone knolls at Doon Lough.



Geological Map of County Leitrim

Pale purple: Precambrian metamorphic rocks; **Pink:** Ordovician sediments; **Beige:** Silurian & Devonian sandstones and conglomerates; **Dark blue:** Lower Carboniferous sandstones; **Light blue:** Lower Carboniferous limestone; **Brown:** Upper Carboniferous shales.

Geological history

The landscape of much of County Leitrim is stunning and varied, with lakes and valleys nestling among flat-topped mountains. Only in the south-east of the county is the landscape more subdued.

The oldest rocks in the county occupy a narrow strip extending from a little north of Manorhamilton, south-westwards past the southern shore of Lough Gill and on to the Ox Mountains in adjacent Co. Sligo. These rocks are believed to have been deposited originally as sandstone, perhaps marine, rich in grains of the mineral feldspar. However, extreme heat and pressure at some time between 540 and 580 million years ago [Ma] metamorphosed these sandstones into a banded, high grade metamorphic rock called gneiss. The original age of the sandstone is difficult to be certain of but it is certainly Precambrian and at least 940 million years. These very ancient metamorphic rocks form the rounded hill of Benbo, just to the south-west of Manorhamilton.

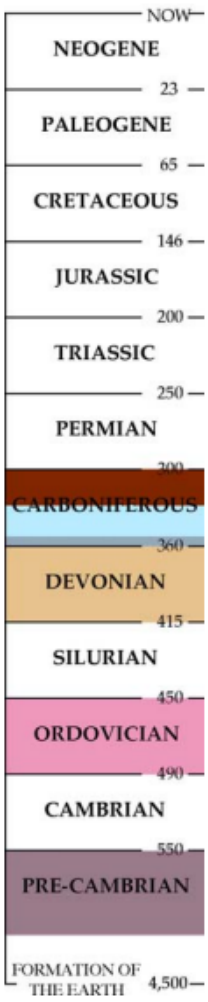
Cliffs in Glencar Limestone (Lower Carboniferous), Swiss Valley

Younger, and less severely metamorphosed, Precambrian rocks, around 600 Ma, occupy a very small area immediately to the west of Manorhamilton. These rocks represent sand, limestone and muddy sand that accumulated on an ancient sea floor, but they were metamorphosed to quartzite, marble and schist by the heat and pressure generated as continental plates moved towards each other.

Immediately south of Drumshambo, in the south of the county, and extending westwards into Co. Sligo for some distance, is a thick sandstone with thin mudstone beds that was deposited in large rivers. It is believed to be of Devonian age, between about 415 and 360 Ma, but no fossils have been found to verify this.

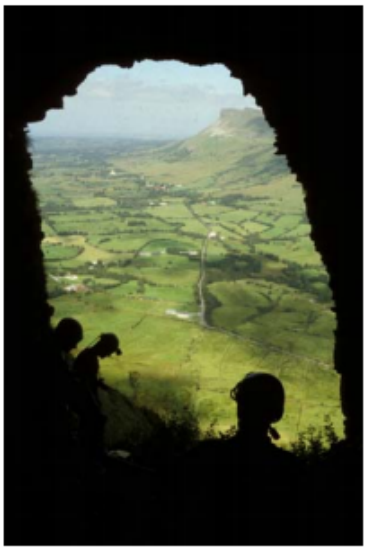
The great majority of the bedrock in Co. Leitrim is Carboniferous in age, between about 360 and 320 Ma. The oldest Carboniferous rocks are pebble beds and sandstones deposited by rivers but these were buried beneath a thick succession of marine limestones, mudstones and sandstones as sea level rose to spread across the flood plains. Limestones, often fossiliferous, formed in clear tropical seas when little sediment was being brought down by rivers. Some of these limestones accumulated as steep-sided 'mud mounds' on the sea floor while others are especially rich in layers of chert, an impure type of flint formed from sponge spicules. When the sediment supply was higher because of increased erosion on land, mudstones accumulated on the sea floor, while some of the sandstones represent deltas that formed at river mouths.

The arrangement of these different rock types within the landscape is one of the main causes of the diversity of the Leitrim landscape. Thick limestones, including 'mud mounds', lie above soft mudstones in the Glencar and Glenade valleys, creating the often sheer-walled appearance of these valleys as huge limestone blocks have slid downwards on the soft mudstone beneath. Elsewhere, as at Doon Lough, a remarkable



Geological timescale showing age of rocks in Leitrim.

In 1997 a cave in the Glenade valley was found to contain the bones of several adult brown bears and many cubs. Carbon-dating has shown these to be less than 4000 years old



rolling limestone landscape has been created where erosion has stripped away the heavily fractured cherty limestones that blanket the more resistant 'mud mound' limestones. Large areas of mountain top in the north-west of the county have flat, plateau-like summits formed on the gently dipping limestones or the sandstones which cap them.

In general across the county the Carboniferous rocks dip gently to the south-east, so that the youngest rocks are found on the hills around Lough Allen. Above the main limestones, which underlie the low ground in the south-east of the county, are more mudstones and sandstones, with a few thin coal seams, forming the hills of Seltannasaggart, Slieve Anierin and Bencroy. These mudstones and sandstones were deposited largely on river deltas but at several levels there are thin black mudstone bands containing marine fossils. These 'marine bands' were deposited when sea level rose for a short time and temporarily drowned the deltas.

The youngest bedrock features in the county are around 60 Ma. They are igneous dykes, fissures cutting through older rocks and filled with solidified basalt lava en route to the surface. Two have been found on the large plateau between Lough Melvin and the Glenade valley with a third, approximately 900 metres long and 35 metres wide, about 3 km south-west of Dromahair.

As elsewhere across much of Ireland, the ice sheets and glaciers of the last Ice Age have substantially modified the Leitrim landscape. Some aspects of this glacial modification are very obvious; the steep-sided overdeepened valleys of Glencar and Glenade are fine examples of glacial U-shaped valleys. The giant landslips which have contributed to these valleys' distinctive topography are also due to the effect of glaciers, or rather the loss of support once the ice has melted thereby allowing huge blocks of limestone to slide downslope on the soft mudstones beneath. On a more subtle note much of the lowlands is blanketed with glacial till, or 'boulder clay'.

Map adapted with permission from Geological Survey of Ireland 1:1,000,000 map 2003.
Image credits: Mike Simms (all).

Text by Mike Simms

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.
Bryozoa	invertebrates belonging to the phylum Bryozoa, ranging from Ordovician to present, often found as frond-like fossils.
Calcite	a pale mineral composed of calcium carbonate, which reacts with dilute hydrochloric acid.
Calp	dark grey, fine-grained, muddy limestone.
Channel	a landform consisting of the outline of a path of relatively shallow and narrow body of fluid, most commonly the confine of a river, river delta or strait.
Chert	a sedimentary rock comprising of very fine-grained quartz.
Cleavage	type of planar rock feature that develops as a result of deformation and metamorphism.
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.
Flute (glacial)	smooth gutter-like channels or furrows made by the abrasive underside of a glacier moving across a rock face.
Fluvial	pertaining to a river or stream.
Foliation	planar surfaces that are developed within a body of rock or sediment as a result of deformation
Geopetal indicator	way-up indicators determine the original top and bottom or orientation of a sedimentary layer.
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.
Goniatite	extinct cephalopods ranging from the middle of the Devonian to the Permian
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).
Haematite (Hematite)	a mineral form of iron oxide, which is the main ore mined as iron.
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.
Lamellibranch	marine or freshwater bivalve mollusk
Limestone	a sedimentary rock consisting chiefly of calcium carbonate (CaCO3), primarily in the form of the mineral calcite.
Limestone pavement	relatively flat, incised surface of exposed ***limestone*** consisting typically of blocks of karstified limestone, known as clints, separated by fissures, or grykes.
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.
Metabasite	metamorphosed basic igneous rock
Metagabbro	metamorphosed gabbro
Metamorphic	referring to the process of metamorphism or to the resulting metamorphic rock, transformed by heat and pressure from an originally igneous or sedimentary rock.
Metasediments	metamorphosed sediments.
Mississippian	earlier (first) of the two subdivisions of the Carboniferous Period, lasting from 358.9 to 323.2 million years ago.
Monocline	a step-like fold in rock strata consisting of a zone of steeper dip within an otherwise horizontal or gently-dipping sequence
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.
Paragneiss	gneiss produced by metamorphism of original sedimentary rock
Pegmatite	a very coarse-grained igneous rock of granitic composition
Mississippian	later (second) of the two subdivisions of the Carboniferous Period, lasting from 323.2 million to 298.9 million years ago
Pillow lava	a lava that forms from an underwater eruption and is characterized by pillow-shaped masses.
Raised Bogs	an area of acid, peaty soil, in which the centre is relatively higher than the margins.
Shaft	a vertical or inclined hole dug in a mine for access, ventilation, for hauling ore out or for pumping water out.
Shale	A fine-grained sedimentary rock, formed by the compaction and lithification of clay, silt, or mud. It has a finely laminated (composed of layers) structure that gives it a fissility, or tendency to split along bedding planes.
Spring	the point where an underground stream reaches the surface.
Stratigraphy	the study of stratified (layered) sedimentary and volcanic rocks, especially their sequence in time and correlation between localities.
Stromatactis	a sedimentary structure characterized by a nearly flat bottom, and a convex-upward upper surface, consisting of sparry-calcite cement, usually in the central part of a reef
Sump	a passage in a cave that is submerged in water
Testate amoebae	microscopic, unicellular, shelled animals which are sensitive indicators of hydrological conditions in peatlands, primarily the depth of the water table.
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
Turbidite	sedimentary deposit of a turbidity current
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	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 Leitrim. 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 (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 of Ireland, Beggars Bush, Haddington Road, Dublin 4. Phone 01-6782837. Email: clare.glanville@gsi.ie

Simplified Geological Map of County Leitrim with site locations indicated.