Leitrim's Geological Heritage

An Exploration of the Geology of County Leitrim

Ronan Hennessy, Robert Meehan, Vincent Gallagher
and Matthew Parkes

Comhairle Chontae Liatroma
Leitrim County Council

Dedication

Dr. Matthew Parkes (1961—2020)

This book is dedicated to the memory our colleague and friend, Matthew Parkes, who passed away unexpectedly in October 2020, shortly before completion of the county geological audit upon which this book is based.

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-1990s on the newly established Irish Geological Heritage Programme in Geological Survey Ireland, and later as curator in the Natural Museum of Ireland.

Matthew worked on and co-authored every one of the County Geological Heritage Audits completed up to 2020, as well as many of the books that accompanied these county audits.

Matthew at Teampall Shetric in 2020.

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An Exploration of the Geology of County Leitrim

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Graphic Design: Ronan Hennessy.

Cover Image: Matthew Parkes at Peakdaw Landslips.

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Comhairle Chontae Liatroma
Leitrim County Council

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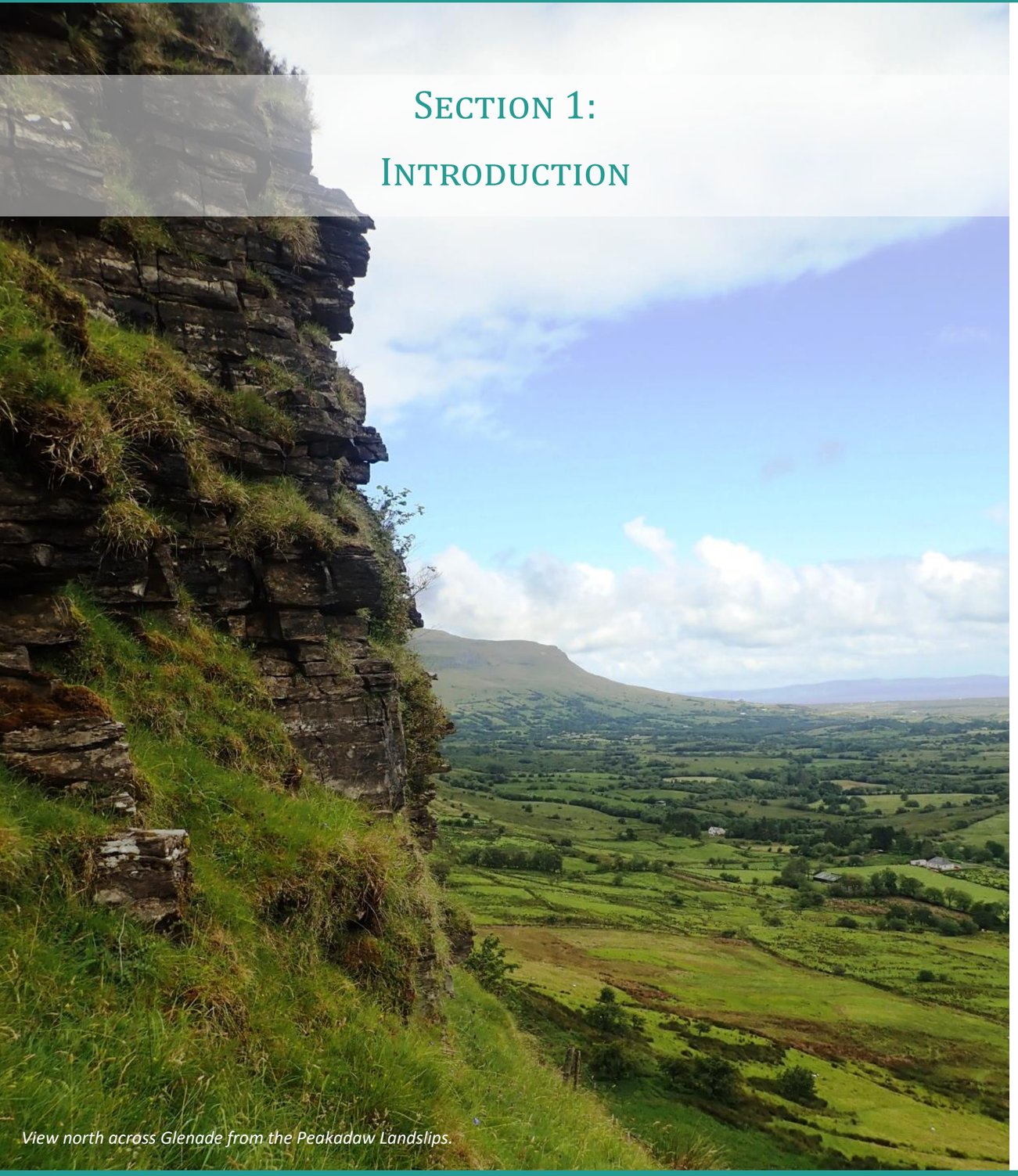


View north across Glenade from the Peakadaw Landslips.

Geological Heritage and Geodiversity

"Geology is the science which investigates the successive changes that have taken place in the organic and inorganic kingdoms of nature; it inquires into the causes of these changes, and the influence which they have exerted in modifying the surface and external structure of our planet."

Charles Lyell, Principles of Geology (1830-1833)

The geological foundation of Leitrim is made up of a rich diversity of rocks, sediments, fossils, and landforms—collectively termed *geodiversity*. Geodiversity can be considered as the abiotic or non-living equivalent of biodiversity. It describes the variety of geological, geomorphological, soil and hydrological features and processes that may occur in a particular region. Geodiversity can benefit society by providing a large number of the resources and services which may be of value to human well-being and prosperity.

Geological heritage, or geoheritage, refers to elements of geodiversity that may be considered worthy of conservation. Such elements may vary in scale from large landscape features to small rock outcrops, and are often referred to as 'geoheritage sites'. Sites may be of value due to their unique scientific value both nationally or internationally, and their research value in contributing to our understanding of geological processes and events.

Geoheritage sites provide valuable clues to decoding the 4.6 billion year history of the Earth, as well as serving as natural learning sites for geological and environmental scientists.

Geoheritage sites also have cultural, economic and aesthetic value, often being sites of historical significance, essential industry, and scenic and recreational interest.

Illustration of Glenade from Geological Survey of Ireland Sheet 42/43 Memoirs, 1885.

This book is arranged in four sections. Section 1 provides an introduction to the geology of County Leitrim, a timescale of Earth history, a rock types refresher, and some maps. Section 2 presents a selection of nineteen County Geological Sites in County Leitrim. Section 3 expands on the geological history of the county. Section 4 provides a full list of Leitrim's County Geological Sites. The Appendix includes a glossary of terms, suggestions of further reading, and some more maps of County Leitrim.

Leitrim's Geological History- Summary

The oldest rocks in County Leitrim are found along a southwest-northeast-oriented belt to the north of Dromahair and Manorhamilton. Known as the Slishwood Division, these rocks are thought to have been deposited during Precambrian times, around 1,700 million years ago. The rocks were later subjected to repeated episodes of folding and were metamorphosed deep within the Earth's crust to produce the banded gneiss that occurs at places such as Benbo.

The bedrock in the southernmost part of the county is Ordovician metamorphic and volcanic rock, the remnants of a former ocean floor and a long-vanished mountain chain.

Devonian conglomerate and sandstone are found to the south of Drumshanbo, whilst Carboniferous sandstone is present in northeastern and southern parts of the county.

Leitrim's geology is dominated by 330 million-year-old Carboniferous limestone. The limestone forms mostly well-bedded, horizontal layers that were originally deposited in a shallow marine environment when Ireland was largely submerged under a warm tropical sea. The sea was rich is marine life as evidenced by the presence in the limestone of abundant fossils such as corals. In Leitrim, the limestone bedrock has long been subjected to a process called karstification, whereby dissolution of the limestone by water has led to the formation of spectacular caves, depressions and other surface karst features in the landscape of the county.

Upland areas in the central part of the county around Lough Allen host younger Carboniferous (Namurian) rocks that record a time of shallow seas, deltas and swamps. The Namurian sandstones, shales and coal seams formed during middle Carboniferous times. After the Carboniferous period ended some 300 million years ago, the rocks on the surface eroded down to what is effectively their present level.

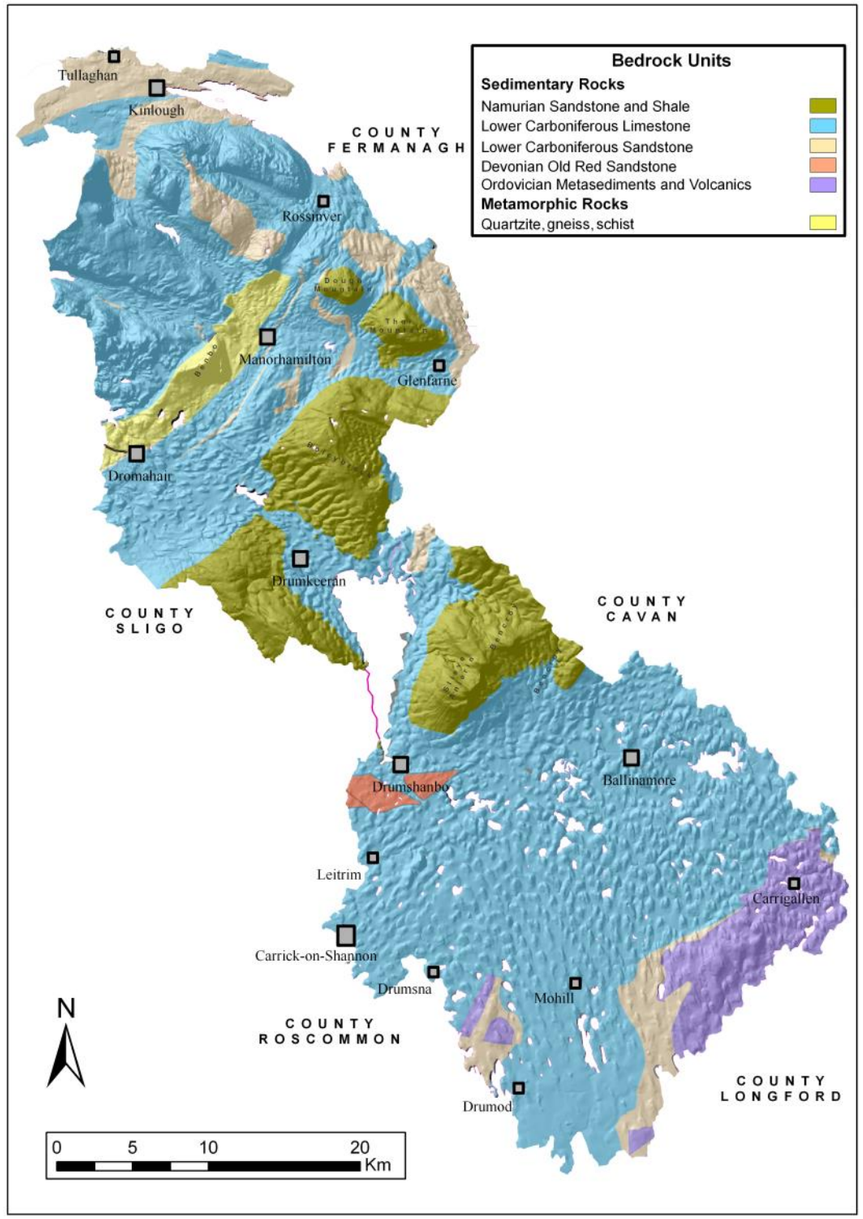
The Ice Age was the most recent event to shape the county. Large ice sheets covered the region, eroding and shaping the land surface. The ice moulded the landscape as it passed over it, depositing sediment debris in the form of drumlins all over County Leitrim.

Deep gullies etched into scree deposits at the southern end of Glenade.

Geological Timescale

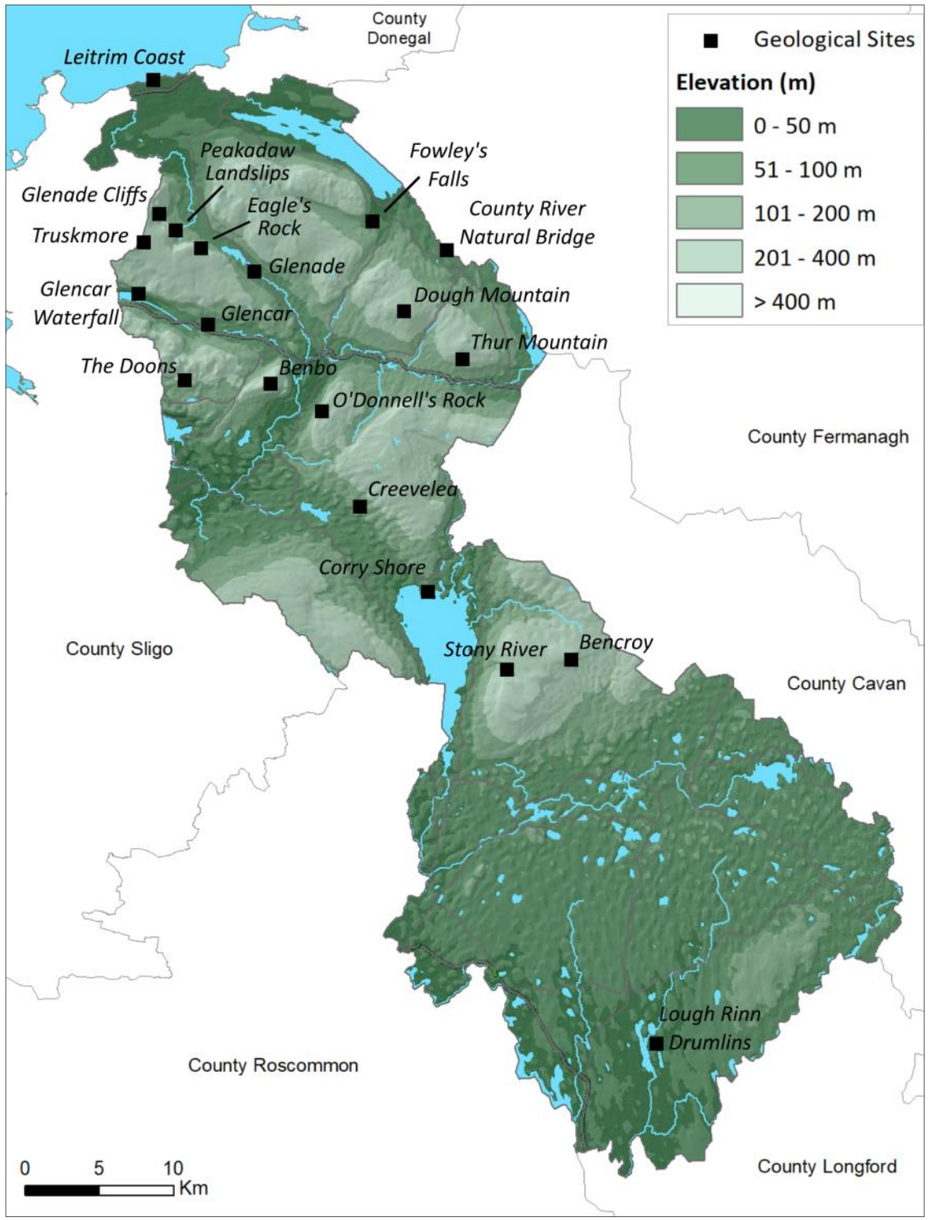
AGE*	ERA	PERIOD	EVENTS IN LEITRIM
2.58	Cenozoic	Quaternary	Several ice ages covering Leitrim, followed in the last 10,000 years by the spread of vegetation, growth of bogs and arrival of humans. Deep glacial valleys sculpted at Glencar and Glenade. Deposition of (till) boulder clay in ribbed moraines and drumlins. Dissolution of limestone beneath Quaternary sediments.
23		Neogene	Uplift and erosion. *No record of rocks of this age in Leitrim.*
66		Palaeogene	Desert conditions on land. No *record of rocks of this age in Leitrim.*
145	Mesozoic	Cretaceous	Erosion. *No record of rocks of this age in Leitrim.*
201		Jurassic	Uplift and erosion. *No record of rocks of this age in Leitrim.*
252		Triassic	*No record of rocks of this age in Leitrim.*
299	Palaeozoic	Permian	*No record of rocks of this age in Leitrim.*
359		Upper Carboniferous	Land submerged, limestones, shales, sandstones deposited in tropical seas in Namurian times (Lower-Upper Carboniferous transition).
419		Lower Carboniferous	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 Bencroy area.
443		Devonian	Caledonian mountain building. Sandstones deposited south of Drumshanbo .
485		Silurian	*Shallow seas after closure of Iapetus Ocean. No rocks of this age in Leitrim.*
541		Ordovician	Iapetus Ocean divides Ireland in two. Greywackes, shales, argillites and volcanic rocks around Carrigallen, and southwest of Mohill.
1,000	Proterozoic	Cambrian	*Opening of the Iapetus Ocean. No record of rocks of this age in Leitrim.*
1,600		Neoproterozoic	Neoproterozoic quartzites, gneisses and schists present in a wide, crescentic band between Dromahair and Manorhamilton.
2,500		Mesoproterozoic	*Some of Irelands oldest rocks deposited in northwest Ireland.*
4,000	Archean and Hadean	Palaeoproterozoic	*Oldest known rocks on Earth.*
4,600			*Age of the Earth.*

Geological Map of County Leitrim



Bedrock Geology Map of County Leitrim

County Geological Sites in This Book



Map of Geological Sites presented in this book.

Rock Types - Refresher

Some of the language and terminology used to describe geological forms, features, characteristics and time periods may be new to some readers. Therefore, a refresher about the three main rocks types is provided, along with a geological timescale. For specific terminology, see the glossary towards the end.

Igneous rocks are formed by the cooling of very hot, molten material called magma that originates deep inside the earth. Magma rises up towards the earth's surface because it is hotter and lighter than the surrounding rock. Magma that reaches the earth's surface, as happens with a volcanic eruption, is called lava. Lava cools quickly, losing its heat to the surrounding atmosphere or surface water, so that the crystals that form it do not have time to grow large. Basalt is an example, it is dark in colour, and is made up of very fine crystals. If the magma does not reach the surface of the earth, and takes up residence within the earth's crust it is referred to as an intrusive igneous rock. Such rocks cool slowly and their crystals can grow to very large sizes. Granite is an example of an intrusive igneous rock.

Sedimentary rocks are formed by the deposition of fine-to-large fragments that have eroded from existing 'parent' rocks. We can think of it as recycling older rocks to form newer rocks. Organic materials, such as plants and shells, can also accumulate to form sedimentary rocks such as limestone, chalk and coal. Sedimentary rocks generally consist of sand, pebbles and mud removed from the land by erosion, carried by rivers, or blown by the wind and eventually deposited in water (seas and lakes) and in deserts. Sediments are generally deposited in layers called beds, or strata. As the layers accumulate on top of one another, each layer is buried under layers of younger sediment, and the weight compresses it into solid rock.

Bricklieve Limestone Formation rocks at Keshcarrigan Quarry.

Most of the southern, low-elevation part of County Leitrim is underlain by limestone bedrock. Limestone is a sedimentary rock made up of a mineral called calcium carbonate ($CaCO_3$). The calcium carbonate shells and skeletons of sea creatures, such as fish, corals and shellfish accumulate on the seafloor when they die. Over time, thick layers of calcium-carbonate-rich muds build up on the sea floor where they are compressed to form the limestone we see throughout the county.

Metamorphic rocks are formed by the alteration of existing, 'parent' rocks to form a new type of rock. The word 'metamorphic' comes from the Greek meta meaning change and morphe meaning form. The change in the type of rock, called metamorphism, is a result of extreme pressure (compression) or heat, or a combination of both.

If a limestone is subject to metamorphism it changes to a more crystalline rock called marble. Marble has a very wide range of colours, due to the presence of mineral impurities such as clay, silt, sand or iron oxide, which were present as grains or layers in the original limestone. If a granite is metamorphosed it typically forms gneiss, one of the many rock types found in Leitrim.

The three different rock types: igneous, sedimentary and metamorphic, may be transformed into one another. Sedimentary rock can become igneous, metamorphic or another sedimentary rock. Metamorphic rock can become igneous, sedimentary or another metamorphic rock. And igneous rock can become sedimentary, metamorphic or another igneous rock. So any rock can be changed into another rock type—it just takes time. Usually a very long time...

Glenade Sandstone Formation rocks on Truskmore.

Section 2:

County Geological Sites

Wave-cut platform in sandstone and shale beds of Mullaghmore Sandstone Formation on Leitrim Coast.

Leitrim Coast

Four kilometres long, the Leitrim coastal section is of considerable geological importance. The central part of the coastline, along with Mullaghmore Head to the south in County Sligo, forms part of the type section for the Carboniferous Mullaghmore Sandstone Formation. A type section is the specific exposure of a particular stratigraphic unit that serves as the standard of reference.

This region was the last place in Ireland to be inundated by the northwards advancing Carboniferous sea. Early limestone deposition was followed by a sudden influx of mud prior to development of deltas fed by rivers flowing from the north. These muds are seen in the Bundoran Shale Formation to the northeast. This was followed by the Mullaghmore Sandstone Formation, comprising cyclic units of siltstones and shales topped by thick channel sandstones. Much of the site comprises a platform cut by waves along the shallow-dipping strata. Cliff exposures provide excellent examples of the cyclic sequences of interbedded sandstones, siltstone and shales. Fossils are abundant in the shale beds, but trace fossils, sedimentary structures left by animals moving through the sediments, are more typical of this formation. Channel-fill structures can also be seen in the sandstones.

Coastal exposures at cove along Leitrim coastline.

Geological Summary:

Wave-cut platform sandstone and shale of Mullaghmore Sandstone Formation .

Bedrock Age: Lower Carboniferous.

Location: North Leitrim

Lon: 54.46694°

Lat: -8.36740°

Channel structure in shale infilled by lobe of sandstone at cove midway between Tullaghan and Mullaghmore.

Glenade and Glencar

Glenade and Glencar are wide glacial valleys that were shaped and moulded by glacier ice during the Quaternary Period. The uplands flanking the valleys are considered to be among the best upland karst landscapes in Ireland, for the quantity and complexity of karst features in a relatively small area. At the northeastern side of Glenade, Arroo Mountain hosts limestone pavement, numerous caves and potholes, all of which are indicative of extensive limestone karstification. At the southwestern side of Glenade, Largy – Gorteenaguinnell is the most extensive plateau karst doline field in Ireland. The caves at Poll na mBear and Teampall Shetric are the result of extensive karstification. Glencar Waterfall is a spectacular feature overtopping the limestone cliffs at the edge of the uplands. Glenade Cliffs reveal the stratigraphic sequence of local limestone bedrock units. Truskmore hosts the most superb complex of periglacial features found in Ireland. And Eagle's Rock and the Peakadaw landslips are evidence of dramatic post-glacial geological actions.

Geological Summary:

Wide glacial valleys with upland karst on flanking mountain tops.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.35133°

Lat: -8.30159°

Northeast end of Glenade .

Glenade Cliffs

The Glenade Cliffs are situated at the northern end of Glenade. When the glacier that occupied the valley melted and retreated at the end of the last glaciation, the cliffs were exposed. The steep walls of the wide valley were no longer supported by the glacier, and this led to some localised collapse, along the valley sides. The upper portions of the cliffs are fine-grained, cherty limestones (Dartry Limestone Formation), whereas the lowermost units are fine limestones and calcareous shales (Glencar Limestone Formation). Both units are of Lower Carboniferous (Mississippian) age. Accumulations of landslipped Dartry Limestone boulders and cobble-sized blocks have fallen off the escarpment along the northwestern side of Glenade, and have either dropped in steps on the underlying Glencar Limestone Formation, or rolled down onto the Benbulben Shale Formation further below. Scree slopes also feature, the slopes of which are incised by mountain streams, such that spectacular deep gullies can be seen along the valley sides, particularly at the southern end.

Geological Summary:

Limestone bedrock units exposed in cliffs along the northwest side of the Glenade .

Bedrock Age: Lower Carboniferous

Location: Central Leitrim

Lon: 54.38195°

Lat: -8.29309°

The limestone cliffs and scree slopes at the northwest end of Glenade.

Peakadaw Landslips

Peakadaw is a limestone pinnacle on a landslip on the southwestern side of Glenade. The site also includes a series of landslips of the limestone escarpment. Large landslipped blocks of Dartry Limestone Formation have foundered along the escarpment on this section of the southwest side of Glenade. They have dropped in steps, either on the underlying Glencar Limestone Formation, or on the Benbulben Shale Formation below that. The blocks show little rotational movement and thus comprise a series of platforms that have 'stepped down' along the side of the valley. The exception to this is towards the outer, downslope blocks, which have some tilt of the normally flat lying limestone beds.

As with the Swiss Valley in Glencar, and Eagle's Rock further northwest in Glenade, these landslips probably occurred soon after the glaciers in Glenade and Glencar melted away around 14,000 years ago. The lack of support from the ice mass in a glacially deepened valley meant the sides were prone to collapse, with large blocks breaking away from the cliffs.

Geological Summary:

Limestone pinnacle on landslips along southwest side of Glenade.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.36914°

Lat: -8.30987°

View westward from Peakadaw across the landslips.

Landslipped limestone block at Peakadaw, looking eastwards over Glenade Lough.

Truskmore

Truskmore is the highest mountain in Counties Leitrim and Sligo, and has excellent exposures of rock weathering features visible adjacent to the summit. The features of interest here are periglacial features that formed during the later stages of the last glaciation in Ireland, approximately 10,000 years ago.

Stone banked terraces on southeastern flank of Truskmore.

Periglacial features originate from geomorphological processes that result from seasonal thawing of snow in areas of permafrost, the runoff from which refreezes in ice wedges and other structures. The term 'periglacial' therefore suggests an environment located on the margin of past glaciers, similar to the tundra areas in places like Siberia today. As the last ice sheet retreated across the Irish landscape at the end of the last Ice Age, periglacial processes took hold in the areas not still actually covered by ice.

The summit of Truskmore would have been ice-free early at the end of the last glaciation, allowing for the many freeze-thaw cycles required to shatter and move the rock.

Relict periglacial features flanking the sandstone plateau on Truskmore, include sorted nets of stones, stone-banked terraces, stone stripes, and a bedrock terrace with an

Geological Summary:

Highest mountain in County Leitrim with periglacial features such as debris fans, stone banked terraces and stone stripes.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.37214°

Lat: -8.36520°

Stone stripes south of the summit.

Debris fan on mountain flanks northeast of the telecommunications mast.

associated debris fan. Sorted nets displaying a fish-net-tights pattern are exposed close to the summit, and appear as vegetated centres with stone borders that exhibit varying sizes, from approximately 1 m to 5 m in diameter. They probably formed due to frost sorting and heave.

The stone borders, consisting of stones of the Glenade Sandstone Formation and ranging in size from pebble to boulder, are quite angular, indicating that they have not travelled far from their source.

Mass movement of weathered Glenade Sandstone Formation rocks has also produced stone stripes (up to 4 m wide and 100 m long) and stone banked terraces on the southeast side of the summit. These features formed as seasonally thawed material moved slowly downslope under the influence of gravity.

The northeast side of the plateau hosts a 120 m-long bedrock terrace that has been cut into the rocks of the Glenade Sandstone Formation as a result of frost shattering. A large debris fan associated with the terrace covers the slope below.

The spread of sorted nets of stones to the east of the telecommunications mast.

Sandstones on Truskmore.

Eagle's Rock

Eagle's Rock is a 330-m high free-standing rock pillar, a prominent, iconic feature in Glenade. The valley was formed during the last Ice Age as a consequence of glaciation. On either side of Eagle's Rock the valley walls are recessed owing to weathering under glacial conditions.

Eagle's Rock formed after the glacier that occupied the valley had retreated. The glacier had provided support for the steep walls of the wide valley but when it melted the lack of support led to localised collapses in the bedrock.

Eagle's Rock is thus a former part of the valley wall that has broken away to become a free-standing pillar. Similar collapse features are visible at Peakadaw to the south, and at Swiss Valley in Glencar.

Eagle's Rock is within the Ben Bulben, Gleniff and Glenade Complex SAC and proposed NHA. It is popular with walkers and climbers and the site is well-served by the council car park near its base. From the car park a gravel road (right-of-way) leads to a walking trail that winds up the cliff face on the northern side of Eagle's Rock, affording view of the rock itself and the surrounding upland and valley. The latter part of the walking trail is on commonage. The site is well sign-posted in the region.

The sign board in the adjacent car park refers to the formation of cirques leading in turn to the development of Eagle's Rock pillar but the adjacent cliffs do not comprise cirques and formation of the pillar is more properly ascribed to collapse following glacial retreat.

Geological Summary:

Rock pillar and cliffs that form part of the side wall of glacial valley.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.3883°

Lat: -8.33626°

Eagle's Rock (left side of cliffs) viewed from the east.

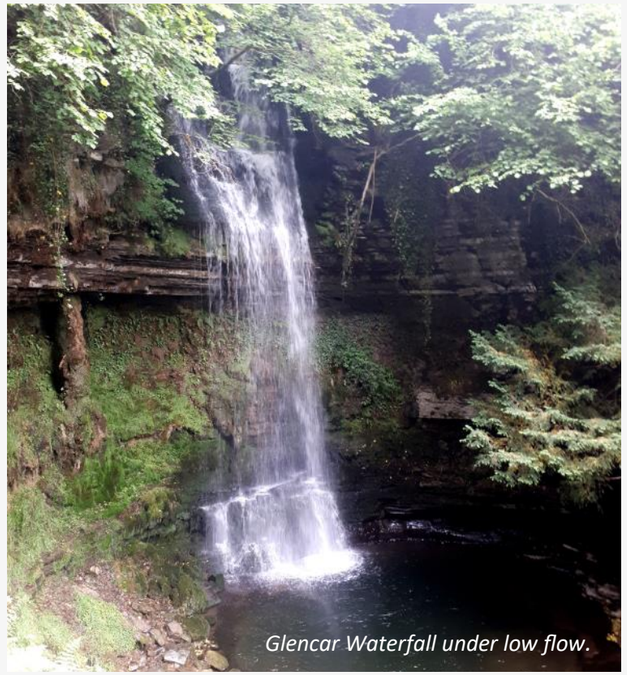
Illustration from Geological Survey of Ireland Sheet 42/43 Memoirs, 1885.

Eagle's Rock.

Glencar Waterfall

Glencar itself is a fine example of glacial erosion, where accumulated ice has scoured out a wide valley, with steep cliff sidewalls. The glacial valley is Quaternary in age, and the waterfall itself is likely to have been present at this location only since glacier ice retreated from the area, approximately 14,000 years ago.

Glencar Waterfall is a spectacular waterfall that spills over the shoulder of the cliffed valley side. The bedrock in the cliff face is Lower Carboniferous (Mississippian) interbedded limestone and shale of the Glencar Limestone Formation, clearly seen at the waterfall. The cascading water is highly calcareous, and as a result a tufa curtain has formed across a portion of the waterfall cliff face. Tufa is formed from the precipitation of calcium carbonate ($CaCO_3$) and is spongy or porous in nature. The tufa curtain is vegetated, with much of the vegetation calcified.



Glencar Waterfall under low flow.

Geological Summary:

Cascading waterfall toppling over cliffs on the side of glacial valley.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.3400°

Lat: -8.36815°

Tufa curtain hanging over alternating limestone and shale beds at the western end of the waterfall.

Viewing area at Glencar Waterfall.

The Doons

The Doons are a group of isolated, steep sided limestone hills north of Doon Lough. The hills are considered to be the best example of relict, glacially-modified tower karst hills in Ireland, with more bedrock exposure and less glacial sediment cover than is the case for similar features elsewhere.

Prior to glacial modification, the hills may have been similar to the classic tower karst of the Guilin area in China. Whilst the presence of other hills in the vicinity possibly reflects variations in the nature of the limestone, the Doons are composed of relatively ordinary bedded Dartry Limestone Formation. Most of the surrounding hills are formed of massive carbonate mudbank rocks that tend to be more resistant to erosion.

The western tower of the main pair is tree covered and the surface features are not visible. In contrast, grazing on the eastern tower has kept the hilltop surface open and visible. The eastern tower was the site of a hillfort, from which unimpeded views of the surrounding landscape could have proved favourable for defence purposes.

The two main towers at the Doons viewed from the south.

Geological Summary:

Steep sided limestone hills north of Doon Lough, near Dromahair.

Bedrock Age: Lower Carboniferous

Location: Central Leitrim

Lon: 54.278636°

Lat: -8.309924°

Eastern tower viewed from the west.

Fowley's Falls

Fowley's Falls, about 2 km west of Rossinver, are a series of spectacular waterfalls that spill over rock steps in a deep, V shaped channel. The bedrock comprises Lower Carboniferous (Mississippian) interbedded limestone and shale of the Glencar Limestone Formation, and shale and calcarenite of the Benbulben Shale Formation. The V-shaped valley is Quaternary in age, and the waterfalls themselves are likely to have been present at this location only since glacier ice retreated from the area, approximately 14,000 years ago.

The river has eroded the limestone to form a deep river gully, and forms a spectacular torrent of water rushing through the steep valley towards Lough Melvin. The rocks form a set of discrete cliffs, each several metres high, and the river cascades over them to form a series of cliffed waterfalls.

Geological Summary:

Stepped waterfalls in steeply incised, V-shaped river valley.

Bedrock Age: Lower Carboniferous

Location: North Leitrim

Lon: 54.38065°

Lat: -8.13416°

One of the waterfalls along the Fowley's Falls walkway.

Cascades at Fowley's Falls.

Dough Mountain

Dough Mountain is a domed, upland ridge approximately 5 km northeast of Manorhamilton. The summit of the mountain has bedrock of Namurian (Lower/Upper Carboniferous) sandstone and shale, while the lower slopes are underlain by limestone of Mississippian (Lower Carboniferous) age, specifically the Dartry Limestone and the Carraun Shale Formations.

Though Dough Mountain itself owes its elevation and form largely to this underlying bedrock, the bedrock itself is mostly invisible as it has been blanketed by thick Quaternary deposits, left during and since the last Ice Age.

The hilly forms on the lower slopes of the mountain are Ice Age, ribbed moraine features. Leitrim is one of the few localities in the world where upland ribbed moraines like these occur. The ridges are up to 1 km long, 300 m wide, and 15 m to 20 m high.

Perhaps the most striking features across the mountain top are deep depressions on the western side, where karstic cavities in the limestone underground have opened up at surface, as a result of the ground above them sinking, and formed enclosed depressions, or dolines. Some of these are up to 30 m across and 20 m deep, and some in turn have developed into swallow holes. Springs emerge from the mountain side in this general area also, and one of the depression features has become a vertical pothole shaft, at the base of which is a recently explored cave, called Polldough. This cave has a waterfall at its entrance, and is deep and dangerous, with the floor up to 50 m below the ground surface. All of these karstic features probably pre-date the Ice Age.

The southeast side of Dough Mountain has been blanketed in scree and other slope deposits in the Holocene Epoch, since the Ice Age, and this has allowed a set of exceptionally straight stream channels to form, flowing radially off the mountain. These straight channels have formed naturally, and such an arrangement is rare hydrologically, and is rarely unaltered by humans. Blanket peat on top of the ridge is of similar age.

Geological Summary:

High, domed upland ridge with unusual glacial features and deep karstic cavities.

Bedrock Age: Lower/Upper Carboniferous (Namurian)

Location: North Leitrim

Lon: 54.329398

Lat: -8.089117

The entrance to Polldough, with a vertical drop of 20 m to the cave entrance.

Pockmarked western flank of Dough Mountain with springs feeding streams which then sink again into enclosed

Gullies on the southeast side of Dough Mountain, viewed from the N16 east of Manorhamilton.

Benbo

Benbo is a steep-sided hill at the northwest end of the Ox Mountains. It affords spectacular views over much of northern Leitrim and neighbouring counties. Extensive bedrock exposures at the summit comprise folded paragneiss of the Precambrian Slishwood Division.

The paragneiss display bedding as well as a strong foliation, and contain numerous pods of dark metabasite as well as abundant veins of granite and granitic pegmatite. These veins cut the foliation and bedding of the paragneiss and therefore clearly post-date them.

Slishwood Division Precambrian rocks have been mapped in three areas: in the Lough Derg inlier in County Donegal, the Rosses Point inlier in County Sligo and in the northeast Ox Mountains.

The intense tectonic foliation in the paragneiss reflects a history of extreme high-pressure and high-temperature metamorphism and deformation. The gneiss was derived from original quartz-feldspar sediments deposited some time after 1,700 million years ago. Basic bodies derived from the mantle were emplaced during later deformation and are now preserved as the metabasite pods within the gneiss. The whole succession is interpreted as having been uplifted from the lower crust during the Grampian Orogeny, around 470 - 480 million years ago. The granite and pegmatite intrusions followed at around 455 million years ago.

This site contains excellent exposures of the Northeast Ox Mountains succession, part of the distinctive Slishwood Division, a Precambrian succession with a history of extreme metamorphism. The summit site affords excellent views over north Leitrim, including the Truskmore massif, Glenade valley and uplands around Lough Allen.

Geological Summary:

Metamorphic rocks with granite veins and metabasite pods.

Bedrock Age: Precambrian (Neoproterozoic)

Location: North Leitrim

Lon: 54.11912°

Lat: -7.92061°

Main outcrop area on eastern side of Benbo summit. Summit cairn visible to west.

Quartz-feldspar pegmatite vein cutting paragneiss on eastern side of summit.

Near circular outcrop of metabasite pod, wrapped by foliated paragneiss on eastern side of Benbo summit. (Wallet for scale).

County River Natural Bridge

The County River forms the boundary between counties Leitrim and Fermanagh. Natural bridges are relatively rare phenomena inland in Ireland and the County River Natural Bridge is an excellent example of this geological karst feature. Dissolution of the limestone bedrock led to the formation of an underground void or cave that formed part of an underground river channel. Continued dissolution followed by almost complete collapse of the walls and roof of the cave has resulted in the small remaining part of the roof forming a natural bridge over the river. In the immediate vicinity of the bridge near vertical limestone cliffs are the remains of the walls of the cave. The bridge is about 5 m wide and has a span of over 10 m. The bridge is the only natural crossing point of the County River between Lough Melvin and Lough Macnean. The rock is fine-grained limestone of the Knockmore Limestone Member, part of the Lower Carboniferous (Mississippian) Dartry Limestone Formation, and is the same formation that hosts the Marble Arch Caves near Enniskillen.

Geological Summary:

Natural archway in bedrock formed by dissolution of limestone.

Bedrock Age: Lower Carboniferous

Location: Northeast Leitrim

Lon: 54.36631°

Lat: -8.05158°

View downstream towards the natural bridge from the Leitrim side of the County River.

Thur Mountain

Thur Mountain is a domed, upland ridge approximately 8 km east of Manorhamilton. The mountain owes its elevation and form largely to the underlying bedrock. However, the bedrock is mostly entirely blanketed by thick Quaternary deposits, left during and since the Ice Age.

Leitrim is one of the few places in the world where upland ribbed moraines were formed by glacier ice, and they are particularly well expressed on the southern side of Thur Mountain; from Barrs West to Lacoon Townlands. The ridges are up to 1 km long, 300 m wide, and 15 m to 20 m high.

Excellent exposures into the bedrock are seen around the mountain flanks where stream gullies have cut through the Quaternary deposits, incising into the bedrock underneath. Bedrock is also visible on the crest of Thur Mountain, both naturally on the summit, and in a number of small quarries.

Geologically, the exposures are good representative sections of the stratigraphy of the Lough Allen area, and specifically the rocks of the Leitrim Group, which is Namurian (Lower/Upper Carboniferous) in age, around 320 million years old.

Stream gully on Thur Mountain.

Geological Summary:

Mountain with stream upland gullies, exposed sandstone, and rare ribbed moraines.

Bedrock Age: Lower/Upper Carboniferous (Namurian)

Location: Northeast Leitrim

Lon: 54.30953°

Lat: -8.03289°

Quarry in the Briscloonagh Sandstone Formation on Thur Mountain.

Upland ribbed moraines on the southern side of Thur Mountain.

O'Donnell's Rock

The O'Donnell's Rock site comprises the central section of a northwest-facing escarpment of limestone bedrock. This site is a good representative section of successive bedrock layers, from the Mullaghmore Sandstone Formation, through the Glencar Limestone Formation, to the Dartry Limestone Formation, all of Mississippian (Lower Carboniferous) age.

The site has a trackway through old broadleaf forestry, which climbs slowly along an escarpment, with a cliff rockface at the top. Bedrock exposures alongside the track and in small quarries and natural cliff faces, especially at the top of the cliff, exhibit a very good representation of the Glencar Limestone Formation, which is a dominant component of the bedrock in Leitrim's uplands.

Exposures of the underlying Mullaghmore Sandstone and Benbulben Shale Formations are quite poor in contrast, but the top of the plateau and an extension of the site to the south includes rocks of the overlying Dartry Limestone Formation, which is also a very significant part in Leitrim's upland karst landscapes.

Glencar Limestone exposure on the track above the woods heading up to O'Donnell's Rock, looking northeast.

Geological Summary:

An escarpment exposing fossiliferous limestone.

Bedrock Age: Lower Carboniferous

Location: North Central Leitrim

Lon: 54.26680°

Lat: -8.18449°

Bed of fossil debris or crushed fossil coral colony on the side of the track.

Glencar limestone exposures in the bank along track through the woods.

Corry Shore

Most of the bedrock stratigraphy mapped in County Leitrim is best seen in sections along hillsides rivers and stream gullies.. One exception is at Corry Shore on the northern shore of Lough Allen, where a 200 m long section is exposed that contributes to the overall understanding of the rock stratigraphy in the northwest region.

The rocks are part of the Mississippian (Lower Carboniferous) age Carraun Shale Formation (part of the Leitrim Group). There are five rock members within the Carraun Shale Formation. The lowest and oldest is the Derreens Limestone Member, and this is the rock type exposed at Corry Shore.

The 15 cm thick Carraun Shale Formation bed is an important paleoecological feature as it presents a condensed deposit with encrusting organisms, reworked fossils, and many animal burrows and trails. A condensed section occurs in the rock where clastic sedimentation rates are low during a marine transgression, resulting in preferential accumulation of the shells of fauna.

Geological Summary:

Fossiliferous shales on the shore of Lough Allen.

Bedrock Age: Lower Carboniferous

Location: Central Leitrim

Lon: 54.16345°

Lat: -8.08054°

Carraun Shale Formation at Corry Shore. A minor fault crosses the section in the middle distance.

Creevelea

Creevelea is the site of the most significant historical iron works in Leitrim. It was originally established in the early 17th century when charcoal made from local forests was used to fuel the smelter. The ore came from large iron nodules that are common within the Namurian shale beds around Lough Allen. At Creevelea, the Dergvone Shale Formation shales include nodules of siderite (an iron carbonate mineral) that can be up to 60 cm in diameter. These nodules are hard but readily become loose from their host shales and can then be found in streambeds. They were scavenged as iron ores from historical times, with iron working in the district dating back to the 16th century at least. The rapid disappearance of forests in Ireland by the 18th century and with them the source of charcoal was offset by the discovery of coal near Arigna. This provided a new fuel source and by the mid-19th century the iron works at Creevelea was making good profits. However, the works were abandoned by 1872 as cheaper imports from Britain undermined their profitability.

Geological Summary:

Iron works that sourced iron from shales beds around Lough Allen.

Bedrock Age: Lower/Upper Carboniferous (Namurian)

Location: Central Leitrim

Lon: 54.21221°

Lat: -8.14086°

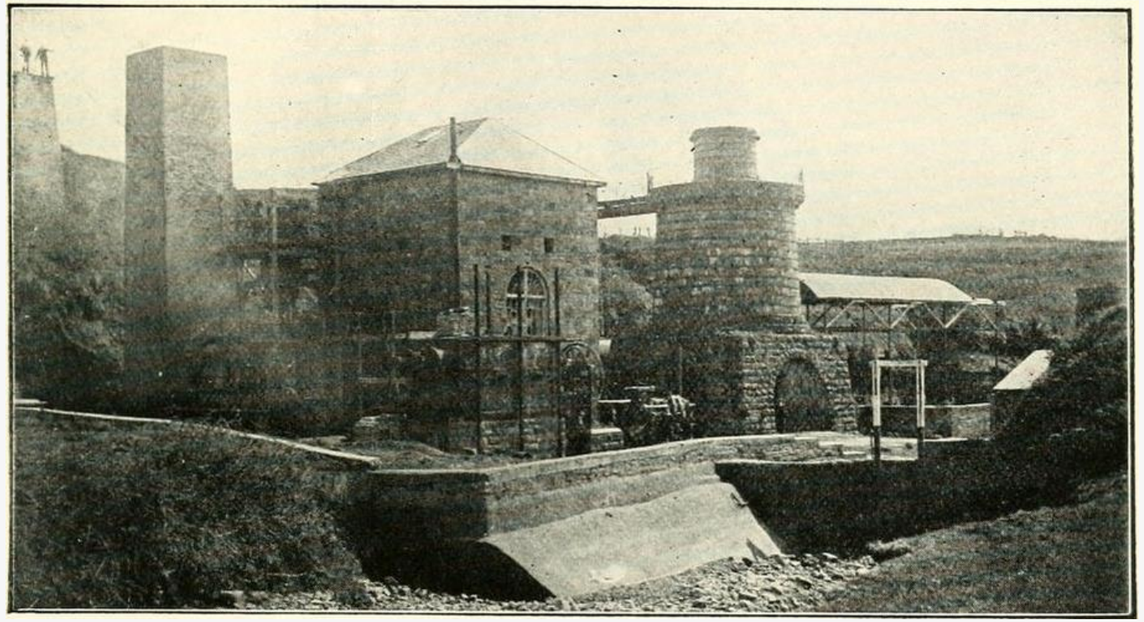
The blast furnace at Creevelea.

As the photograph of the site in 1905 shows, Creevelea developed into a relatively large-scale operation before its closure. Most of the buildings no longer stand, with some demolished and the stone reportedly taken for road-making. The large blast furnace remains as the focal point of the site. The remnant walls of the engine house can be seen beside the furnace while sluice and weir type structures survive in the river channel.

Creevelea is an important part of Leitrim's geological and industrial heritage. The blast furnace is an iconic piece of industrial heritage and it is tied into the landscape and the geological resources that fuelled the iron smelting industry in the district. While the furnace is still substantially intact the growth of trees and vegetation on top and within the mortar will inevitably lead to further deterioration of the structure. The site is private land and visiting is not possible without permission.

Remnants of the engine house at Creevelea.

Creevelea Iron Works 1905.
(Image: The Journal of the Royal Society of Antiquaries of Ireland, 1906)



Coal and Iron in Leitrim - A History

Sliabh an Iarainn ("Mountain of iron") draws its name from the many iron nodules that occur 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 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.

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, in nearby Co. Roscommon. Sandstone and limestone were readily

Coal seam outcrop (beside hammer) below thick sandstone bed at Bencroy.

An iron carbonate nodule in the river bank.

available locally, and there was a persistent belief in the "inexhaustible" nature and the good quality of the iron ore.

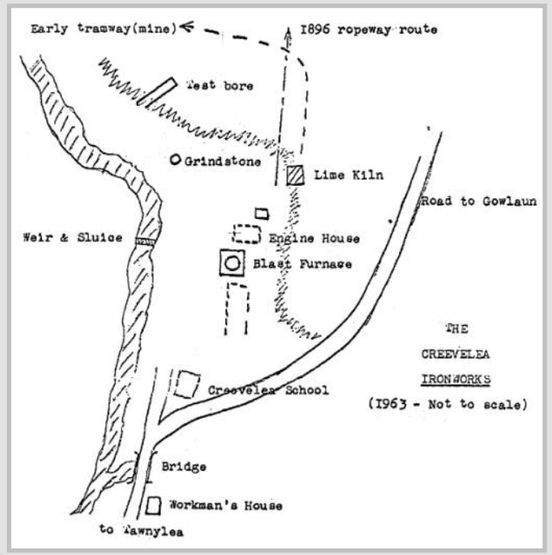
However, several key factors stood in the way of the region becoming the cockpit of an Irish industrial revolution though. Firstly, the remoteness of the area from any potential markets was probably the principal factor inhibiting development of the iron and coal industry in Leitrim and neighbouring 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 producing good-quality iron and periodically making good profits, the works 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 at 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 "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 ESB opened a coal-fired power station at Arigna. 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.



Creevelea Iron Works map. (Geological Survey of Ireland Report 1963).

Close-up of Eagle's Rock, looking south from roadway that leads to summit walking route.

Stony River

The Stony River site comprises an almost 2 km-long river valley on the western flank of Sliabh an Iarainn. The valley is gorge-like in places, with extensive high cliff exposures. These cliffs constitute a near-continuous exposure of the stratigraphic sequence from the Dergvone Shale Formation to the top of the Gowlaun Shale Formation, just below the overlying Lackagh Sandstone Formation.

Excellent exposures of near-horizontally bedded marine shales contain abundant fossils. These fossils have provided an unbroken sequence of mostly goniatite and lamellibranch fauna. A study in the early 1960s described the fossils along the river section and revealed they were of Namurian (Lower/ Upper Carboniferous) age, demonstrating a precise correlation of the strata with beds of the same age in Ireland, Europe and North America. Fossils of Namurian age are also found within the Bencroy Shale Formation on the summit of Sliabh an Iarainn. The entire coal-bearing sequence in the Connacht Coalfield was shown to be Namurian in age and stratigraphically older than the Lower Coal Measures in England, with which the upper coal seams had previously been correlated. The unbroken fossil sequence that forms the basis for this stratigraphic correlation within and outside Ireland is of considerable significance at both national and European level.

Examples of the fossils are housed in the National Museum of Ireland. Apart from the fossil record, the site provides a 78 m thick section through the Gowlaun Shale Formation that has been cited as the type section for this formation. Both the Dergvone and Gowlaun Shale Formations in this site contain abundant iron nodules. These nodules were extracted from the stream bed in the 18th and 19th centuries and carted to smelting works in the region, notably at Drumshanbo.

Geological Summary:

A two-kilometer long gorge-like river valley, with large cliff.

Bedrock Age: Lower/Upper Carboniferous (Namurian)

Location: Central Leitrim

Lon: 54.11196°

Lat: -7.98929°

Stony River valley viewed looking southeast.

Large iron-rich nodule in shale at base of the cliff bank fossil locality.

Fossil locality in cliff bank on northern side of the Stony River.

Bencroy

The summit of Bencroy is at a elevation height of 500 m above sea level, on the eastern flank of Sliabh an Iarainn, and was the most significant coal mining site in the Connacht Coalfield east of Lough Allen. The coal in this part of the coalfield has historically been poorly exploited, probably because of the remoteness of the area from towns and villages, and latterly from the power station at Arigna.

Modern coal mining on the site appears to have begun around 1930, when Coll and Gannon began exploiting the coal seam on the northern part of the site. The seam was mined via adits running northwest from the roadside. One of these, Coll's adit, is still visible above the recently-installed picnic area beside the road. Later mining to the southwest became the site of the Aghacashel colliery, operated by the Wynne brothers in the 1980s. This colliery produced around 100-150 tonnes of coal per week, almost all of it supplied to the ESB power station at Arigna.

Geological Summary:

Former coal mine site on steep mountainside heath.

Bedrock Age: Lower/Upper Carboniferous (Namurian).

Location: Central Leitrim

Lon: 54.11892°

Lat: -7.91903°

View southwest at Aghacashel colliery open cast; coal-rich waste on left.

A plaque erected in 2015 beside the road at the former entrance to the colliery marks the cessation in 1990 of mining at Bencroy and within the Connacht Coalfield as a whole.

Today there are substantial, partially grassed waste heaps on the steep mountain slopes above the adits on the northern part of the site. The remains of an old opencast operation on the site of the Aghacashel colliery, where coal was extracted from the outcropping seam, can also be seen. A thin seam of coal, which underlies the main seam exploited by these collieries, is visible beside the upper of the two paths that run southwest from the road. The lower path leads to a screening plant dating from the 1930s or 1940s. Beside it thick sandstone beds of the Namurian Lackagh Sandstone Formation display large-scale cross-bedding. This cross-bedding is typical of these sandstones, reflecting their formation in a delta environment.

Screening plant with cross-bedded sandstone strata on the right.

Grassed-over waste heaps on hillside beside roadside car park and picnic area.

Lough Rinn Drumlins

The hills around Lough Rinn form part of a small, discrete field of drumlins, south and southeast of Mohill Village. The drumlin field covers an area of 24 km^2 and includes approximately 20 drumlin features.

The drumlins are made up of glacial 'till' subsoil, which overlies bedrock which is mainly of Lower Carboniferous limestone. The drumlin features themselves are Quaternary in age, having been deposited at the base of the ice sheet that moved north-northwest to south-southeast across this part of Ireland during the maximum period of the last Ice Age.

The drumlin field is not only unusual in its small size and 'discreteness', but is curious in that the drumlins are spindle-shaped i.e. they are long and narrow, circular in the middle, and have tapering ends. The features are generally 500 m to 1 km long and 300 m to 400 m or so wide. They reach a maximum height of about 30 m, but are typically 20 m or so high. This is an excellent site in terms of macro-scale Quaternary subglacial geomorphology.

View across drumlins flanking Lough Rinn from Tulcon.

Geological Summary:

A small field of drumlins surrounding Lough Rinn, exhibiting a 'basket-of-eggs' landscape.

Landscape Feature Age: Quaternary.

Location: South Leitrim

Lon: 53.89260°

Lat: -7.84612°

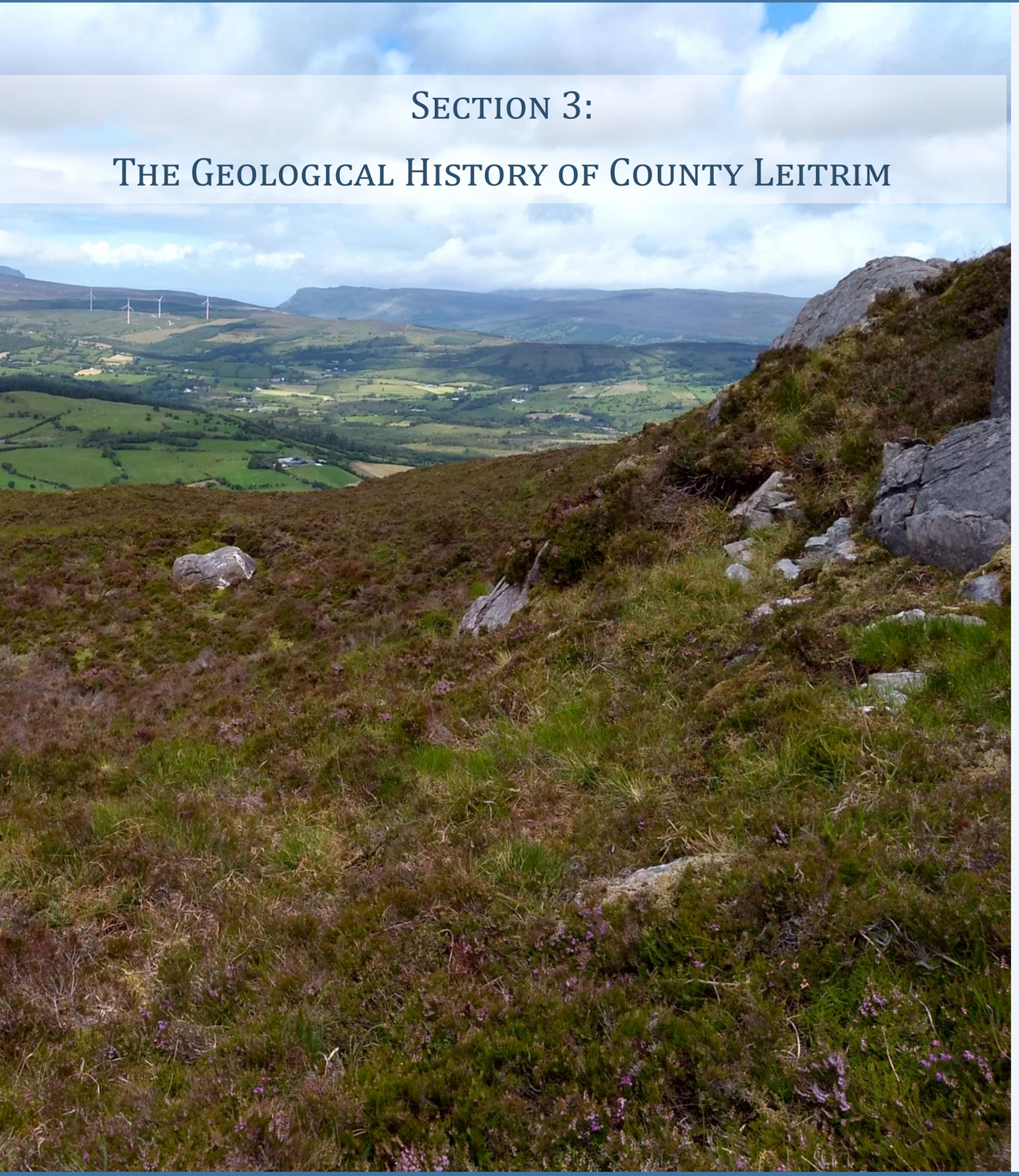
Drumlins on the northwestern side of Lough Rinn.

Rush-dominated drumlin in Clooncoe.

Lough Rinn.

Section 3:

The Geological History of County Leitrim



The Oldest Rocks in Leitrim

The oldest geological terrain in Leitrim is in the northwest of the county, stretching from Manorhamilton southwest to Dromahair. This band of metamorphic and igneous rock stands proud amid a surrounding region of younger Carboniferous sedimentary rock. Extending southwest from Manorhamilton as far as Slieve Gamph in County Sligo, it is known as the Slishwood Division, the oldest rocks in County Leitrim.

Geologists agree that the Slishwood Division is Precambrian in age, older than 541 million years ago. The term Precambrian is used to refer to all parts of Earth's history before the Cambrian period, which began 541 million years ago. The beginning of the Cambrian period is a major milestone in Earth history because it was marked by a burst of evolution (Cambrian Explosion) that saw the emergence of a huge diversity of lifeforms, and the appearance of animal groups still in existence today.

If we consider that the Earth was formed 4,600 million years ago, then Precambrian time spans over 4 billion years. This represents 88% of total Earth history. Geologists have organised the Precambrian into three formal units, called Eons, which are, from the oldest to youngest: the Hadean, the Archean, and the Proterozoic (from Greek, meaning 'earlier life'). Only rocks from the Proterozoic Eon are found in Ireland. The Proterozoic Eon extends from 2,500 million years ago to the 541 million years ago. The oldest rocks in Ireland, which are found on the Mullet Peninsula, County Mayo, are dated at 1,750 million (1.75 billion) years old.

Although the Slishwood Division in County Leitrim is considered to be Precambrian in age, geologists have yet to agree on a precise age for these rocks, which

Granite vein cutting paragneiss foliation on Benbo.

originated as sedimentary rocks and were later metamorphosed. Some geologists suggest the sediments were deposited 700 million years ago, whilst others push the age back a further one billion years as far as 1,700 million years ago. Either way, the oldest rocks in County Leitrim have their origins in a time long before the emergence of plant and animal lifeforms on land.

To appreciate the origins of the Slishwood Division, we must consider that the Earth's oceans and continents are in constant, albeit very slow, movement and that, 1,000 million years ago, the oceans and continents were organised quiet differently from today. During late Precambrian times, present-day northwest Ireland was separated from southeast Ireland by a vast ocean called the Iapetus Ocean. Northwest Ireland was situated on the edge of a great continent known as Laurentia. Southeast Ireland was part of a microcontinent called Avalonia.

The Slishwood Division in Leitrim began as sediments deposited on the margin of Laurentia. The Iapetus

Slishwood Division outcrops on the summit of Benbo.

Ocean started to close roughly 500 million years ago, eventually bringing the two continents of Laurentia and Avalonia closer together, obliterating or sandwiching much of the ocean floor and volcanic islands in between. The whole event involved immeasurably powerful tectonic events such as crustal collisions, volcanism, and mountain-building and folding. It lasted for 100 million years before quietening down around 400 million years at the beginning of the Devonian Period.

With the closure of the Iapetus ocean, the Slishwood Division rocks were buried to a depth of over 45 km below the surface of the Earth. The rocks were repeatedly folded and metamorphosed deep within the Earth's crust. The metamorphic rocks that formed, called gneiss, have a banded and streaky texture that partly reflects their origin as layered sedimentary rocks. Gneiss is the characteristic rock of the Slishwood Division and is exposed in places such as Benbo and in the hummocky terrain north of Dromahair.

At the southernmost part of County Leitrim, buried beneath drumlins, are the remnants of the former floor of the Iapetus Ocean and the roots of a long-vanished mountain chain. Around the area of Carrigallen (from Carraig Álainn, Irish for 'Beautiful Rock'), and southeast of Drumsna, bedrock comprises Ordovician marine sedimentary rocks. These rocks form the southwestern end of the Longford-Down inlier and are related to rocks found as far away as the Southern Uplands in Scotland. Structurally, these rocks are part of the Northern Belt of the Longford-Down inlier, which is the most northerly of three main belts of ocean floor rocks that have been steeply tilted and stacked together on a very large scale.

Most of the Ordovician rocks in Leitrim are part of the Finnalaghta Formation (458-448 million years old) greywacke with minor black shales. The Ordovician rocks in County Leitrim form part of the story of the closure of the Iapetus Ocean that occurred during the Ordovician and Silurian Periods and the events that led to joining of northwestern and southeastern parts of Ireland.

Ordovician greywacke rocks at Finnalaghta Quarry.

Lower Carboniferous - Sea and Coast

The Curlew Mountains southwest of Leitrim comprise sedimentary and volcanic rocks that are among the last vestiges in the northwest of Ireland of the Devonian landmass that extended across Ireland around 350 million years ago. At the beginning of the Carboniferous period, the shoreline of this landmass lay close to today's south coast of Ireland. Sea levels began to rise and the coastline moved gradually northwards over a period of millions of years. In the area of Leitrim erosion of the land to the north led to deposition of sandy sediments in rivers and streams while limestones and shales were deposited in the sea.

Limestone at Carrikbaun Quarry.

These early limestones included marine mudmounds such as those exposed in Carrickbaun Quarry near Drumshanbo. Marine mudmounds are accumulations of sediment composed of fragments of marine life, similar to a coral reef system. These reef systems are very common in the Carboniferous of Ireland. At Carrickbaun, the mudbank limestone is Arundian in age, stratigraphically halfway between the Waulsortian and the Asbian banks. Carrickbaun is possibly the sole example remaining in Ireland of a quarry with accessible exposures of this rare Arundian Mudbank facies.

Fault movements caused substantial uplift of the land to the north and as a consequence the sea around Leitrim was inundated by sand and mud deposited by large rivers. Along the shoreline thick deposits of sand accumulated at the mouths of rivers to form deltas that extended southwards from the coast. These are represented today by the thick sandstone beds of the Mullaghmore Sandstone Formation, well exposed along Leitrim's coast. The formation comprises cyclic units of siltstones and shales topped by thick sandstones deposited in river channels. Eventually, delta formation declined and limestone and mudstone deposition resumed with rising sea levels. The latter include the shale of the Benbulben Shale Formation. As the sea deepened, pure limestones of the Glencar Limestone Formation accumulated. The O'Donnell's Rock site provides a very good representation of the fossiliferous Glencar Limestone Formation.

As the sea deepened further, the Glencar Limestone Formation was succeeded by the Dartry Limestone

Glencar Limestone Formation at O'Donnell's Rock.

Formation. Fine debris accumulated in deep seas where conditions on the seafloor were largely unfavourable to life. In consequence the great thicknesses of fine-grained limestones that form the

Glencar Limestone Formation at O'Donnell's Rock.

Dartry Limestone Formation contain few fossils. Under the deep-water conditions, nodules and bands of chert, a hard flintlike rock, formed from sponges that accumulated on the seafloor. Above these deep-water limestone accumulations reef systems formed, preserved today as fossil-rich mudmounds within the Dartry Limestone Formation. Both the Darty Limestone and the Glencar Limestone Formations are best exposed in Leitrim in the high limestone cliffs along the side of Glenade.

Although the Dartry Limestone Formation was largely formed in relatively deep waters, some parts of Leitrim were under shallower seas and saw the accumulation of more typical bioclastic limestones, today preserved as members of the Bricklieve Limestone Formation. This formation is best exposed in the Bricklieve Mountains in County Sligo but in County Leitrim there is a fine exposure in Keshcarrigan Quarry. Some steeply dipping limestone beds, as well as intensely folded and almost vertical beds of limestone, are visible in the quarry. The limestone is very pure and highly fossiliferous, with corals and brachiopods commonly observed. The Dartry Limestone and Bricklieve Limestone Formations represent the peak of Carboniferous limestone formation in the northwest of Ireland, when the tropical seas reached their maximum depth and extent.

Following the deposition of the Dartry Limestone and Bricklieve Formations, uplift occurred. Subsequent erosion of the uplifted landmass led to an influx of clastic sediments, mud and sand, that comprise a rock succession known as the Leitrim Group. This distinctive Carboniferous sequence occurs widely in the northern part of Ireland but it is best exposed in Leitrim and is known as the Leitrim Group.

The first unit in the Leitrim Group is the Meenymore Formation, comprising laminated dolomites, shales and some evaporite layers, and include features such as desiccation cracks and algal laminites that indicate shallow water deposition in a sabkha-type environment (a coastal mudflat or salt flat in an arid climate). The Meenymore Formation and the younger Bellavalley Shale Formation are exposed in Aghagrania stream northeast of Drumshanbo.

Further north the shales of the Meenymore Formation were followed by sandstones of the Glenade Sandstone Formation, best seen on Truskmore and Aroo Mountain. The Carraun Shale Formation is the final member of the Leitrim Group that is dated as Lower Carboniferous. It is well exposed at Corry Shore on the northern shore of Lough Allen.

Deltas and Namurian Times

The remainder of the Carboniferous rocks in Leitrim have been dated as Namurian in age, a period that spans the Lower Carboniferous (Mississippian) and Upper Carboniferous (Pennsylvanian) boundary. The Namurian strata comprise mainly shales, typically formed in deeper water than those of the preceding Leitrim Group rocks deposited in earlier Carboniferous times.

These marine shales contain abundant fossils, best known in the Dergvone and Gowlaun Shale Formations. The deeper water also favoured the formation of iron nodules, which are abundant within the shale beds. The marine sedimentation was interrupted by two periods of delta formation that left behind the Briscloonagh and Lackagh Sandstone Formations. The Namurian sequences have had a profound impact on the landscape and on the social and economic history of Leitrim. The iron nodules in the shale beds provided the raw material for a local iron industry from the 17th century onwards. The

Namurian bedrock exposures along Meenymore stream section.

Lackagh Sandstone Formation contains hard sandstone beds that have resisted erosion to form the distinctive flat-topped hills around Lough Allen. It also contains several coal seams that make up the Connacht Coalfield, one of three significant coalfields in Ireland.

At Larkfield and Meenymore, an almost complete section through the Namurian Leitrim Group is exposed in stream sections. The stratigraphy starts with the Dergvone Shale Formation followed by the Briscloonagh Sandstone Formation - the type section for this formation is in the Larkfield stream, where a section of 59 m depth is exposed. Above this the Gowlaun Shale Formation is exposed and, on the plateau above the steep stream gorges, the Lackagh Sandstone Formation is present but poorly exposed.

The Stony River site on the western slopes of Sliabh an Iarainn also provides a section through the Leitrim Group, from the Lower Carboniferous Carraun Shale Formation to the Bencroy Shale Formation. The Stony River is one of the most significant Namurian sites in Leitrim because it was here that the Namurian age of this part of the Leitrim Group was first established. A study of the fossils in the shales revealed a Namurian age and demonstrated a precise correlation with beds of the same age in Ireland, Europe and North America. A Namurian age was also demonstrated for fauna within the Bencroy Shale Formation that overlies the Lackagh Sandstone Formation on the summit of Sliabh an Iarainn. The Lackagh Sandstone Formation includes the entire coal-bearing sequences in the Connacht Coalfield. Therefore the Namurian Connacht coal deposits are stratigraphically older than their "equivalents" in England and elsewhere in Ireland, in the Slieve Ardagh and Leinster Coalfields.

The Glacial Legacy of County Leitrim

In describing the rocks of County Leitrim, the 'soft' rocks are often overlooked, which is the material left by the ice sheets of the Quaternary Period of the Earth's history, in the last two million years or so. These superficial deposits overlying the bedrock provide a spectacular record of ice activity as well as literally forming the ground beneath our feet across most of County Leitrim.

During the Tertiary Period (about 50 million years ago) Earth's climate began to cool down slowly from the tropical temperatures of the time, and by two million years ago ice had developed at the poles. Since then, every 100,000 years or so, the climate has cooled markedly for a period of around 30,000 to 50,000 years. During these long periods the polar ice sheets have grown to cover much of the mid-latitudes, shrinking again as temperatures rise. This has probably happened in Ireland several times, but so destructive are the ice sheets when they arrive that they completely remould the landscape and obliterate pretty much all evidence of the previous glaciation.

The last Ice Age in Ireland occurred between 73,000 and 10,000 years ago and was responsible for creating many of the physical features we see today. These were fashioned by the erosive power of ice hundreds of metres thick moving across the land, by the vast amounts of rock and sediment left behind when the ice sheets retreated, and by the action of flowing water as the glaciers melted.

As the glacier ice moves out towards its margins, large amounts of loose rock and sediment become attached to its base by freezing onto it and may become incorporated into the lower layers of the ice sheet. This makes the base of the glacier highly abrasive and

Streamlined bedrock on top of Truskmore; the form of the summit has been moulded by ice which has flowed across the ridge.

'Moundy' drumlin landscape near Rossinver, north Leitrim.

it starts to scour away the land underneath, picking up eroded material as it moves outwards and eventually depositing it at, or close to, the ice sheet margin. When the ice melts, the transported material is left as one of the many piles of debris (landforms) produced by glacial ice.

Many stones within glacial sediments show striations – scratches etched onto the rock surface during transportation by the ice. Rock fragments, ranging from pebbles to huge boulders, may be carried far away from their source and deposited either at the surface or incorporated into the subsurface. These are known as erratics.

At the maximum extent of the last Ice Age, Leitrim was completely buried by ice. We know this because the summit of Truskmore, the highest point in the county, shows polished rock forms (roche moutonnées) which have been streamlined by the ice passing over them. As well as this, erratic blocks of sandstone have been dropped across the top of the summit ridge by the ice sheet. The only way these boulders could have been transported to the top was by an ice sheet higher than the summit.

Where sediment is deposited by the ice at its base, great mounds of debris may lie atop the bedrock. Leitrim has particularly large volumes of glacial sediment left as rounded hills, or drumlins, at the base of the ice. These hills are up to 30 metres high, usually several hundred metres wide and up to a kilometre long. As they are formed underneath the ice they are streamlined along the direction of ice flow, and from examination of the orientation of drumlins in north Leitrim the flow of ice from southeast to northwest is clearly seen, while in the south of the county ice flowed from northwest to southeast. Other features formed under the flowing ice include ribbed moraines, which are corrugated features deposited either transverse to or perpendicular to the flow. Ribbed moraines are common on the lowlands of Leitrim, as well on parts of the uplands, something that is unique in a global sense.

Carrickaport Lough near Drumshanbo, impounded by drumlins.

The drumlins and ribbed moraines are comprised of material called till, or 'boulder clay'. Till is unsorted, unbedded, mixed-up subsoil material consisting of stones, sand, silt and clay. The poorly sorted nature of the material reflects its bulldozing and grinding at the base of the ice sheet. Tills are generally quite consolidated and tightly packed, meaning that when digging a trench the subsoil material is usually much stiffer than the topsoil. Till is the most common glacial sediment in Leitrim, covering over 60% of it, which means that most of the county's back gardens are underlain by till subsoil.

Discrete drumlin at Mohill. Ice flow was from left to right.

Many of Leitrim's lakes owe their origin to glacial action. Although classic U-shaped valleys (caused by glacial erosion) are only present in the north, for example Glencar and Glenade, long, linear depressions have been gouged out of the limestone in the rest of the northern half of the county, and contain lakes such as Lough Macnean Upper and Lough Melvin. Glenade Lough, Carrigeencor Lough and Belhavel Lough are a result of ice erosion and deposition acting together. Drumlins confine most of the other lakes in the county, such as Adoon Lough, Lough Rinn, Seltan Lough and Drumcollop Lough, and the many smaller lakes interspersed with the drumlin landforms.

During glaciation the ice worked on the landscape, ever so slowly forming the features just described. Ice sheets may move only a few millimetres per year, meaning the scraping and etching of rock crags, or the transport of material within the ice, may go on for centuries and millennia, at a pace almost imperceptible. At the end of an ice age however, when ice melt and deglaciation occur, processes are much speedier and often spectacular, with glacial meltwater being released rapidly and in huge volumes.

Most of Leitrim's subsoils, therefore, owe their genesis in one way or another to the action or melting of ice. Since the end of the last Ice Age 10,000 years ago, the action of modern rivers and the infilling of lakes, along with the formation of peat bogs and development of beaches, have been the main natural processes affecting both Leitrim's landscape and geology.

Leitrim's Postglacial Geology and Soils

Following the last Ice Age, the Holocene Epoch ushered in **a** warmer climate that effected a large change in the environment. The modern river systems of Leitrim emerged during this recent period of geological history and were largely shaped by the pre-existing glacial landscape as rainwater runoff exploited the lowest corridors available *i.e*. the glacial meltwater channels and outwash river courses. The floors of these valleys now take the form of modern alluvial floodplains. The Shannon River, for example, has a wide floodplain along much of its course, resulting from the deposition of alluvium as the river has meandered across its valley since the Ice Age.

The change in climatic conditions also resulted in the growth of peat bogs. Raised bogs developed in many both small and extensive lake basins across Leitrim, between the ribbed moraines and drumlins, and spreading over time to the surrounding land. These occur extensively in the west of the county and many have been exploited for centuries by locals for turf fuel, notably the wide expanses between Dromod and Mohill. Large blanket bogs occur across the high ridge plateaux in the northern portion of the county also, across Slieve Anierin and Bencroy, Boleybrack, Curry, Thur, Dough and Arroo Mountains, and Truskmore. Such mountain blanket bogs occur on relatively flat terrain in the mountain ranges above 200m altitude in Ireland, where rainfall is high and evaporation is low. Blanket bogs are rain fed and their peat is acidic. |They literally blanket the mountain sides on which they form. In Leitrim, many of the blanket bogs have also been cut for turf fuel for centuries.

The modern coastline began to develop after the postglacial sea-level stabilised at its present height more than 5,000 years ago. Though Leitrim's coastline is quite short, that period still saw the formation of the beach at Bunduff, while blown sand has built up into

The wide Shannon floodplain at Tully, outside Carrick on Shannon.

sand dunes at Lisgool and Knockbrack. Much of the rest of the coastline comprises a platform cut by waves along the shallow-dipping strata, by the sea when the water was relatively high compared to now, sometime in the Quaternary period.

Since the end of the Ice Age, modern-day soils have been continually forming across the Leitrim landscape. The soil is the uppermost layer of the Earth's surface which is capable of supporting life, and is usually no more than 1.4m deep. Most soils in Leitrim are formed from the dominant glacial or postglacial deposits, rather than from underlying solid rock. They generally reflect the varied origin, texture and chemical reaction of these deposits. Irish soils can be grouped into major classes on the basis of their soil profile. Soils of the same type behave similarly and are strongly associated with relief or topographic situation. These major classes are referred to as Great Soil Groups and the most common found in Leitrim are gleys, blanket peats, brown earths, grey brown podzolics, basin peats and lithosols.

Gleys are soils with impeded drainage and develop under conditions of permanent or intermittent waterlogging. Gleys are usually not suitable for cultivation unless artificially drained, with poor conditions retarding growth in the spring. They are frequently used for pasture production. Gleys are the most common mineral soil type in Ireland, and in Leitrim cover much of the area of the county. Thus, rush-dominated pasture is relatively common, and the soils need intensive drainage schemes to make them workable for agricultural purposes.

Blanket peats on the uplands of Leitrim take the form of peat expanses covering high upland plateaux. Blanket peat soils are waterlogged for the majority of the year.

Poorly drained gley soil with mottled orange and grey colours, due to saturation, at Corglass, Carrigallen.

Areas of cutover blanket peat on Conwal Mountain.

Brown earths are relatively mature mineral soils possessing a rather uniform profile, with little differentiation into horizons. The brown earths usually possess loamy textures with desirable structure and drainage characteristics. With proper management, they can support high quality grassland and are also ideally suitable for a wide range of forest-tree species. Brown earths are common in the well- drained areas around Fenagh in Leitrim.

Grey-brown podzolics are inherently associated with leaching of clay minerals through the soil during their development. These soils usually form over limestone-dominated subsoil, typically glacial till, and are usually moderately acidic to neutral in reaction. They are good all-purpose soils under Irish climatic conditions and are used for the production of a wide range of crops. Grey-brown podzolics are common around Keshcarrigan, where limestone bedrock generally underlies limestone subsoils, overlain in turn by limestone-dominated, grey-brown podzolic topsoils.

Basin peats around the bogs of Leitrim take the form of peat-filled hollows or depressions in which the surface of the peat rises from the margins to the centre forming a dome, thus being "raised". Peat formation began almost immediately following the last glaciation about 10,000 years ago. Midland basin bogs tend to be deep, with up to 10m depth of peat recorded in places. Basin peat soils have a more limited use-range unless they have been harvested for peat and cut away, and subsequently reclaimed.

Lithosols have poorly developed, rocky horizons and are therefore considered immature. Only a shallow brown sod overlies a bedrock, gravelly horizon. They are formed in area where bedrock is close to the surface. They are therefore extensive on the uplands of Leitrim adjacent to where bedrock crops out at the surface, and where topography has not allowed peat soils to cover them.

Deep, well drained grey-brown podzolic soil at Kilclare, Keshcarrigan.

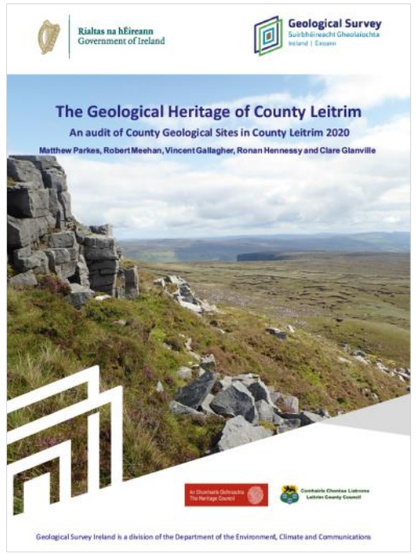
Section 4:

County Leitrim Geological Heritage Site Audit

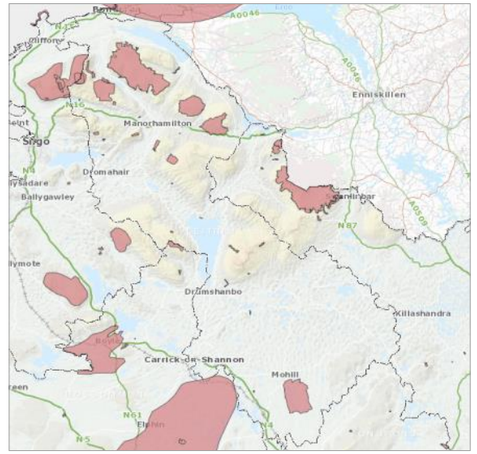
Limestone strata in rock pinnacle in Glenade valley.

County Leitrim Geological Heritage Site Audit

The Audit of Geological Heritage Sites in County Leitrim was carried out in 2020 as an action of the County Leitrim Heritage Plan 2020-2025. The Geological Heritage Sites Audit documents what is understood by the Geoheritage Programme of Geological Survey Ireland to be the most important geological sites in County Leitrim. The audit lists 33 sites and proposes them as County Geological Sites for inclusion within the Leitrim County Development Plan. The audit report is available on the Geoheritage Programme section of the Geological Survey Ireland website (www.gsi.ie).



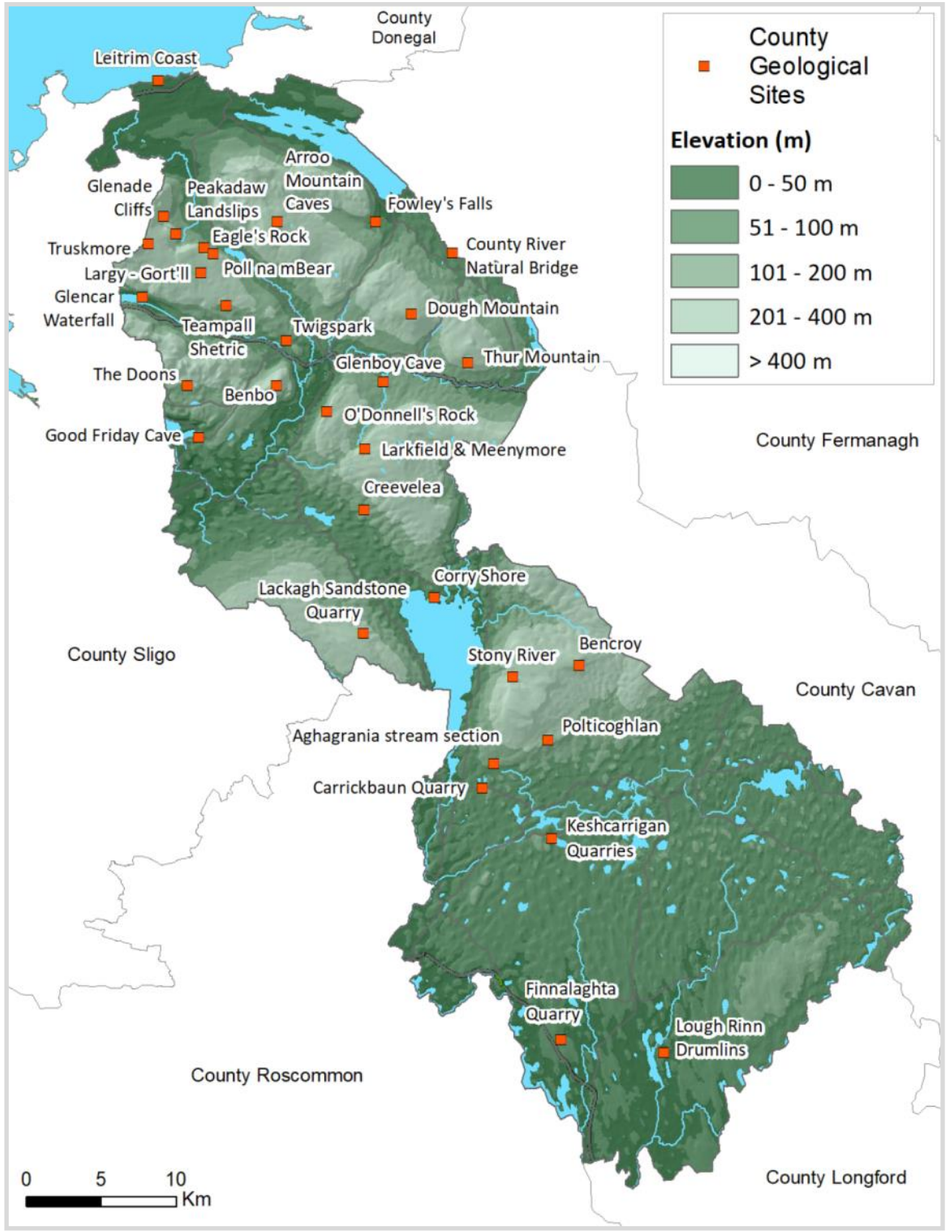
The Leitrim Geological Heritage Project was funded by the Heritage Council and Leitrim County Council and supported by the Geological Survey of Ireland. Some of the sites described in the report are considered to be of national importance as a best representative example of a particular geological formation or feature. 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. County Geological Sites do not receive statutory protection like Natural Heritage Areas (NHA) but receive an effective protection by being included for appropriate consideration ion in the planning system. The report included preliminary sections relating to geological heritage, summary geological history, geological maps, links to sources of further information relating to geology, geomorphology, hydrogeology among other sources. A three-page site report is available for each of the 33 County Geological Sites, providing a summary of the features of geological heritage interest, site photographs, and site location maps.



Geological Survey Ireland Online Mapping Viewer showing County Geological Sites.

The location of each County Geological Site is can be viewed on Geological Survey Ireland's online mapping viewer (www.gsi.ie) and are listed in the following table.

Map of County Geological Heritage Sites



Map of County Geological Sites in County Leitrim.

Geological Heritage Sites in County Leitrim

County Geology Site	Irish Geological Heritage (IGH) Code and Theme
Aghagrania Stream Section	IGH8 Lower Carboniferous
Arroo Mountain Caves	IGH1 Karst
Benbo	IGH5 Precambrian
Bencroy	IGH9 Upper Carboniferous and Permian
Carrickbaun Quarry	IGH8 Lower Carboniferous
Corry Shore	IGH3 Carboniferous-Pliocene Palaeontology
County River Natural Bridge	IGH1 Karst
Creevelea	IGH15 Economic Geology
Dough Mountain	IGH1 Karst
Eagle’s Rock	IGH7 Quaternary
Finnalaghta Quarry	IGH4 Cambrian-Silurian
Fowley’s Falls	IGH14 Fluvial/Lacustrine Geomorphology
Glenade Cliffs	IGH8 Lower Carboniferous
Glenboy Cave	IGH1 Karst
Glencar Waterfall	IGH7 Quaternary
Good Friday Cave	IGH1 Karst
Keshcarrigan Quarries	IGH8 Lower Carboniferous
Lackagh Sandstone Quarry	IGH9 Upper Carboniferous and Permian
Largy - Gorteenaguinnell	IGH1 Karst
Larkfield and Meenymore	IGH8 Lower Carboniferous
Leitrim Coast	IGH8 Lower Carboniferous
Lough Rinn Drumlins	IGH7 Quaternary
O’Donnell’s Rock	IGH8 Lower Carboniferous
Peakadaw landslips	IGH1 Karst
Poll na mBéar	IGH7 Quaternary
Polticoghlan	IGH1 Karst
Stony River	IGH9 Upper Carboniferous and Permian
Teampall Shetric	IGH1 Karst
The Doons	IGH1 Karst
Thur Mountain	IGH9 Upper Carboniferous and Permian
Truskmore	IGH7 Quaternary
Twigspark	IGH15 Economic Geology

County Geological Sites in County Leitrim.

Appendix

View across Glenade from the Peakadaw Landslips.

Glossary

Term	Definition
Asbian	Stage in the Mississippian (Lower Carboniferous) dated 337.5 To 333 Ma
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.
Alluvium	a term for unconsolidated clay, silt, sand and gravel, deposited by a body of running water.
Amphibolite	a metamorphic rock rich in the minerals amphibolite and plagioclase.
Basalt	a dark grey to black extrusive volcanic rock. It is finegrained due to rapid cooling of the extruded lava (preventing large crystal growth) at the Earth's surface.
Basic Rocks	rocks which contain a relatively low percentage of silica, e.g. basalt.
Basin	low areas in the Earth's crust, of tectonic origin, in which sediments have accumulated.
Bedding Plane	the contact between individual beds of rock.
Bedrock	a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
Bivalve	mollusc with two hinged shells of similar shape and size
Blanket Peat	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.
Brachiopods	a marine invertebrate of the phylum Brachiopoda - a type of shellfish. Ranging from Lower Cambrian to present.
Calcarenite	limestone comprising sand-sized grains of either quartz or calcareous clasts in a calcareous matrix.
Calcareous	containing calcium carbonate.
Calcite	a pale mineral composed of calcium carbonate, which reacts with dilute hydrochloric acid.
Caledonian	relates to Caledonian orogeny that took place towards the end of the Lower Palaeozoic era, affecting Ireland, Scotland, Scandinavia and Greenland
Carbonate	a rock (or mineral), most commonly limestone (calcite) and dolomite.
Chert	a sedimentary rock comprising of very fine-grained quartz.
Clast	an individual constituent, grain or fragment of a sediment or rock, usually produced by mechanical weathering (disintegration) of a larger rock mass.
Cleavage	finely spaced planar parting caused by compressive deformation of rocks; a rock showing cleavage is said to be *cleaved*
Coal	a fossil fuel comprised primarily of carbon formed by the decomposition of plant matter in non-marine environments billions of years ago.
Conglomerate	coarse-grained sedimentary rock with more than 50% rounded clasts greater than 2mm in size.
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).
Cross-bedding	layering in sedimentary rocks at an inclined angle to bedding formed by current-ripples.
Crust	the outermost, solid, layer of the Earth.
Dalradian Supergroup	thick late-Precambrian (c. 900Ma) to mid-Cambrian (c. 550Ma) sequence of sediments, limestones and volcanic rocks in Ireland and Scotland
Deformation	physical alteration of rocks and minerals under conditions of high pressure, e.g. orogeny
Delta	a fan-shaped body of sediment situated at a river mouth, often extending beyond the coastline.

GLOSSARY (CONTINUED)

Term	Definition
Doline	circular/oval closed depression found in karst terrain.
Dolomite	calcium and magnesium-bearing carbonate mineral; also a rock, usually forming when magnesium replaces some of the calcium in limestone after burial.
Drumlin	a streamlined mound of glacial drift, rounded or elongated in the direction of the original flow of ice
Dyke	a tabular igneous intrusion that cuts across the bedding or foliation of the country rock.
Enclosed depression	regarded as the most common landforms of karst. Range in diameter from a few m to tens of km and in depth from a few cm to hundreds of m. The smallest of these features are termed dolines.
Erratic	a large rock fragment that has been transported, usually by ice, and deposited some distance from its source. Generally differs from underlying bedrock.
Escarpment	steep slope or cliff
Esker	an elongated ridge of stratified sand and gravel deposited in a subglacial channel by meltwaters.
Evaporite	a chemical sediment that forms in layers through the evaporation of seawater (or lakes) in arid climates.
Facies	the character of the rock derived from its original sedimentary environment and process of deposition
Fan	triangular deposit of sand and gravel deposited by a glacial stream, either under a lake or under air.
Fault	a fracture in rocks across which there has been some displacement or movement.
Fauna	collective term used to group all animal life.
Feldspar	the most abundant mineral in the earth's crust, composed of variable proportions of potassium, sodium and calcium in combination with silicon, aluminium and oxygen.
Floodplain	a flat or nearly flat land area adjacent to a stream or river that experiences occasional or periodic flooding.
Fluvial	pertaining to a river or stream.
Fold(ing)	flexure in layered rocks caused by compression.
Foliation	a finely spaced planar parting caused by compressive deformation of rocks.
Formation	a formal term for a sequence of related rock types differing significantly from adjacent sequences
Fossiliferous	pertaining to a rock with a high concentration of fossils.
Fossils	any remains, trace or imprint of a plant or animal that has been preserved in the Earth's crust since some past geological or prehistorical time.
Glaciofluvial	pertaining to the meltwater streams flowing from wasting glacier ice and the deposits and landforms produced by such streams.
Gneiss	coarse-grained, banded rock formed during high-grade metamorphism where light-coloured and dark-coloured bands are produced by separation of minerals into bands.
Granite	a coarsely crystalline intrusive igneous rock composed mostly of quartz and feldspar.
Greywacke	dark grey, poorly sorted sandstone with more than 15% clay content.
Gully	a deep valley created by running water eroding sharply into bedrock or subsoil
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

GLOSSARY (CONTINUED)

Term	Definition
Igneous	a rock or mineral that solidified from molten or partially molten material i.e. from a magma
Inlier	area of bedrock of a particular age surrounded by bedrock of younger age
Interglacial	the time interval between glacial stages, or pertaining to this time
Intrusive rock	an igneous rock emplaced within the Earth's crust, not extruded onto its surface like lava
Karren	minor solutional features developed on carbonate rocks
Karst	general term used for landscapes formed by weathering of soluble rocks, usually limestone, by surface water and/or groundwater
Knoll	a small hill or hillock sticking up from generally flat terrain
Lamellibranch	a bivalve mollusk
Laminated	finest example of stratification or bedding, typically exhibited by shales and fine-grained sandstones
Limestone	a sedimentary rock consisting of calcium carbonate ($CaCO_3$), primarily in the form of calcite
Lithology	the description of rocks on the basis of such characteristics as colour, composition and grain size
Mantle	the main part of the Earth between the crustal plates and the core
Massive	a rock or rock unit, such as a bed, with no obvious internal structure
Meltwater channel	a channel cut by glacial meltwater, either under, along or in front of an ice margin
Metabasite	metamorphosed basic igneous rock
Metamorphic	pertaining to the process of metamorphism or to its results i.e. a metamorphic rock
Moraine	any glacially formed accumulation of unconsolidated debris, in glaciated regions, such as during an ice age
Mudstone	a very fine grained sedimentary rock, containing quartz and clay minerals. Similar to shale, but not as easily split along the plane of bedding
Namurian	a stage in the regional stratigraphy of NE Europe dated c. 326 and 313 million years ago. Straddles the Mississippian (Lower Carboniferous) and Pennsylvanian (Upper Carboniferous) boundary
Ore	a mineral which is concentrated enough to be exploited by mining
Orogeny	the creation of a mountain belt by tectonic activity
Outcrop	part of a geologic formation or structure that appears at the surface of the Earth
Outwash Plain	an area of meltwater deposition produced at the leading edge of a glacier
Paragneiss	gneiss produced by metamorphism of original sedimentary rock
Pavement (limestone)	a bare plane surface of limestone, commonly divided into blocks (clints) by solutionally widened joints (grikes), and pitted by solution pans
Pegmatite	a very coarse-grained igneous rock, of granitic composition but including intermediate and basic varieties
Periglacial	cold but non-glacial climatic conditions. Environment located on the margin of glaciers

Glossary (continued)

Term	Definition
Platform	a continental area of relatively flat or gently sloping, mostly sedimentary strata, overlying a basement of consolidated igneous or metamorphic rocks
Quartz	the second most abundant mineral in the earth's crust, composed of silicon and oxygen (SiO_2)
Quartzite	a hard, metamorphosed sandstone, composed recrystallised quartz grains that are tightly interlocking
Ribbed moraine	a subglacially formed type of moraine landform
Sandstone	a fine to coarse sedimentary rock, deposited by water or wind, and composed of fragments of sand (quartz grains), cemented together by quartz or other minerals
Sandur (pl. Sandar)	a plain formed of glacial sediments deposited by meltwater outwash at the terminus of a glacier
Schist	a medium to coarse grained rock, formed by the metamorphism of a sedimentary mudstone by heat and pressure. The minerals are aligned in parallel layers giving the rock a fabric known as schistosity
Scree	loose debris or talus deposits comprising angular stones and boulders
Sedimentary	a rock formed by the deposition of sediment, or pertaining to the process of sedimentation.
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 mudstone, containing quartz and clay minerals, that splits easily along the plane of bedding.
Siltstone	a rock whose composition is intermediate between those of sandstone and shale
Sink	or swallow hole, the point where a stream passes underground
Slate	metamorphosed mudstone, i.e. a fine-grained rock produced under conditions of high pressure, characterized by a cleavage along which the rock splits easily
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
Swallow hole	the point where a stream passes underground, sinking below the ground surface
Till	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock as sand, silt or clay; also known as boulder clay
Transgression	an incursion of the sea over land area.
Tufa	formation associated with hard-water springs, where groundwater rich in calcium bicarbonate comes to the surface
Turbidite	deposit of a turbidity current
Turlough	a seasonal lake that fills and empties through springs and sinkholes.
U-shaped valley	a characteristic U-shape valley, with steep, straight sides and a flat bottom formed by glaciation
Volcanic Rock	any rock produced from volcanic material, e.g. ash, lava
Volcanism	the process by which magma and its associated gasses rise into the crust and are extruded onto the Earth's surface and into the atmosphere

Further Reading

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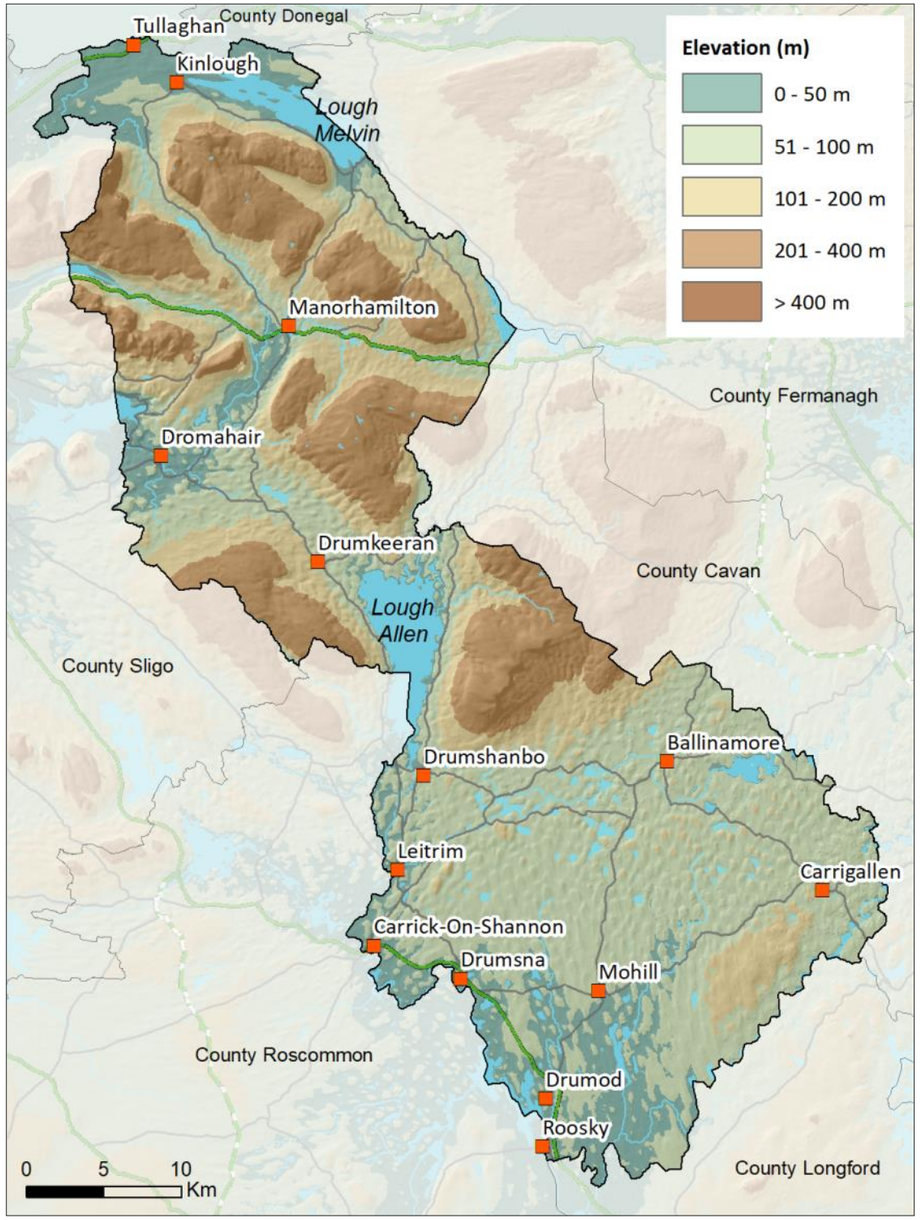
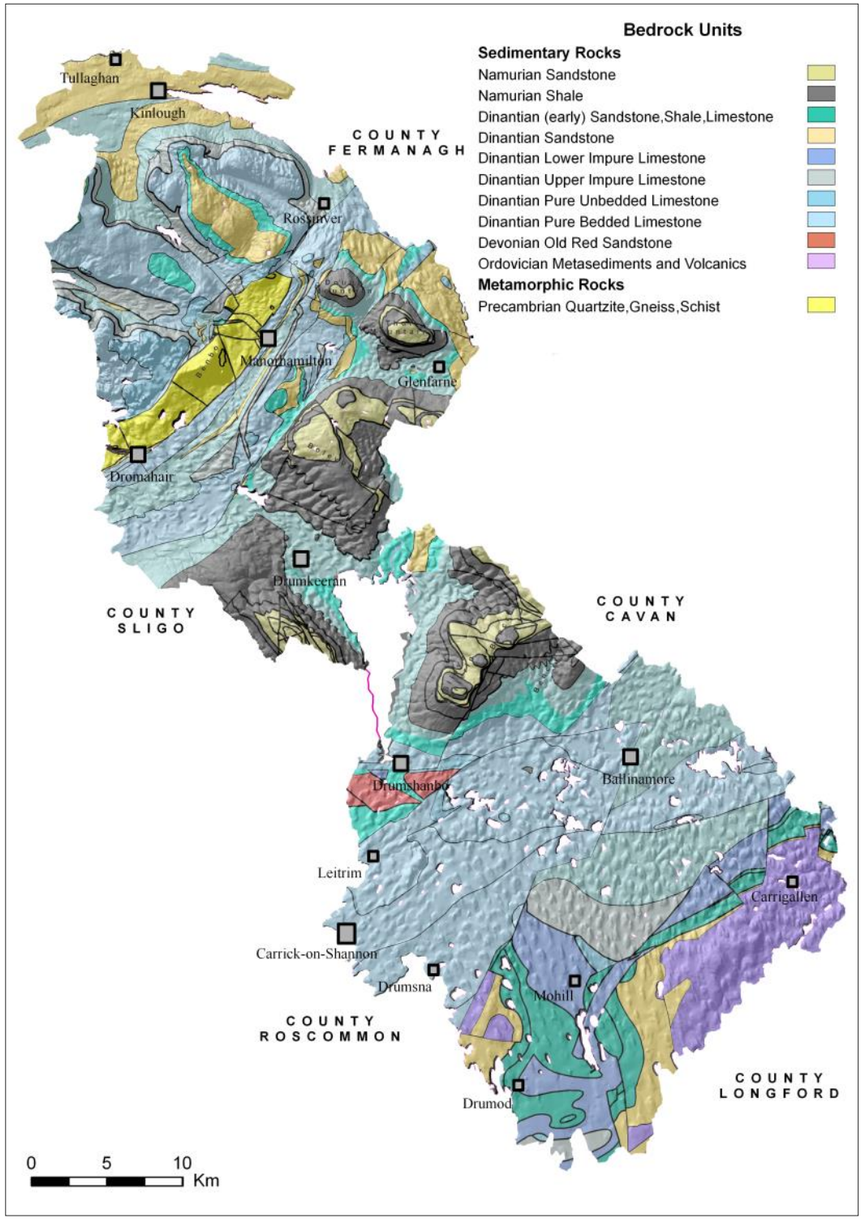
Online Resources

www.leitrimcoco.ie	Leitrim County Council
www.gsi.ie	Geological Survey Ireland (GSI)
https://secure.dccae.gov.ie/goldmine/	GSI Online Map and Document Library.
www.geologicalmaps.net	Historical geological maps from Geological Survey Ireland and British Geological Survey
www.geology.ie	Irish Geological Association
www.iqua.ie	Irish Quaternary Association (IQUA)
www.progeo.ngo	European Association for the Conservation of Geological Heritage
www.iucn.org/	International Union for Conservation of Nature (IUCN)

Topographical Map of County Leitrim



Detailed Geological Map of County Leitrim



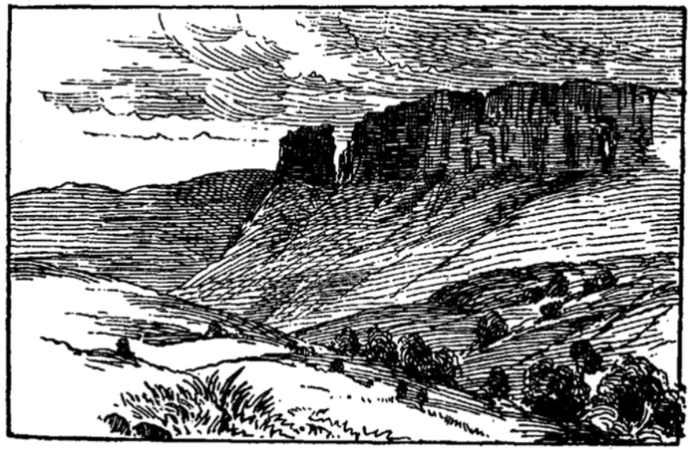


Figure 5. Geological Survey of Ireland Memoirs to accompany Sheet 42 and 43. Published 1885.

About the authors

Ronan Hennessy graduated from National University of Ireland Galway with a BSc and later completed a PhD in 2009 on 3D Visualisation and Multimedia in Geoscience Education. He has co-authored books on geological heritage in several counties, and has co-authored numerous County Geological Heritage Audits. Ronan worked with the Burren and Cliffs of Moher UNESCO Geopark when it was awarded UNSECO Global Geopark status in 2011. Ronan teaches in the Geoscience Department at University College Cork.

Robert Meehan graduated from University College Dublin with a BA in Geography and Economics, and went on to complete a PhD in 1998 on the effects of the last Ice Age on the landscape of northwest County Meath and adjacent parts of Westmeath and Cavan. Robert has previously worked for the Geological Survey of Ireland and Teagasc, and since 2006 as a consultant geologist. Robbie has published nationally and internationally on the Ice Age History of Ireland has co-authored books on geological heritage in several counties, and numerous County Geological Heritage Audits.

Vincent Gallagher graduated from University College Dublin with a BSc and remained at UCD to complete a PhD in 1987 on the geochemistry of W and Li deposits in southeast Ireland. Since then he has worked largely in Geological Survey Ireland on a variety of subjects including geological controls on radon in Ireland, gold metallogenesis, geochemistry of abandoned mine sites, mineral potential mapping and the Tellus geochemical mapping programme. He has co-authored numerous County Geological Heritage Audits and geoheritage books.

Matthew Parkes (1961—2020) graduated from Sheffield University with a BSc and went on to complete a PhD in 1990 on the palaeontology of the Ordovician rocks in Ireland at University College Galway. His reputation as a pillar of Irish geoheritage was established in Geological Survey Ireland through his work in the Irish Geological Heritage Programme from 1998 to 2005, developing lists of potential NHAs and County Geological Sites with the help of expert panels. He continued to play a central role in each county audit after taking up a curatorial position in the National Museum of Ireland, until his last audit, of County Leitrim, in 2020. Matthew published widely on many aspects of Irish geology and authored several geoheritage books.

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