

Annex 2 Geological Heritage and Conservation

Geological Summary

The rocks found in the Joyce Country and Western Lakes geopark region span the Precambrian, Ordovician to Devonian, Carboniferous, Palaeogene and Quaternary. They are metamorphic rocks (e.g. marble, quartzite), igneous rocks (e.g. granite, basalt) and sedimentary rocks (e.g. limestone, conglomerate) and represent the various climates and conditions that Ireland experienced throughout its tectonic history, moving from the Southern Hemisphere to its current latitude. The geology of international significance comes from the opening of the Iapetus Ocean and the complete record of the Grampian-Taconic Orogeny associated with its closing. It can all be seen over an area of 1560 km². It is also part of an international story that spans from North America to Scotland and to Norway. Other notable features include its karst landscape, Ireland's only fjord, and its glacial legacy.

Geological Heritage and Conservation

General geological description

The record of the Iapetus Ocean opening and closing happened continuously over several hundreds of millions of years, from the Precambrian to the Devonian – it is what makes the geology in this aspiring geopark internationally significant. Our story starts ~700 Ma (million years ago) in the Neoproterozoic Era of the Precambrian. At this time, very little of the place we now know as Ireland existed. The supercontinent of Rodinia was starting to rift apart. This rifting created the Iapetus Ocean, and sediments started to accumulate on the continental margins and the ocean floor.

By ~590 Ma Rodinia had separated to form Laurentia (where parts of north-west Ireland are found) and Gondwana. Gondwana further rifted, forming Avalonia (where parts of south-east Ireland are found). ~490 Ma, the Iapetus Ocean started to close. This subduction of one plate beneath another created a chain of volcanic islands, and the associated arc volcanism is responsible for forming the 2D and 3D pillow basalts found in the region.

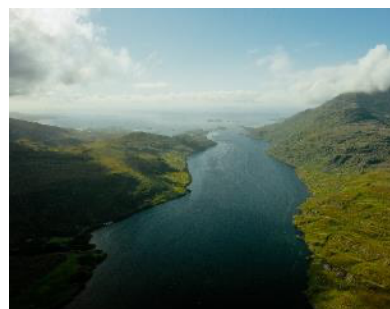
North of these volcanic islands was the South Mayo Basin, where various sediments were being deposited from the erosion of rocks from around this basin including rocks from the north, from the magmatic arc and also from the metamorphic rocks of Connemara towards the end of the Ordovician. It also brought north west and south east Ireland together, creating Ireland during the Silurian around 425 Ma. The metagabbros intruded during this time at Currywongaun are extremely important geologically, as they have helped with dating the rocks in this area and determining the sequence of events.

Timing of geology:

Date	Event
~700 Ma	Opening of Iapetus Ocean with rifting of the supercontinent Rodinia. Deposition of sediments and growth of limestone on continental margin. Geosite: Corr na Móna, Glen Inagh & 12 Bens Margin of continent Laurentia same as parts of Norway, Scotland, Greenland, Canada, USA
480 to 420 Ma - 480 Ma - 475 Ma - 463 Ma - Continuous	Closing of Iapetus Ocean – Grampian-Taconic Orogeny - Arc volcanism due to subduction. Creation of pillow basalt. Geosite: Finny, Aill Dubh - Magmatic arc intrusion – Currywongaun. Deformation and metamorphism – marble, quartzite, schist. Geosite: Glen Inagh & 12 Bens, Corr na Móna - Intrusion of Oughterard Granite. Final phase of folding in Connemara (D4) - Volcanics and thick sedimentary basin sequence preserved in south Mayo
450 to 425 Ma	Continent-continent collision and final closing of Iapetus Ocean. Joining of north west and south east Ireland. Deposition of sediments in north Connemara and south Mayo. Some marine fossils are preserved and reflect marine transgression. Geosite: Aill Dubh, Cong, Finny, Killary Fjord
400 Ma	Intrusion of Galway Granite – part of a suite of Caledonian granites straddling the Iapetus Suture
330 Ma	Deposition of limestone. Geosite: Clonbur, Cong, Ballinrobe
2.6 Ma	Glacial and inter-glacial phases lead to Ice Ages that shaped the landscape. Geosite: Killary Fjord, The Deircs

Table 1: Summary of the timing of our geological history

Our geological story continues in the Carboniferous where Ireland, located at the Equator, was under conditions akin to the Great Barrier Reef and extensive limestone deposition occurred. Further deposition might have occurred in the 300-million-year period that followed and brought us to the present, but no record is found in the region, apart from Palaeogene igneous intrusions linked to the opening of the Atlantic Ocean. This rifting is also thought to be responsible for the formation of the mountains we see today. Karst features started to develop from around 35 Ma in Ireland and some of the features in the region appear to predate the Quaternary. This current geologic period saw repeated ice ages, with glaciers and ice sheets covering the entire island of Ireland, particularly during the last Ice Age that ended 11,400 years ago. These glaciers eroded and carried many sediments offshore and deposited glacial till over most of the country. They are also responsible for shaping our aspiring geopark's landscape, and the stark contrast between the uplands of Joyce Country and the lowlands of the Western Lakes.



Epikarst on limestone pavement and Killary Fjord

Listing and description of geological sites

There are 40 Geosites with various levels of interpretation online and in publications, but 10 have been developed so far with onsite interpretation. Nine of the ten geosites, listed below in Table 2, have been chosen based on their geological importance, natural and cultural heritage, ease of access, viewpoints, and the absence of risk to their conservation. They are also important in terms of their educational usage.

Orogenic geosites	
Site Name:	Arc Volcanism at Finny – the most important site internationally
Description:	Intrusion of pillow (underwater) basalt during arc-continent collision at the start of Iapetus Ocean closing. Dated to the early Ordovician, this was important to the early understanding of the Grampian-Taconic Orogeny internationally.
Value:	International significance, Scientific, Educational, Viewpoint, Easy access
Geosite:	Glen Inagh & The Twelve Bens
Description:	Sediments related to opening of Iapetus Ocean and metamorphism related to its closing.
Value:	International story, Scientific, Educational, Viewpoint, Easy access, Historical quarrying, National walking trail
Geosite:	Corr na Móna Marble Outcrop
Description:	Sediments related to opening of Iapetus Ocean and metamorphism related to its closing.
Value:	International story, Scientific, Educational, Easy access, National walking trail
Geosite:	Aill Dubh Mountain Building
Description:	Volcanism associated with closing of the Iapetus Ocean; Unconformity with later deposited sedimentary rocks; Glacial landscape features
Value:	Scientific, educational, viewpoint, easy access, Quaternary geomorphology, cultural (place name)
Karst and epikarst geosites	
Geosite:	Cong Woods Karst Landscape
Description:	Limestone bedrock deposited in Carboniferous with karst and epikarst features
Value:	Scientific, Educational, Viewpoint, Easy access, Historical, Angling fishing, Flora, Fauna, Karst, Hydrogeology, Amenities, Culture, National trail, Playground
Geosite:	Clonbur Woods Karst Landscape
Description:	Limestone bedrock deposited in Carboniferous with karst and epikarst features
Value:	Scientific, Educational, Viewpoint, Easy access, Angling fishing, Flora, Fauna, Karst, National trail, Playground
Geosite:	(Moore Hall &) Lough Carra
Description:	Marl lake formed from surrounding limestone catchment, surrounded by karst landscape
Value:	Scientific, Educational, Viewpoint, Easy access, Historical, Angling fishing, Flora, Fauna, Karst, Art
Quaternary geosites	
Geosite:	Killary Fjord
Description:	Unconformity between Ordovician and Silurian sedimentary rocks; Glacial landscape features – Ireland's only fjord
Value:	Scientific, Educational, Viewpoint, Easy access, Historical, Aquaculture, Resilience to climate change and geohazards, Water activities
Geosite:	The Deircs
Description:	Deposition of Ordovician sediments during early closing of Iapetus Ocean; Glacial landscape features
Value:	Scientific, Educational, Viewpoint, Easy access, Bog/ Peatland, Ecology

Table 2: Description of geological sites

Current or potential pressure on geological sites

Steps to mitigate any potential pressures on the geosites include: selecting them based on their ease of access and the absence of risk to their conservation; having a 'Geopark Code of Conduct' on our website which includes partnership with the 'Leave No Trace' campaign; and promotion using pre-existing trails. Our educational programmes, such as the Geopark Ambassador Course and visits to schools, highlight this code and promote safe and respectful access to all our geosites.

Current potential pressures on the geosites include degradation from natural processes, landslides, 'wild' fires caused by uncontrolled burning, groundwater flooding in the karst areas and coastal flooding and damage in the coastal areas.

Current status in terms of protection

Several designations to protect our geosites are found in the region, Table 3. These include:

Local and National protection

- County Geological Sites (CGSs) designated by the Irish Geological Heritage Programme in Geological Survey Ireland in association with the Heritage Councils and the Local Authorities (County Councils). Protection given through the 5-yearly County Development Plans and through the Planning section in Geological Survey Ireland
- Some CGSs are proposed NHAs (National Heritage Areas). Work is underway on granting this additional protection through the National Parks and Wildlife Service (NPWS)
- Nature Reserves designated by the National Parks and Wildlife Service
- Wildfowl Sanctuaries designated by the National Parks and Wildlife Services

European Protection

- Special Areas of Conservation (SACs) designated by the EU Habitats Directive and National Parks and Wildlife Service
- Special Protection Areas (SPAs) designated by the EU Birds Directive and National Parks and Wildlife Service

Figure 13 on page 21 of the application dossier maps out these designations in the region while all the geological sites are listed on our geosite database, Annex7 of the dossier.

Designation	Total number of sites	At which geosites
County Geological Site (CGS)	30 (26 of these are recommended as Natural Heritage Areas (NHAs). Further details in Annex 7)	<ul style="list-style-type: none">• Arc Volcanism at Finny• Aill Dubh Mountain Building• Corr na Móna Marble Outcrop• The Deircs• Cong Woods Karst Landscape
Special Area of Conservation (SAC)	14	<ul style="list-style-type: none">• Glen Inagh & The 12 Bens• Moore Hall & Lough Carra• Clonbur Woods Karst Landscape
Special Protection Area (SPA)	4	<ul style="list-style-type: none">• Moore Hall & Lough Carra• Clonbur Woods Karst Landscape
Nature Reserve	2	<ul style="list-style-type: none">• Glen Inagh & The 12 Bens
Wildfowl Sanctuary	1	<ul style="list-style-type: none">• Moore Hall & Lough Carra

Table 3: Protected sites in region