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The Geological Heritage of Cork City

An audit of County Geological Sites in Cork City **2022**

by Erin Leahy, Clare Glanville and Brian McConnell

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

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This report is a contribution to the programme of work supported by Geological Survey Ireland in establishing a national dataset of sites of geological significance (known as County Geological Sites).

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Executive Summary

Cork City, whose administrative boundaries cover 187 km^2 on Ireland's southern coast, is found to the east of the Lee River Valley. The River Lee, fed by Lough Inniscarra to the west, passes through Cork City and envelops the island that makes up the city centre, before reaching the sea at Cork Harbour to the southeast. Red sandstones in east-west bands to the north and south define Cork's characteristic hills, while a central east-west band of white limestone bedrock defines the lowlands, over which the River Lee travels. These lithologies are often said to have inspired Cork City's red and white flag.

Geology is an integral, if often overlooked, part of Cork City's natural heritage, defining the landscape and architecture of the city. Despite the urban setting, there is substantial bedrock exposure throughout Cork City; many outcrops are incorporated into the urban landscape, and extensive historical quarries point to the city's rich heritage of using local building stones in landmark constructions. Furthermore, though some sites of glacial deposition have been depleted during quarrying for the construction industry, glacial deposits from the last ice age (between approximately 10,000 and 18,000 years ago) are visible in some parts of the city, and glacial deposits are also found within karst systems.

Awareness of Cork City's rich geological heritage is not common. This report aims to record and highlight the diverse range of geological heritage sites that occur within the city. The sites represent the accessible examples of the city's bedrock foundation (e.g. Beaumont Quarry, Patrick's Hill), sites with historical connections (e.g. Blackrock Diamond Quarry), karst and Quaternary landforms (e.g. Ballinlough Fields, Beaumont Quarry, Inniscarra Bar), and iconic buildings in the Cork City urban landscape (e.g. Shandon Tower).

This report documents what are currently understood by the Geoheritage Programme at Geological Survey Ireland to be the most important representative geoheritage sites in Cork City. The report proposes the sites as County Geological Sites, for inclusion in future City Development Plans (CDP). The audit provides a reliable summary record of County Geological Sites to replace a provisional listing dating from the 1990s, which was based on desk studies and subsequently adopted in the past and current CDPs.

County Geological Sites do not receive statutory protection like Natural Heritage Areas (NHA), but they do receive an effective protection from their inclusion in the planning system. Some of the sites described in this report are potentially of national importance as a best representative example of a particular geological feature. Such sites are provisionally notified to the National Parks and Wildlife Service (NPWS) by Geological Survey Ireland, as recommended for designation as a Natural Heritage Area (NHA). NHA designation would only occur following further surveying and consultation with landowners where relevant. Some County Geological Sites fall within existing pNHAs and SACs where the ecological interest is founded upon the underlying geodiversity.

The adoption of sites identified in this audit within future CDPs would ensure that Cork City follows an established and effective methodology for documenting geological heritage, and ensure that geoheritage is not overlooked in the general absence of allocated resources for progress at national level.

This report is compiled in non-technical language (with a glossary for unavoidable geological terminology) and will serve to inform the work of Geological Survey Ireland's Geoheritage Programme and is available on Geological Survey Ireland's website (www.gsi.ie). The report will also

serve as a working document for use by the Heritage Officer and the Planning Department of Cork City Council. The report can be made publicly available via the Council website. A section of the report includes recommendations on how to best present and promote the geological heritage of Cork City to the people of the region.

The preliminary sections, summary geological history and accompanying map, and timescale column particularly may be used to preface a booklet or as website information in the development of this work, and for information, as seen fit by the Heritage Officer, and as funding permits. The main report and individual County Geological Sites reports content provide essential information for a general interest publication communicating the geological heritage of Cork City. Adequate recognition of the geological heritage of Cork City may add value to sustainable tourism and education initiatives into the future.

1. Cork City in the context of Irish Geological Heritage

This report brings Cork City to the forefront of geological heritage within Ireland, as a geological heritage audit has been completed for most of the country. The geological heritage audit for Cork County commenced in 2021 and will run for a three-year period. In the absence of significant political and economic resources available at a national level to the relevant bodies for conservation of geological heritage as Natural Heritage Areas (NHA), local authority-level geological heritage audits play a significant role in defining and safeguarding Ireland's geological heritage. County Geological Site audits (county and city) are the only effective means of geological conservation at present in Ireland, albeit with only an advisory role within the context of City and County Development Plans. County Geological Site audits in themselves confer no statutory protection on geological sites, although City and County Development Plans can provide such protection as required. Similar geological audits have been completed in urban and suburban regions including Dublin City, South Dublin, Dún Laoghaire-Rathdown, Fingal and Galway City.

This audit report will also serve to support commitments on the part of the local authority to fulfil its obligations to incorporate geology into the spectrum of responsibilities under the Heritage Act 1995, the Planning and Development Act 2000, Planning and Development Regulations 2001, and the Wildlife (Amendment) Act 2000 and the National Heritage Plan (2002). Geological Survey Ireland views partnerships with the local authorities, as a very important element of its strategy on geological heritage (see Appendix 1).

County Geological Audits completed by 2022 (shown in green).

Geological heritage (or geoheritage) is a set of geological elements with significant scientific, educational and/or touristic (cultural, aesthetic) values. Identifying geological elements as heritage implies an assessment of their value (benefits and potential use), together with their protection and sustainable management for their conservation. Geodiversity is defined as the variety of the non-living elements of nature – including its minerals, rocks, fossils, soils, sediments, landforms, topography, geological and morphogenetic processes, and hydrological features such as groundwater, rivers and lakes. Geodiversity underpins biodiversity and is the basis of habitats and ecosystems, but has its own value independent of biodiversity.

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

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

IGH THEMES

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

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

Designation of geological NHAs is the remit of Geological Survey Ireland's partner in the geoheritage/natural heritage programme, the National Parks and Wildlife Service (NPWS). Once designated, any geological NHAs will be subject to normal statutory process within the Cork City

Council Planning Department and other relevant divisions. **However, compared to many ecological sites, management issues for geological sites are generally fewer and somewhat different in nature. The subsequent section considers these issues.**

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

A Master List of candidate CGS and NHA sites is used in Geological Survey Ireland, originally compiled with the help of Expert Panels for all 16 IGH themes. Currently, Geological Heritage Audits are completed based on administrative boundaries, typically on a county-by-county basis, though in some cases smaller regions are assessed. These audits consider, among others, all of the Master List sites of any IGH theme within the relevant administrative boundaries. The inclusion of all sites as County Geological Sites (CGS) in Cork City's planning system will ensure that they are not inadvertently damaged or destroyed through lack of awareness of them outside of the Geoheritage Programme in Geological Survey Ireland.

The sites proposed here as County Geological Sites (CGS) in Cork City have been visited and assessed specifically for this project, and represent the current state of knowledge. It does not exclude other sites being identified later, or directly promoted by the Cork City Council or Geological Survey Ireland, or by local communities wishing to draw attention to important sites for amenity or education with an intrinsic geological interest. New excavations, such as major road cuttings or new quarries, can themselves be significant and potential additions to this selection.

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

1.1 Cork City Geological Sites

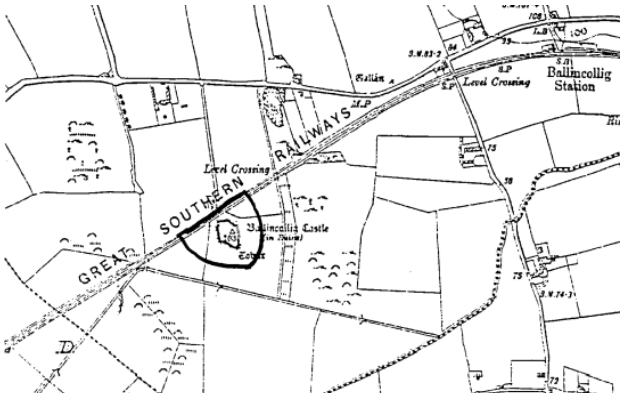
Site Name	Designation	IGH Primary	IGH Secondary	IGH Third	CGS site ID
Ballinlough Fields	CGS	IGH7	IGH1	IGH15	CC001
Beaumont Quarry	CGS	IGH1	IGH8	IGH15	CC002
Blackrock Diamond Quarry	CGS, recommended for Geological NHA	IGH6	IGH1	IGH7	CC003
Inniscarra Bar	CGS	IGH7			CC004
Patrick's Hill	CGS	IGH10			CC005
Shandon Tower	CGS	IGH15	IGH8	IGH10	CC006
St Fin Barre's Cathedral	CGS	IGH15	IGH3		CC007
St Joseph's Section	CGS, recommended for Geological NHA	IGH8	IGH10		CC008

1.2 Rejected, combined and renamed sites

The Geoheritage (IGH) Master Site list for Cork City was limited, with only two sites listed; Blackrock Diamond Quarry, and St Joseph's Section. Both sites were assessed as suitable County Geological Site candidates in this audit. Additional sites were assessed based on aspects of geological heritage that may have been initially overlooked by the Geoheritage (IGH) expert panel when compiling the Master Site List for Cork City, or which have come to light in the interim period. The geological characteristics at several sites were built over, inaccessible, no longer visible, or were not deemed suitable for CGS status. The rejected sites are listed below with brief notes as to why they were deemed unsuitable for inclusion.

Ballincollig Cave

Ballincollig Cave, an apparently short cave under and beside Ballincollig castle, is a pNHA due to geomorphological and ecological (botanical) interest. Whilst the ecological interest is confirmed, in the Report on Areas of Scientific Interest in County Cork (Goodwillie, R., 1986) the geological significance is merely surmised – "it seems likely to contain some fossil material as it has a natural and accessible opening… The cave is thought to contain deposits of scientific interest though as far as is known it has not yet been excavated." Similarly, the report states "Cave exploration except by specialists should not be encouraged in this area as this could damage any remaining scientific interest." Due to the limited accessibility, and absence of any confirmed fossil remains, this site was not selected as a CGS.



Excerpt from the 1986 Report on Areas of Scientific Interest in County Cork (Goodwillie, R.)

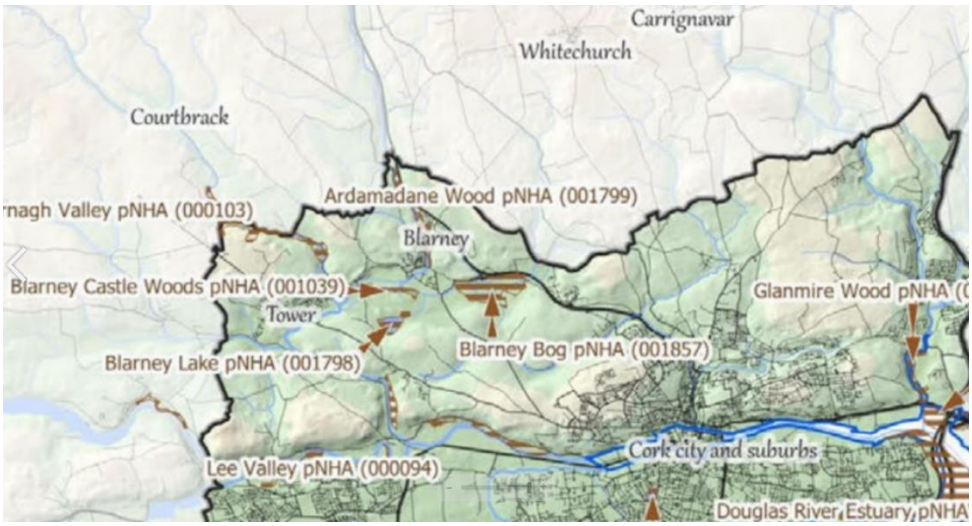
Bell's Field

The bedrock of Cork City is closely linked to city's geomorphology The River Lee travels over the low ground of the more easily eroded and weathered limestone, following the contact between limestone and sandstone in places, with tributaries seen in approximately north-south trending faults. Situated at the top of Patrick's Hill, the views of the River Lee and associated low grounds from Bell's Field allow for consideration of how both fluvial processes and the underlying bedrock contribute to geomorphology. However, the main morphological feature observable from Bell's Field is a north-south trending fault plane rather than fluvial geomorphology. In addition, urbanisation has obscured much of the fluvial geomorphology, so it is not considered suitable as a CGS under IGH theme IGH14.

View looking west from Bell's Field – a north-northwest – south-southeast trending gulley immediately visible, with the east - west trending river valley visible to the south.

Blarney Bog

Blarney Bog, more commonly known as Clogheenmilcon Fen, is a pNHA within Cork City's administrative boundaries, proposed primarily due to its ecological importance. Historically, moderately extensive peat was associated with this site, most of which has since been cut away to the south. Though there are also historical accounts of quaternary gravels and clays, such deposits are not clearly evident, and the existing site appears to be comprised entirely of a small fen. As such this site has not been selected as a CGS.



Location of Blarney Bog pNHA as identified within the Cork City Draft Development Plan 2022-2028 SEA

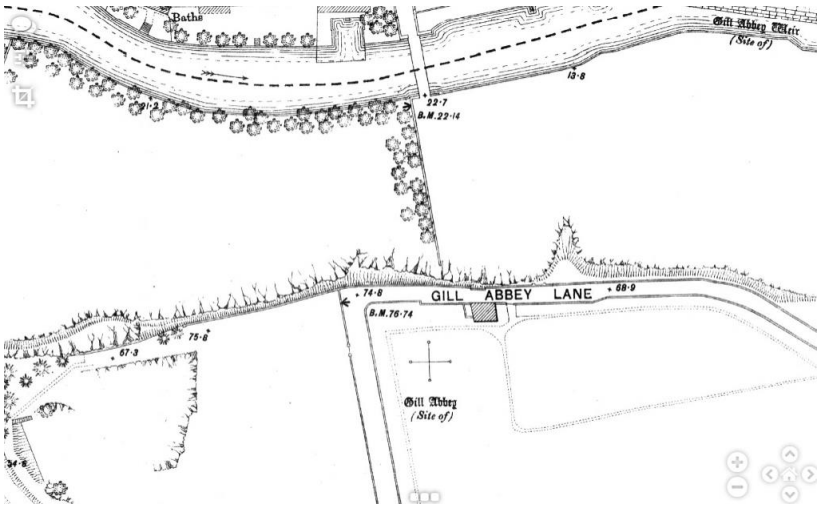
Brickfield Quarry

Brickfield Quarry was one of the principal sandstone quarries in Cork, in use until the 1860s. The red sandstone from Brickfield was used during construction across the city, notably in the North Cathedral and St Peter and Paul's Church and Convent. Following nearby fossil finds, including the tree *Archaeopteris hibernica* and the bivalve *Archanodon jukesi*, it was proposed further excavation of these beds in Brickfield quarry may provide new fossil material. However, due to the limited accessibility of the outcrop and dearth of recorded historical fossil finds at this site, it is not considered suitable for CGS status.

Left: View of Brickfield Quarry from the public road. Right: Extract of Map of Cork City showing Brickfield Quarry, OSI 1869, map digitised by UCD Library.

Gillabbey Park

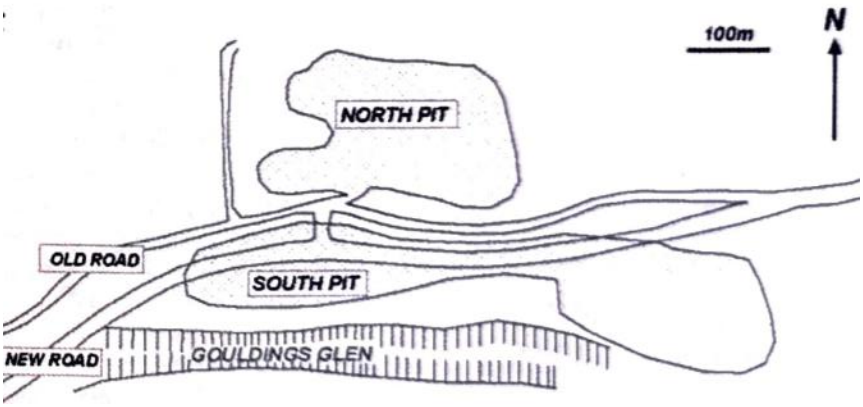
Gillabbey Park is the site of a large limestone outcrop, historically used as a quarry. It has traditionally been held that St Fin Barre spent time in contemplation in a cave found at or near this locality; though there is little karstification evidenced at the current outcrop, there is a small hollow in the cliff face, partially obscured by vegetation. As Beaumont Quarry, Blackrock Diamond Quarry, and Ballinlough Fields are all better examples of karst features within inactive quarries, Gillabbey Park was rejected as a CGS.



Extract of Map of Cork City showing site of Gillabbey Park, OSI 1893, map digitised by UCD Library.

Lake Ballyvolane

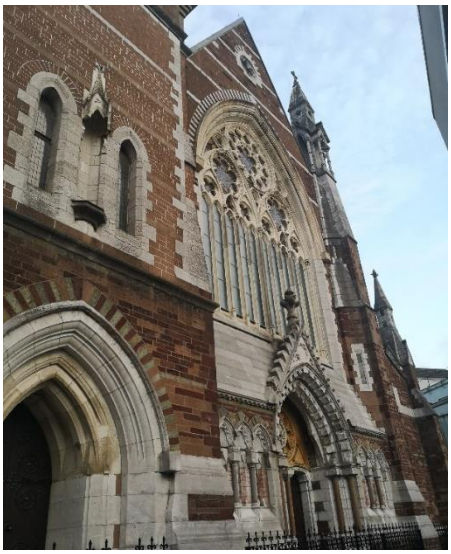
Pleistocene glacial lake deposits to the north of Gouldings Glen were logged and recorded photographically in 1974/75, with interpretations published in MacCarthy, 2001. This paper states that although many of the deposits seen in earlier gravel pits were either built upon or modified, some of the sediments remained in situ. However, subsequent construction works have further obscured any surviving exposures, and there is no notable record of the original quaternary deposits at this site. Lake Ballyvolane is therefore not designated CGS status.



Extract from MacCarthy, 2001, showing the locations of historic gravel pits and exposures, where "New Road" is thought to be the R635.

St Peter and Paul's Church

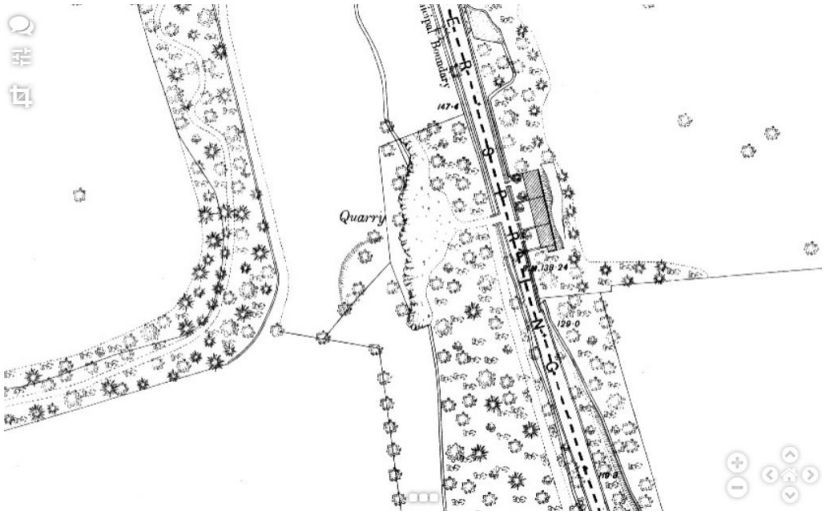
St Peter and Paul's Church is a beautiful building in the heart of Cork City, primarily built from local sandstone with local limestone dressings. A range of other lithologies are also in use in the building, including Carrara and Italian white vein marbles, highlighting the role of geology in international trade markets. However, St Fin Barre's Cathedral provides a more extensive built example of economic geology, with greater detail available about the provenance of the rocks used, and so St Peter and Paul's Church is not accepted as a CGS for Cork City.



St Peter and Paul's Roman Catholic Church

Tivoli Quarry

Tivoli Quarry, a long-decommissioned sandstone quarry on the lower Glanmire Road, was the source of fossil specimens of *Archaeopteris hibernica* and the bivalve *Archanodon jukesi*, as mentioned in relation to Brickfield Quarry above. The site of this excavation has now been extensively built upon, and no significant trace of historical quarrying is visible, so this site is not deemed a suitable CGS.



Extract of Map of Cork City showing suspected site of Tivoli Quarry, OSI 1890, map digitised by UCD Library.

Upper John Street

Built into the wall on Upper John St there is an outcrop of Old Red Sandstone, with very minor folding likely related to the larger scale east-west trending folds of Cork City. This outcrop is easily accessible, with clear bedding, and demonstrates a strong history of human interaction with Cork's geology. However, a similar outcrop of sandstone on Patrick's Hill, also with clear bedding, better illustrates the relationship between bedrock and geomorphology, and was chosen over this site as a CGS.

Old Red Sandstone outcrop in the wall of Upper John Street

2. Cork City Council policies regarding geology and geological heritage

There is little specific inclusion of geological heritage in the Cork City Development Plan (CDP 2015-2021), which, when considering heritage, is largely concerned with archaeological, historical and architectural heritage. Geological heritage is an often overlooked but fundamental part of Cork City's natural and cultural heritage. Although many of the aspirational objectives and actions apply in a general way to this audit, geological heritage is specifically considered within the Natural Heritage and Biodiversity section of the CDP 2015-2021.

This section examines the few existing points in the CDP (2015-2021) plan relating to geological heritage. It also considers the policies currently outlined in the draft of the new Cork City Development Plan, scheduled for release in 2022, which is likely to build on the existing objectives from the CDP (2015-2021) to protect geological heritage from inappropriate development. With the production of this Cork City Geological Audit, future CDPs should be equipped to include more specific objectives relating to County Geological Sites and geological conservation, and to include a listing of County Geological Sites in an appendix or a map of their locations as provided herein.

As stated in the CDP 2015-2021;

> *"Heritage is defined under the Heritage Act 1995 as items such as monuments, archaeological objects, heritage objects, architectural heritage, flora, fauna, wildlife habitats, landscapes, seascapes, wrecks,* ***geology****, heritage gardens and parks and inland waterways."*

Under CDP (2015-2021) Objective 10.11 Non Designated Areas of Geological Importance, *"To seek the conservation of important features of geological interest in the city"*, it is further stated that:

> *"Cork City Council recognises the need to maintain and preserve important features of geological interest in the city and will work with The Geological Survey of Ireland, as appropriate, to conserve the sites identified as being of geological interest,"*

The written statement for the Cork City Draft Development Plan 2022-2028 states;

> *"Cork City's natural heritage includes flora, fauna, geology and landscape. This variety of life is often referred to as biological diversity or biodiversity. Wildlife habitats occur throughout Cork City and include rivers, recreation areas, gardens and graveyards with many mammals, birds, invertebrates, trees and plants having adapted to live alongside humans in the urban environment."*

The Cork City Draft Development Plan 2022-2028 recognises that *"the Geology of Cork City is an integral part of our natural heritage and defines the landscape and layout of the city,"* and in section 6.73, states that;

> *"Cork City Council recognises the need to maintain and preserve important features of geological interest in the City and will work with relevant stakeholders, as appropriate, to conserve the sites identified as being of geological interest."*

The draft CDP (2022-2028) contains: Objective 6.27 Areas of Geological Importance, *"To seek the conservation of important features of geological interest in Cork City,"*; and the Strategic Environmental Objective to *"Safeguard areas of prime agricultural land and designated geological sites."*

The CDP (2015-2021) notes that *"there are a few areas within the city which are considered to be areas of geological importance."* Those sites which were initially identified as potential CGSs on the IGH Master List are highlighted in Section 3.6.4 Sites of Geological Interest of the SEA (2015-2021), as well as in Section 4.8.1 Geological Sites of the SEA for the Draft CDP (2022-2028):

1. *St. Joseph's section on Lee Road, (GR 164000, 071400), under IGH Theme IGH 10 Devonian.*
2. *Blackrock diamond quarry, Ballintemple, (GR 169400, 071400), under IGH Theme IGH 6 Mineralogy.*

Table 4.1 Environmental Protection Objectives (EPOs) the CDP (2015-2021) identifies the objective *"To protect and where appropriate, enhance the diversity of habitats, ecosystems, geological features and species in their natural surroundings."* In many cases, geology provides key environments for ecosystems to thrive, with increased geological diversity promoting increased biodiversity. As such, geological heritage must also be considered within larger ecological systems.

Geology within biodiversity policies

The significance of geology and geological heritage is often referenced within their association with ecology, habitats and biodiversity. The draft CDP (2022-2028) references the Cork City Heritage and Biodiversity Plan (2021-2026), which is currently in production, and which *"sets out a series of realistic and practical actions to protect, conserve and manage our heritage … It will include actions on … natural heritage ... The actions from this Heritage and Biodiversity Plan will strengthen Cork City's heritage and biodiversity and its economy, by supporting the tourism and the recreation sectors."* The implementation of these objectives will be aided by the publication of this Geological Audit.

Table 6.13: Strategic Biodiversity Goals in the draft CDP (2022-2028) includes two goals relevant to geological heritage within natural heritage:

> *1. To protect and enhance designated areas of natural heritage and protected species and to adhere to all relevant biodiversity legislation*
>
> *2. To ensure that sites and species of natural heritage and biodiversity importance in non-designated areas are identified, protected and managed appropriately*

Section 10.48 of the CDP (2015-2021), Non-Designated Areas of Natural Heritage, references Beaumont Quarry, which is identified within this audit as a CGS, and states

> *"It is important to realise that the natural heritage and biodiversity of Cork City is not just contained within designated areas alone but is found throughout the city. Many areas which do not have formal protection under legislation, have a local natural heritage value in terms of the urban environment in which they are located, the plant and animal life that they support and the biodiversity that lies within them. There is a need to conserve these non designated areas which support wildlife species and habitats."*

However, it is recognised in the CDP (2015-2021) that *"[t]o date sites of geological interest have not been comprehensively covered by the existing nature conservation designations."*

The Cork City Draft Development Plan 2022-2028 SEA Report includes statements of direct or loose relevance to geoheritage:

Soils

The Cork City Draft Development Plan 2022-2028 SEA states:

"4.11.5 Peatlands

> *Peatlands provide a valuable natural and archaeological resource. Peatlands are also important controllers of water levels in river catchments, providing a source of water in dry conditions and soaking up excess water during wetter periods; they actively capture and hold carbon and are an important natural resource in combatting climate change. Cutaway bogs have the potential to facilitate land uses such as employment, renewable energy generation, waste management, industrial, and tourism and recreation. Peat soils are often indicative of areas that are the most sensitive to development due to ecological sensitivities and impeded drainage issues. Blarney Bog in the north of the City is subject to ecological designations (see Section 4.6)."*

3. Geological conservation issues and site management

Geodiversity is often overlooked as the foundation for much of the biodiversity that has been identified for conservation through EU nature conservation policy SAC or NHA designations. It is therefore unsurprising that many of the most important geological sites are actually in the same areas as SAC, NHA and pNHA sites. In such formally designated areas for nature conservation, geological heritage more often than not enhances and cements the value of the sites. Therefore, a recognition and acknowledgment of geological heritage value requires no additional designation of actual land areas, other than citation of the geological interest.

The term biodiversity dominates the European nature conservation framework. The understanding of biodiversity as restricted to species diversity is all-too-frequent, even if the term also includes genetic as well as habitat and ecosystem diversity. The EU nature conservation policy, based exclusively on the Birds and Habitats Directives, unfortunately gives no importance to EU geoheritage and geodiversity, leaving at risk this exceptional type of natural heritage and natural diversity.

Broadly speaking, there are two types of site identified by the Geoheritage Programme. The first, and most common, includes small and discrete sites. Examples include disused quarries, natural bedrock or quaternary exposures on hilly ground, coastal cliff sections, or other natural cuttings into the subsurface, such as stream sections. These discrete sites typically host a feature or features of specific interest such as fossils, minerals, springs, or they are a representative (type) section of a particular stratigraphical sequence of rocks. **The second type of site is a larger area of geomorphological interest, i.e. a landscape that incorporates features that illustrates the processes that formed it.** The Quaternary theme (IGH 7) and the Karst theme (IGH 1) often include such large sites. In Cork City, all of the sites identified by the Geoheritage Programme belong to the first type of site.

It is also important from a geological conservation perspective that planners are cognisant of the landscape importance of geomorphological features which may not in themselves warrant any formal site designation, but which form an integral part of the character of Cork City. A lack of awareness in the past, has led to the loss of important geological sites and local character throughout the country. Awareness of the city's geological heritage can enable planners to maintain the unique character of the city, and consider this heritage when planning for new road infrastructure and public amenity and green space planning. In Cork City, a Landscape Characterisation Assessment was completed in 2008 and incorporated into the subsequent City Development Plans. This Landscape Characterisation Assessment provides a tool for planners to help maintain the character of the City, however, it is a methodology that could be considered to place inadequate value on the underlying geodiversity in defining landscape character areas.

A map of Physiographic Units, cartographic representations of the broad-scale physical landscape of a region, has been compiled in support of the actions to be implemented in National Landscape Strategy for Ireland 2015 – 2025. This map, delineating physical regions showing internal uniformity with respect to one or more environmental attributes that can be clearly differentiated from neighbouring regions, can be viewed online under the Physiographic Units tab on the GSI Map Viewer.

The Strategic Environmental Assessment within the City Development Plan can support the conservation and promotion of geological heritage. In addition, the now routine pattern of consultations with Geological Survey Ireland, either by the City Council's planning department or by

consultants conducting Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), can greatly improve the representation of the geodiversity and geoheritage in planning and development.

There are large differences in the management requirements for geological sites in comparison to biological sites. Geological features are typically quite robust and generally few restrictions are required in order to protect the scientific interest. In some cases, paradoxically, the geological interest may even be served better by a development exposing more rock. **The important thing is that the relevant planning department is aware of the sites and, more generally, that consultation can take place if development is proposed for a site deemed of geological interest.** In this way, geologists may be afforded the opportunity to learn more about a site or area by recording and sample collection of temporary exposures, or to influence the design outcome so that access to exposures of rock is maintained for the future, or occasionally to prevent a completely inappropriate development through the presentation of a strong scientific case.

In many counties, working quarries are included as County Geological Sites because the quarries host the best representative sections available of specific rock sequences in areas where exposure may otherwise be poor. No restriction is sought on the legitimate operation of these quarries. However, maintenance of exposure after quarry closure is sometimes sought in agreement with the operator and planning authority in such a case. Issues relating to quarries are explored in a set of Geological Heritage Guidelines for the Extractive Industry, published jointly by Geological Survey Ireland and the Irish Concrete Federation in 2008 (Gatley and Parkes, 2008).

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

When considered on a nationwide scale, some sites may require restrictions and a typical case might be at an important fossil or rare mineral locality, where a permit system may be required for genuine research, but the opportunity for general collecting may need to be controlled. Few, or none of Cork City's sites are likely to require such an approach.

Waste dumping

Illegal waste dumping is a problem throughout the country. Not only is waste unsightly and messy, waste material dumped in areas where rock is exposed (e.g. quarries or disused gravel pits) may leach into groundwater as the waste degrades. This can cause groundwater pollution and can affect nearby drinking water supplies in wells or springs. Groundwater Protection Schemes (DELG 1999) help to combat pollution risks to groundwater by zoning the entire land surface within counties into different levels of groundwater vulnerability.

New exposures in development

Local authorities can play a key role in the promotion and protection of geology in the case of new roads and infrastructure. Wherever major new carriageways are to be built, or in other major infrastructural work, it should be a policy within the Council Planning Department that where new rock exposures are created, they be left open and exposed unless geotechnical safety issues arise (such as where bedding dips are prone to rock failure). Traditionally, the grading and grassing over of

slopes in cuttings is largely a civil engineering convenience. However, it leads to sterile and uninteresting roads that look the same throughout the country. Leaving rock outcrops exposed where they are intersected along the road can improve the character and interest of the route, by showcasing the geology and landscape of the locality. Tree or shrub planting, when done in unison with rock exposure, especially where they show interesting features, not only assists the geological profession, but also creates new local landmarks. This can also potentially save money on the construction costs. It may also contribute to road safety by providing diversity of surroundings to maintain drivers' attention.

Geoparks

An extremely interesting development in geological heritage, not just in Ireland but internationally, has been the rapid recent growth and adoption of the UNESCO Geopark concept. **A Geopark is a territory with a well-defined management structure in place** (such as local authority support), **where the geological heritage is of outstanding significance and is used to develop sustainable tourism opportunities.** Initially it was largely a European Geoparks Network (EGN) but since 2004 has expanded worldwide as the Global Geoparks Network (GGN) and is fully assisted by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). [See www.globalgeopark.org and www.europeangeoparks.org.] A fundamental basis of the Geopark concept is that it is driven from the bottom up. The communities in the Geopark are the drivers of the project and are the main beneficiaries. UNESCO Geopark branding therefore helps promote the geological heritage resource so that the community can benefit from it. However, significant management support from local authorities has proven to be essential across the network.

There are three UNESCO Global Geoparks on the island of Ireland: the cross-border Cuilcagh Lakelands UNESCO Global Geopark (https://cuilcaghlakelands.org/); the Copper Coast UNESCO Global Geopark (www.coppercoastgeopark.com) and the Burren and Cliffs of Moher UNESCO Global Geopark (www.burrengeopark.ie). The Joyce Country and Western Lakes Aspiring Geopark Project in north County Galway and south County Mayo is progressing and will hopefully be successful in its bid for UNESCO Geopark status in 2022 (www.joycecountrygeoparkproject.ie). In addition, the Mourne Gullion Strangford Aspiring UNESCO Global Geopark project is progressing, and the Causeway Coast and Glens Heritage Trust are also exploring the work and infrastructure required for applications. At present, Cork City's geological heritage would not be suitable for the Geopark concept.

3.1 BEES Geology Museum, UCC

Opened in 1849, the BEES Geology Museum was originally housed in the North Wing of the Quadrangle. Following a period when the specimens were kept in storage, the museum was relocated to its current space off the Ted Neville Geological Laboratory in the Robert Kane (Science) Building in 1981. The museum is considered part of the outreach work of the School of Biological, Earth and Environmental Sciences.

The collections, which include a combination of donations and purchases, are arranged systematically in their original oak cases. Donations include those from organisations including the Geological Society of London, the Geological Survey, and the Cork Cuvierian Society. Donations were also made by individuals such as Lady Windle, Colonel Charles Coote Grant (Canadian fossils), William Helier Baily (many of the Lyme Regis specimens), George Victor Du Noyer (plant specimens from Co. Antrim) and Miss E. Cotter of Mallow (the type specimen of the rare quartz mineral, Cotterite.)

As well as substantial rock and mineral collections, there is a large amount of fossil material. Included among the museum's collections are the skull and antlers of the Giant Irish Deer, *Megaloceras giganteus*, a cast of Lyme Regis's type specimen of the marine reptile *Plesiosaurus macroephalus*, and a cast of the Berlin specimen of the 'bird ancestor' *Archaeopteryx lithographica*. There is also a recently restored fossil Ichthyosaur, *Icthyosaurus cf. intermedius*, from the Liassic (Lower Jurassic) in age, and a cast of the Devonian tetrapod trackway from Valentia Island, Co. Kerry. Other specimens belonging to the School of Biological, Environmental and Earth Sciences are found throughout their buildings, including a small but comprehensive display of rock and mineral specimens in the Butler Building. In total, there are approximately 20,000 rock, mineral and fossil specimens, as well as a similar number of geological maps, thin sections, photographic slides, offprints and books, which act as an excellent teaching and research resource within Cork City.

3.2 UCC Geological Garden

Maintained by the School of Biological, Earth and Environmental Sciences at University College Cork, the Geological Garden houses 10 large boulders of important lithologies from across Ireland. Each boulder has a QR code, linking visitors to online geological interpretations of the boulders.

Old Red Sandstone (c.370 Ma), (a specimen of the bedrock excavated during the geophysics garden's creation,) and the Faulted Limestone (c.340 Ma), represent the main lithologies of Cork. Valencia Slate (385 Ma) and Liscannor Flagstone (c.320 Ma) represent well defined burrowing and feeding trace fossils respectively, and have both been used widely in construction. Volcanic Agglomerate (c.475 Ma) and Volcanic Breccia (c.475 Ma) show evidence for explosive volcanism in Ireland during the Ordovician, and have been used for aggregate and as rock armour. Lithium pegmatite (c.405 Ma) represents igneous intrusions in Ireland, and has been prospected for lithium mining. The Connemara Marble (650-750 Ma) and garnetiferous Psammitic Gneiss (>900 Ma) are metamorphosed sedimentary rocks, while the Banded Amphibolite (600-650 Ma) is a metamorphosed igneous rock. Each of these metamorphic rocks has been used in the construction industry.

The UCC Geological Garden is an excellent outreach initiative within the city, and provides introduction to a range of geological concepts. However, the garden is not currently well promoted, with its location not featuring on any of the UCC maps or online. Further promotion would increase the reach of this resource.

The UCC geology garden is a rock garden outside the Butler Building on the North Mall Campus.

4. Summary and Recommendations

4.1 Proposals and ideas for promotion of geological heritage in Cork City

This section briefly examines the existing objectives in the draft Cork City Heritage and Biodiversity Plan (2021-2026), which is currently in preparation, particularly how the objectives relate to geological heritage. The draft Cork City Heritage and Biodiversity Plan (2021-2026) states:

> *"The city of Cork, built on a geology consisting of red sandstone and white limestone, has an attractive physical setting formed by the River Lee Valley and Estuary nestled amongst the ridges rising to the north at Shanakiel, Montenotte and Tivoli and to the south at Maryborough and Grange.*
>
> *…*
>
> *The Geology of Cork city is an often overlooked, but integral part of our natural heritage and defines the landscape and layout of the city. It is often said that the red and white colours of the Cork flag reflect the red sandstone and white limestone that predominates the cities geology. This stone has been quarried and used for generations in the building of landmark buildings and churches throughout the city. Cork city has two unaudited County Geological sites (CGSs):*
>
> • *Blackrock diamond quarry, Ballintemple, (GR 169400, 071400), under IGH Theme IGH 6 Mineralogy.*
>
> • *St. Joseph's section on Lee Road, (GR 164000, 071400), under IGH Theme IGH 10 Devonian"*

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

> **Objective 2**: Support Heritage related Education, Research and Training
> **Action**:
>
> 2.4 Carry out audit of geological assets in the city.
>
> 2.5 Produce new and promote existing Cork City Council and other relevant heritage publications and guidelines
>
> **Objective 3**: Raise awareness, appreciation, engagement with and enjoyment of heritage and communicate heritage message to a wider audience.
> **Action**:
>
> 3.7 Support and promote the work of national heritage organisations e.g., Heritage Council, Bird watch Ireland, NPWS, Pollinator Plan, Irish Georgian Society etc
>
> **Objective 4**: Increase level of community activity for heritage and support economy and local tourism.
> **Action**:
>
> 4.4 Work with Tourism and business organisations to promote and develop heritage resources in the city particularly in relation to accessibility and signage.

Action 2.4, and partially action 2.5, is fulfilled by this geological heritage audit, which includes field mapping to define the site and GIS definition of site boundaries. The remaining actions are only assisted by the production of this audit in as far as it provides information. For many of the publicly accessible sites, this audit may help to communicate the geological interest in an amenity site which is undervalued, unexploited or simply not well understood.

4.2 Ideas for Projects

Hardcore Cork https://hardcorecork.ie/
Hardcore Cork is an excellent outreach project by two Cork residents, represented primarily by a website and supported by Geological Survey Ireland's 2020/21 Geoheritage Small Grant Scheme. The resulting website offers an accessible and engaging introduction to the geology of Cork City, and has a range of resources aimed to increase public awareness of the local geology. This includes digital reconstructions of Cork City through geological time, a virtual exhibition of fossil, mineral and rock samples, and a series of walking tours through the city, highlighting key sites.

Screenshot of the Hardcore Cork homepage

This project has laid an excellent groundwork for geological outreach in Cork City. Opportunities for building on this include: further promotion of the website resource, particularly within schools; the production of walking tour leaflets to accompany the current Google Maps files; and a small physical exhibit to reflect the existing virtual exhibit.

Cork fossils https://sites.google.com/dcscork.ie/corkfossils/home
Cork fossils is a recent initiative to promote accessible fossils in Cork City. With a map of fossil localities, and a description of the fossils to be found there, it provides an excellent resource for school children, and alongside Hardcore Cork can be used to develop geology-themed walking tours of Cork City for different ages and interests.

Cork Geological Association
Founded in 1992, this association, in conjunction with UCC, presents a series of lectures and fieldtrips focussing on the theme of geology, and is composed of both professional and amateur geologists. This group is an excellent resource for examining and promoting geological heritage in Cork City.

Leaflets
Publicly available leaflets on the geology or geological heritage of Cork City would serve as a useful resource to visitors, schools and the local community, making existing initiatives accessible for those with less confidence using, or limited access to, certain technologies. Leaflets with guided trails and 'points-of-interest' could be made available as PDF downloads on the City Council website or via local community heritage, tourism and education programmes, building on the work of the Hardcore Cork and Cork Fossils projects.

Books
The 1:100,000 Geological Survey Ireland map report for Sheet 25 Geology of South Cork covers Cork City and is an essential resource.

It is suggested that much of the content in this audit report and accompanying site reports could be edited to produce a geological heritage of Cork City, similar to publications produced for Counties Mayo, Clare, Roscommon, Longford, Sligo, Fingal, and Waterford following geological audits in those counties.

Signboards
Simple explanatory or interpretive signboards or posts may be considered at key geological heritage locations but their location and individual siting should be selective. Cork City Council should have a controlling input, in conjunction with support from the Geoheritage Programme at Geological Survey Ireland. It is suggested that a single panel communicating various heritage interests at a location is preferable to multiple topic-specific panels. It is important to consult with potential partners in the planning stage so that duplication does not occur.

The collation of appropriate text and graphics on information panels requires both geoscientific and graphic design skills. The Geological Survey Ireland Geoheritage Programme can provide advice on appropriate content if signboards are considered.

Museum exhibitions
Section 3.1 and 3.2 detail two important outreach resources within University College Cork: the BEES Geology Museum, UCC, which hosts a wide selection of fossils, minerals and rock specimens, as well as a range of geological maps and books; and the UCC Geological Garden, a collection of 10 boulders from across Ireland, each with a QR code that can be scanned to provide a geological interpretation. Each of these collections would benefit from increased publicity, in as far as they are open to the public, and could provide important opportunities for public engagement.

The specimen of Connemara Marble on display in the BEES Geological Garden, UCC. A QR code is affixed to the side of each specimen for further information.

In addition, with some extra research covering human dependence on geology and resources, particularly within the context of Cork's rich quarrying history, and alongside the Hardcore Cork project, an interesting exhibition could be put together for display in the Cork City Council Offices, City Library branches or other public spaces based on the resources compiled in the audit. Similar exhibitions have been showcased following the completion of audits in counties Carlow, Dun Laoghaire-Rathdown, Waterford, Wicklow, and Longford.

New Media

There are increasing numbers of examples of new methods of promoting Earth Sciences, via mobile phone applications and other electronic media. Self-guiding apps on specific sites would be one of these, such as those produced by Ingenious Ireland (www.ingeniousireland.ie) for Dublin city geology, and the app for tourists in the Burren and Cliffs of Moher UNESCO Geopark. Hardcore Cork has produced walking tours that can be followed using the Google Earth app, and further promotion of these, as well as development of new routes, is encouraged.

Geoschol website www.geoschol.com

Geoschol is an educational project, now essentially represented by a website, which was largely aimed at producing educational materials on geology for primary schools. A four-page PDF summary of the geology of County Cork (including Cork City) is available for download (see Appendix 8).

City Geological Heritage Research Archive

A geological heritage research archive was produced for the Burren and Cliffs of Moher UNESCO Geopark, with public access to PDF publications, reports and academic papers. The reference lists provided in this audit report could form the foundation for such an initiative in Cork City. The availability of technical references of direct relevance to Cork City geology and geomorphology may assist users and researchers into the future. The literature is specialist in nature, such that a geological heritage section with a select bibliography on the City Council Heritage web pages might suffice for most users with general interest in heritage.

Maps

The inclusion of County Geological Sites and geological heritage information in the future Ordnance Survey Ireland paper map editions of the 1:50,000 Discovery Series would be a welcome venture. Some EastWest Mapping maps, including County Wicklow and County Mayo, currently include Geological Survey Ireland data.

5. A summary of the geology of Cork City

Concise simple summary of the geology of Cork City

Cork City is primarily underlain by two main types of sedimentary rock: Old Red Sandstone, from the Devonian, in ridges to the north and the south; and Carboniferous limestone in two east-west bands through the centre of the city and further north, near Blarney. These layers of rock are folded along an east northeast-west southwest axis. These main rock types can be seen in buildings and infrastructure throughout the city. The land surface is mainly controlled by the locations of the harder sandstone and softer limestone, but has also been further shaped by glaciation, glacial deposits, karst features and fluvial processes along the path of the River Lee.

More detailed summary of the geology of Cork City

The bedrock lithologies of Cork City primarily record a northwards marine transgression. During the Devonian, sediments were deposited in a low-latitude, semi-arid desert environment. Near the Devonian-Carboniferous transition, the shallow tropical sea to the south began to inundate the continent of Laurussia. Subsequent deposition in the early Carboniferous occurred within different depositional environments within the South Munster basin, in increasingly deeper seas.

Old Red Sandstone, from the Famennian of the Upper Devonian (~372-359 Ma), forms the northern and southern bands of rock in Cork City. These rocks are predominantly green, grey and red sandstones, siltstones and mudstones, with examples of cross-bedding, flaser-bedding and infrequent fossil material. Purple mudstones and red sandstones were deposited by fluvial systems in semi-desert environments to form the Ballytrasna formation, which were overlain by the sandstone, mudstone and siltstone of the Gyleen formation, deposited on the coastal plain bordering the sea to the south of the continent. The flaser-bedded Old Head Sandstone formation was subsequently deposited in intertidal and subtidal zones during the uppermost Devonian, as shallow tropical seas began to inundate the continent to the north and the South Munster Basin subsided.

Carboniferous limestones from the Dinantian (~359-331 Ma) are fossiliferous and exhibit karst features including caves and springs, and are found primarily in two east-west bands: one through the centre of the city; and one further north, near Blarney. Throughout the Carboniferous, subsidence of the South Munster Basin continued at decreasing rates, and the shore-line of the late Devonian - early Carboniferous sea continued to move northwards, with Carboniferous Limestones deposited primarily on the North Munster Shelf. The Carboniferous Kinsale formation, including the Castle Slate member and the Cuskinny member, is predominantly composed of mudstone with some sand-lensing, and represents a depositional water depth above the storm wave base. As the basin continued to subside, crinoidal, muddy limestones and shales from the Ballysteen formation were deposited, and mounds of fossiliferous Waulsortian limestones formed near the base of the continental shelf. These were overlain by thick successions of limestone, including the Cork Red Marble and Little Island formation, deposited in increasingly shallow depths on the shelf.

The Variscan Orogeny disrupted these earlier depositional environments, and the associated folding and faulting began to shape the landscape we see today. east northeast-west southwest trending fold axes define the folding in Cork City, including the “Cork Syncline,” and are responsible for the repeating pattern of Old Red Sandstone units to both the north and south, with a core of limestone units through the centre and another east-west band near Blarney. A series of approximately north

northwest-south southeast trending faults are seen today in linear gulley features, and may have historically acted as tributaries to the River Lee.

Bedrock geology controls the physical landscape of Cork City, and has produced Cork's distinctive ridges and lowlands. Areas of raised ground are typically underlain by Old Red Sandstone, and topographic lows in the city are characteristic of more easily eroded Carboniferous limestone bedrock. The River Lee is almost entirely underlain by Carboniferous limestone, with some siltstone and mudstone beds, and loosely follows the northern contact between the main sandstone and limestone units.

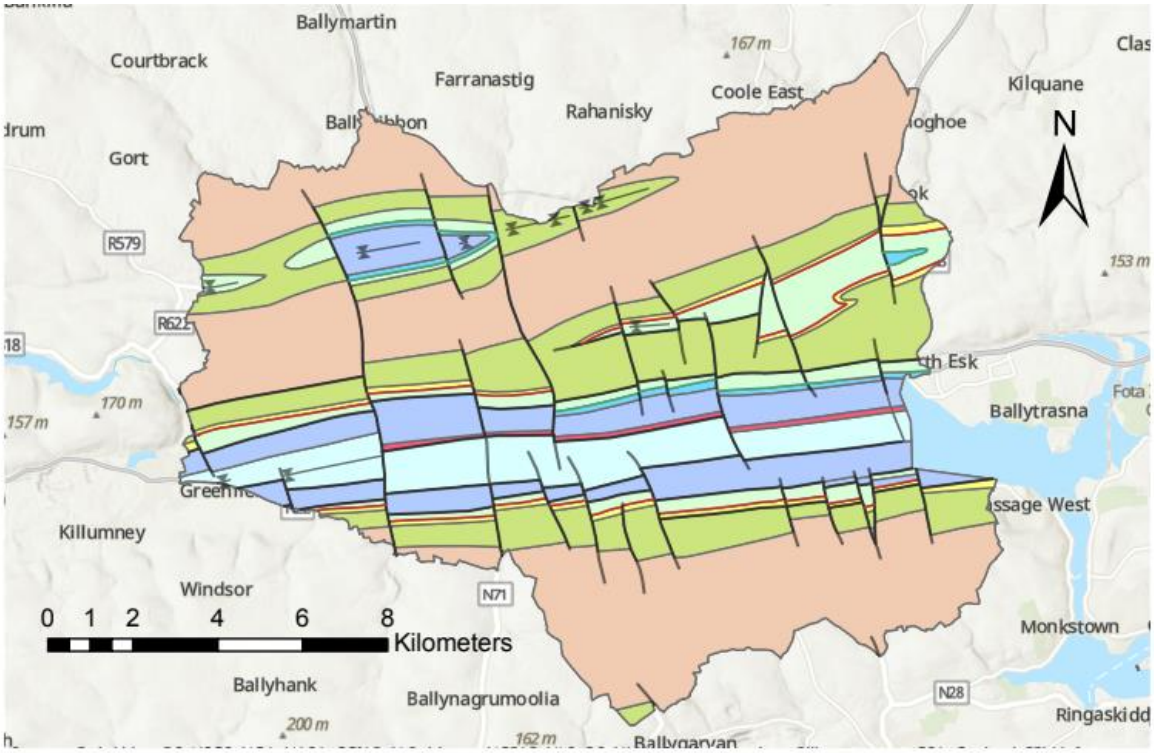
However, during the Quaternary Period, glaciation also had a major effect on the Irish landscape. For the last 1.6 million years Ireland's climate has oscillated between arctic and temperate conditions. Glacial erosion shaped the hills and surrounding terrain, and deposits from either glacier ice or glacial meltwater from the last Ice Age (ending approximately 11,000 yrs ago) account for most of the surface deposits in the city. The landscape topography in the city reflects the influence of glacial activity in the region during the last glaciations. Striae, tills, boulder clays, gravels, sands, silts and clays evidence the ice sheet that had covered the area, and reflect the rocks over which the ice flowed, with glacial deposits largely composed of Devonian and Carboniferous sandstone and shale, with smaller amounts of Carboniferous limestone in places. Sand and gravel deposits in particular are exploited for use in the construction industry.

Formation name	**Age**	**Lithological description**
Little Island Formation	Lower Carboniferous	Fine grained **limestone** with fossil crinoid material
Cork Red Marble Formation	Lower Carboniferous	Red, brecciated **limestone**, not technically a marble
Waulsortian Limestones	Lower Carboniferous	Unbedded **lime-mudstones**
Ballysteen Formation	Lower Carboniferous	Fossiliferous dark-grey muddy **limestone**
Ringmoylan Shale Formation	Lower Carboniferous	Calcium carbonate rich **shale** and **limestone**
Cuskinny Member (Kinsale Formation)	Lower Carboniferous	**Sandstone** alternating with thin layers of **mudstone**, and **mudstone**
Castle Slate Member (Kinsale Formation)	Lower Carboniferous	Grey-black slaty **mudstone**
Old Head Sandstone Formation	Upper Devonian	**Sandstone** alternating with thin layers of **mudstone**, and minor **mudstone**
Gyleen Formation	Upper Devonian	**Sandstone** with **mudstone** and **siltstone**
Ballytrasna Formation	Upper Devonian	Purple **mudstone** and **sandstone**

Table with simple descriptions of lithologies found in Cork City, adapted from Geological Survey Ireland Bedrock datasets

AGE (Million Years Ago)	ERA	PERIOD	EVENTS IN CORK CITY	IF THIS TIMESCALE WAS A DAY LONG…
2.58	Cenozoic	Quaternary	Extensive glaciation across a series of ice ages. Glacial erosion shaped much of Cork City's landscape, and glacial deposits can be found in the city.	Ice ages would begin 38 seconds before midnight
23		Neogene	*Erosion. No record of rocks of this age in Cork City.*	Neogene period begins at 11.52 pm
66		Palaeogene	*Erosion. No record of rocks of this age in Cork City.*	Palaeogene period begins at 11.40 pm
145	Mesozoic	Cretaceous	*Erosion. No record of rocks of this age in Cork City.*	Begins at 11.15 pm
201		Jurassic	*Uplift and erosion. No record of rocks of this age in Cork City.*	Age of the dinosaurs, starting at 10.55 pm
252		Triassic	*Active faulting and erosion. No record of rocks of this age in Cork City.*	10.41 pm
299	Palaeozoic	Permian	*Active faulting and erosion. No record of rocks of this age in Cork City.*	Starts at 10.26 pm
359		Carboniferous	Sand and mud deposited in the deepening South Munster Basin, and limestone deposited in shallow tropical seas on the North Munster shelf. Sedimentation stops due to Variscan Mountain building, which produces folds and faults.	The Carboniferous rocks we see in Cork City today are deposited until ~10.16 pm
419		Devonian	Sediment, eroded from the north, is deposited under semi-desert conditions in the Munster Basin. Marine conditions begin in the latest Devonian.	Cork City rocks start to be deposited between 10.03 and 10.08 pm
443		Silurian	*Shallow seas and mountain building following closure of Iapetus Ocean. No record of rocks of this age in Cork City.*	Starts at 9.42 pm
485		Ordovician	*Iapetus Ocean divides Ireland into two, with subduction related volcanism and deposition of sediments on the ocean floor. No record of rocks from this time in Cork City.*	Begins at 9.28 pm
541		Cambrian	*Opening of the Iapetus Ocean, with deposition in the basin and oceanic crust formation. No record of rocks of this age in Cork City.*	Starts at 9.11 pm
2500	Proterozoic	Precambrian	*Some of Ireland's oldest rocks form in the northwest and southeast of Ireland. No records of rocks of this age in Cork City*	Beginning 11.00 am
4000	Archaean		*Oldest known rocks on Earth*	Beginning 3.00 am
4600			*Age of the Earth*	Beginning 1 second after midnight

The Geological Timescale and Cork City



Limestones

- Little Island Formation
- Cork Red Marble Formation
- Waulsortian Limestones
- Ballysteen Formation

Structural Symbols

- Fault
- Synclinal Axis

Siliciclastic rocks

- Ringmoylan Shale Formation
- Cuskinny Member (Kinsale Formation)
- Castle Slate Member (Kinsale Formation)
- Old Head Sandstone Formation
- Gyleen Formation
- Ballytrasna Formation

Geological Map of Cork City outlining the main geological units. Map created from Geological Survey Ireland's Bedrock datasets.

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- Kenneth Higgs, School of Biological, Earth & Environmental Sciences, University College Cork, for his assistance with the St Joseph's Section on Lee Road CGS;
- Bettie Higgs, School of Biological, Earth & Environmental Sciences, University College Cork, for her assistance sourcing papers through the Cork Geological Association;
- The authors of GSI's previous County Geological Heritage Audits, whose work informed the writing of this report.

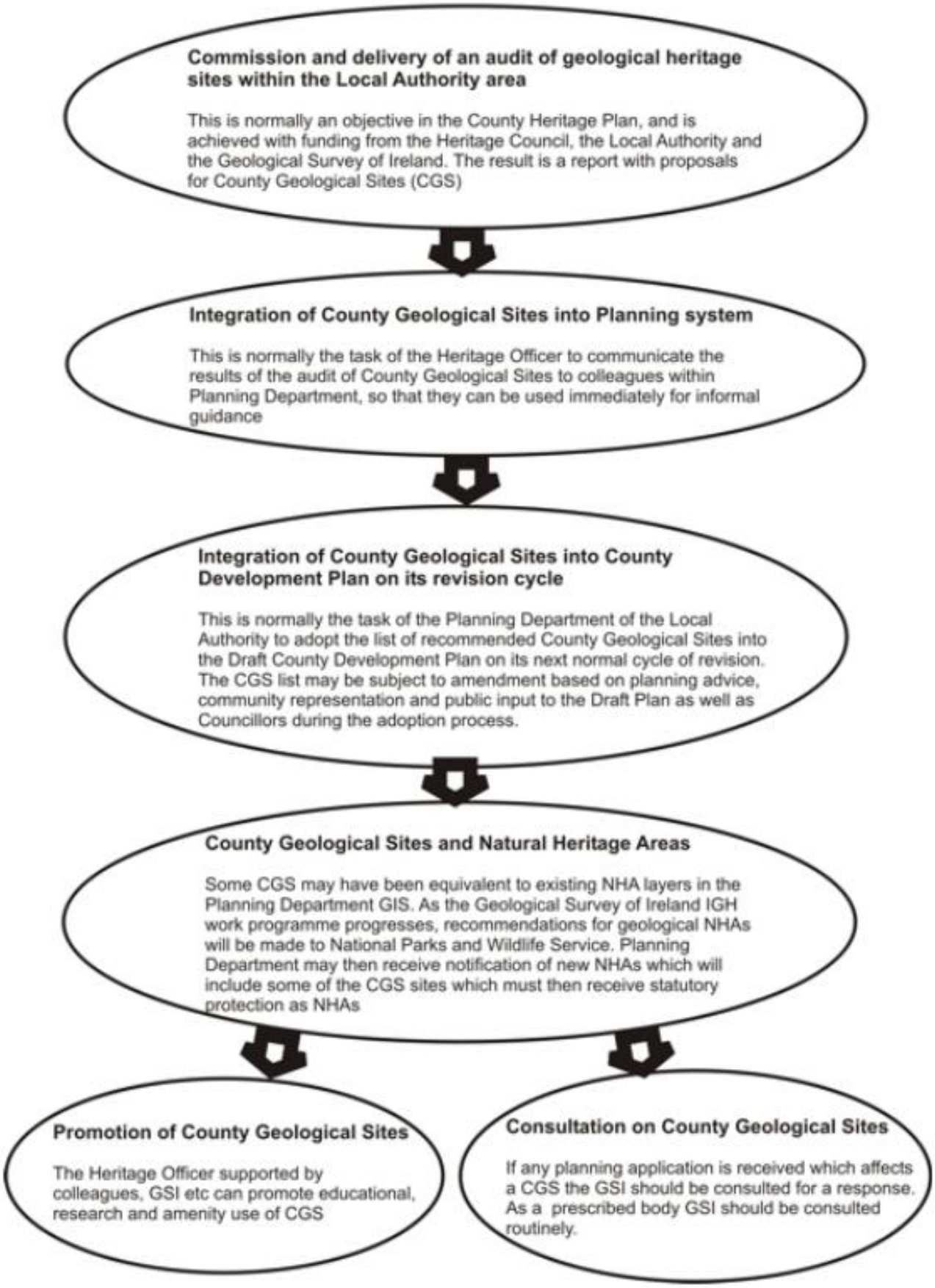
Appendix 1 – Geological heritage audits and the planning process

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

Geology is now recognised as an intrinsic component of natural heritage in three separate pieces of legislation or regulations, which empower and require various branches of Government, and statutory agencies, to consult and take due regard for conservation of geological heritage features: the Planning and Development Act 2000 [e.g. Sections 212 (1)f; Part IV, 6; First Schedule Condition 21], the Planning and Development Regulations 2001, the Wildlife (Amendment) Act 2000 (enabling Natural Heritage Areas) and the Heritage Act 1995. The Planning and Development Act 2000 and the Planning Regulations, in particular, place responsibility upon Local Authorities to ensure that geological heritage is protected. Implementation of the Heritage Act 1995, through Heritage Officers and Heritage Plans, and the National Heritage Plan 2002, allow County Geological Sites to be integrated into County Development Plans.

The chart below illustrates the essential process, established by the Geoheritage Programme (formerly IGH) in Geological Survey Ireland, over the course of numerous county audits since 2004. Due to timing and external factors, on this occasion, the Audit was carried out by Geological Survey Ireland. However, the overall process and principles remain the same.

County Geological Sites - a step by step guide



Appendix 2 Bibliography – Geology of Cork City

Appendix 2 provides a reference list of papers, books, articles and unpublished reports relating to the geology and geomorphology of Cork City and surrounding areas. Some regional geological papers may not be specifically relevant to Cork City. Appendix 3 includes Quaternary references.

Shortlist of Key Geological References

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

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Appendix 3 Bibliography – Cork City Quaternary References

Due to the very extensive influence of glaciation on the Irish landscape, and the relative accessibility for study there is an enormous body of literature on the Quaternary, or Ice Age geology of Ireland, and Cork. Appendix 3 includes Quaternary references, split into references specifically covering sites or features in Cork City, and a section of national or regional papers which have some data from or on Cork City included. Some papers that refer to regional quaternary geology may not be specifically relevant to Cork City.

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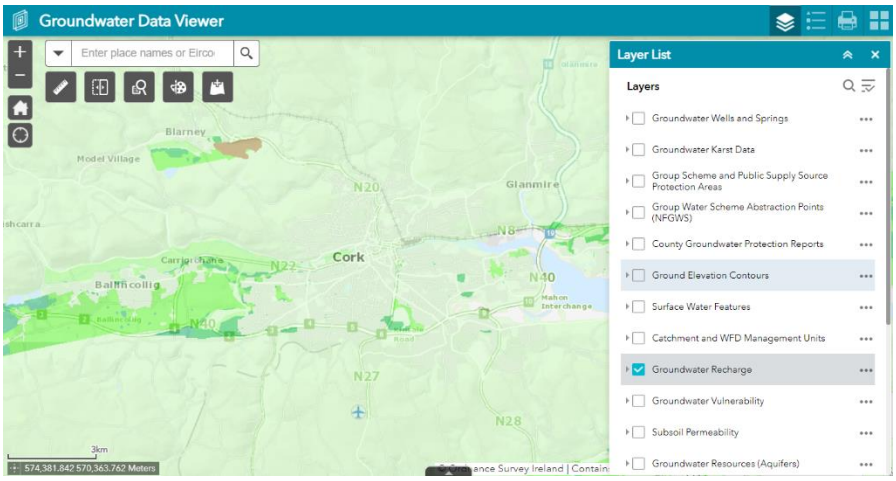
Appendix 4 – Geological heritage versus geological hazards

Ireland is generally considered low risk in terms of major geological hazards: there are no active volcanoes in Ireland; Ireland's location on a stable tectonic plate, distant from the closest active plate boundary (c. 2,500 km) means that earthquakes are rare; and from the annals of recorded history, Ireland has not experienced disastrous landslides, mudflows or other geological catastrophes that occur in other parts of the world. Aside from being spared from cataclysmic natural disasters, the risk of one-off events always remains, such as a potential tsunami which could occur in the aftermath of the collapse of seamounts in the Canary Islands. This section briefly explores the record and nature of geological hazards in Cork City and the relationship of the County Geological Sites to those hazards.

The difference between human timescales and geological timescales can be difficult to comprehend but, for many geological processes, there are periods of sudden activity encompassing major events, and then prolonged quiet periods in between. The County Geological Sites in Cork City represent evidence of past geological environments and processes, including semi-desert conditions in the upper Devonian, the shallow tropical seas of the Carboniferous, mountain-building events (Cork Syncline), and arctic environmental conditions when ice sheets covered the land surface.

Flooding

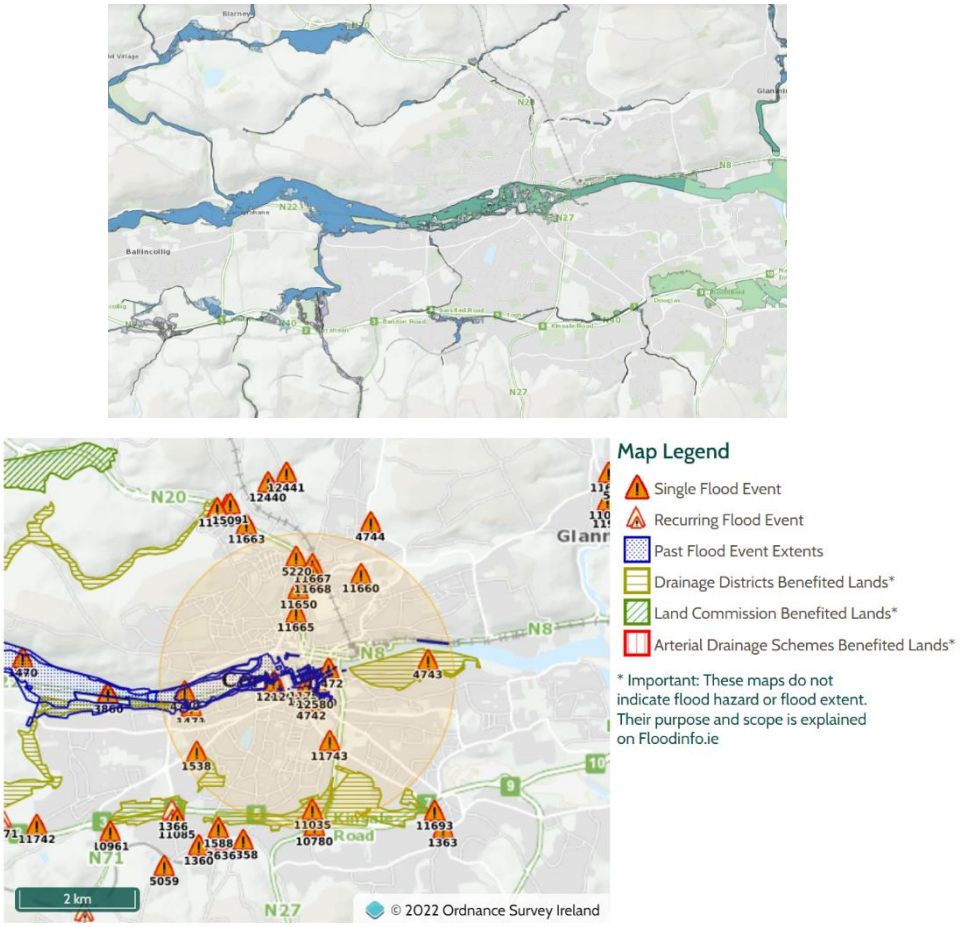
With water from pluvial, fluvial, coastal and groundwater sources, there are two main types of flooding that need consideration; river flooding and karstic flooding. River flooding occurs inland when the rainfall exceeds the capacity of the ground to absorb moisture, and the river channels cannot adequately discharge it to the sea.



Screenshot of Geological Survey Ireland Groundwater Data Viewer.

Groundwater flooding maps (historic & predictive) are available through Geological Survey Ireland web map viewers, such as the Groundwater Level Data Viewer. The historic flood maps provide information of historic flooding, both surface water and groundwater. The predictive groundwater flood map provides information on the probability of future karst groundwater flooding (where available). For information on the development and limitations of these flood maps, please check the associated user guidance notes.

The OPW website (www.floodinfo.ie) can be consulted for details of individual flood events in and around Cork City. Karstic flooding can occur when underground passages are unable to absorb high rainfall events. The River Lee in Cork City is largely underlain by a central E-W band of Carboniferous Limestone, and is prone to flooding. In the wider region there is also evidence of historic flooding associated with the Rivers Blackwater and Bandon, Glashaboy Estuary, Lee Estuary and Lough Mahon, including areas subject to recurring flooding events.

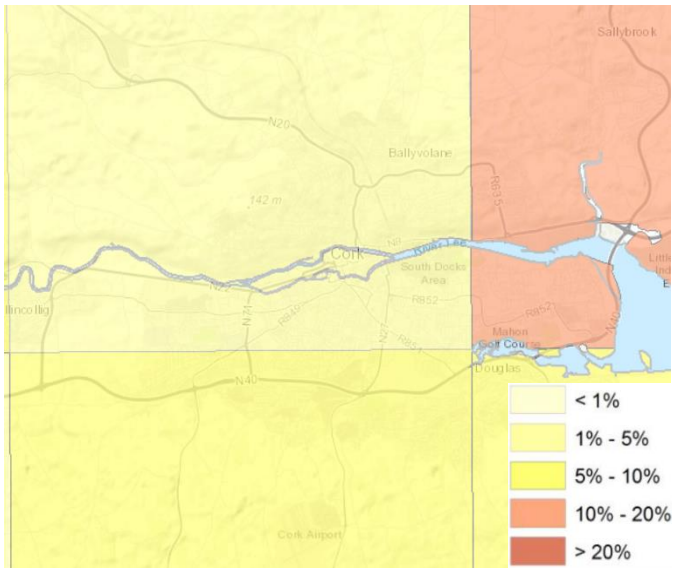


Screenshots of OPW Flooding Probability Map showing Cork City. Top: Green areas indicate potential coastal flooding events. Blue areas indicate potential fluvial flooding events. Bottom: locations of historic floods in Cork City

Strategic Flood Risk Assessments are required by 'The Planning System and Flood Risk Management Guidelines for Planning Authorities' (DEHLG and OPW, 2009) when creating County or City Development Plans, and the report for the Cork City Draft Development Plan 2022-2028 can be found online.

Radon

Radioactive minerals and gases at high concentrations can be carcinogenic. Radon can seep into homes and workplaces and can be carried in water supplies. A map showing the areas predicted to be at particular risk from radon in Ireland, called High Radon Areas, can be viewed on the Environmental Protection Agency (EPA) website (see EPA High Radon Areas map).



Screenshot of EPA Radon Map showing Cork City and environs. Legend is estimated percentage of homes above the Reference Levels. See www.epa.ie

Groundwater pollution

Whilst not such an obvious hazard as physical collapses, flooding and landslides, the pollution of groundwater supplies carries a serious risk to human health. As there are karstified groundwater aquifers underlying Cork City, it should be noted that karstic springs are especially vulnerable to pollution since the flow is mainly within fissure conduits allowing rapid transmission of pollution from source to water supply. There is also a regionally important gravel aquifer in Cork City, although here the opportunity for microbial attenuation of pollutants is far greater as the granular deposits act as a natural filter.

Landslides

Geological Survey Ireland has been compiling national data on landslides in the past decade. Cork City is predominantly classed as having a low level of landslide susceptibility, though there are small areas of moderate to high susceptibility found mainly along steep river valleys. No major landslide events have occurred in recent decades. See http://www.gsi.ie/Programmes/Quaternary+Geotechnical/Landslides/

Coastal Vulnerability

Geological Survey Ireland is undertaking a coastal vulnerability mapping initiative to gain an insight into the relative susceptibility of the Irish coast to adverse impacts of sea-level rise through the use of a Coastal Vulnerability Index (CVI). The main areas of vulnerability will be identified by both CVI and the analysis of individual variables, also called coastal indicators: geomorphology, cliff type, coastline orientation, regional coastal slope, tidal range, significant wave height, relative sea-level rise, and long-term shoreline erosion and accretion rates. The first phase of CVI mapping (2019-2021) is focused on the Irish Sea coast. https://www.gsi.ie/en-ie/programmes-and-projects/marine-and-coastal-unit/projects/Pages/Coastal-Vulnerability-Index.aspx

Ground Instabilities

As part of the FP7 PanGeo project, Geological Survey Ireland has developed a map and report identifying areas of potential or observed ground instabilities within Cork City. Satellite measurements of ground and building movement, combined with Geological Survey Ireland datasets and limited field validation, were used to develop these maps and reports. In total 25.31 km^2 of the 40 km^2 surveyed has potential or observed ground instabilities, with observed instabilities primarily associated with compressible ground, and potential instabilities largely related to dissolution of the limestone bedrock. A link to the report can be found at https://www.gsi.ie/en-ie/publications/Pages/PanGeo-Geohazard-Description-for-Cork.aspx

Appendix 5 Data sources on the geology of Cork City

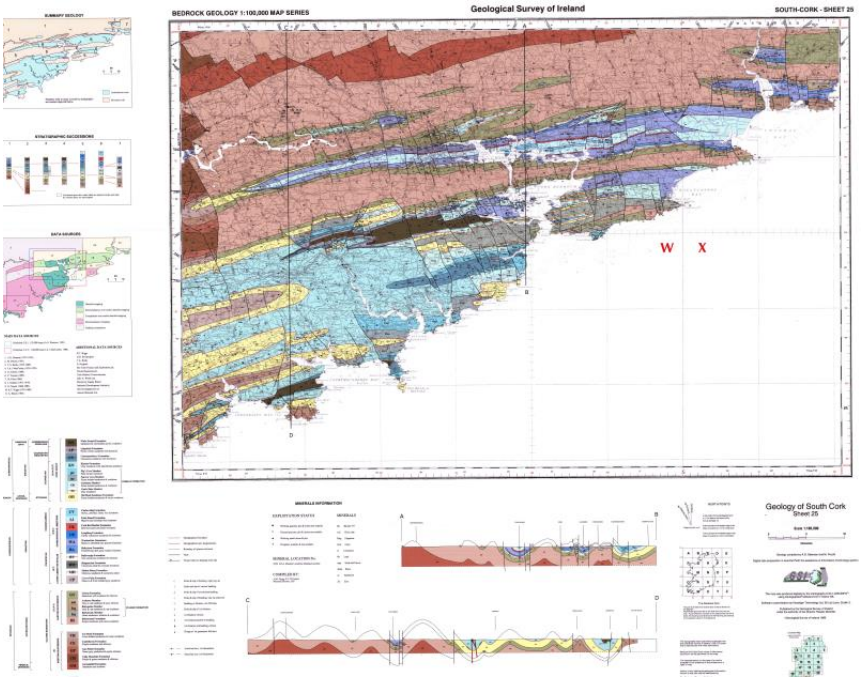
This section is a brief summary of various data resources that may be of assistance for queries relating to geology, groundwater and mapping. Geological Survey Ireland has accumulated an abundance of disparate data since it began mapping Ireland's geology in 1845. A Document Management System (called GOLDMINE) is freely available online, into which about half a million documents and maps have been scanned. Data is available free of charge. Key datasets include:

GOLDMINE

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

1:100,000 Map Report Series

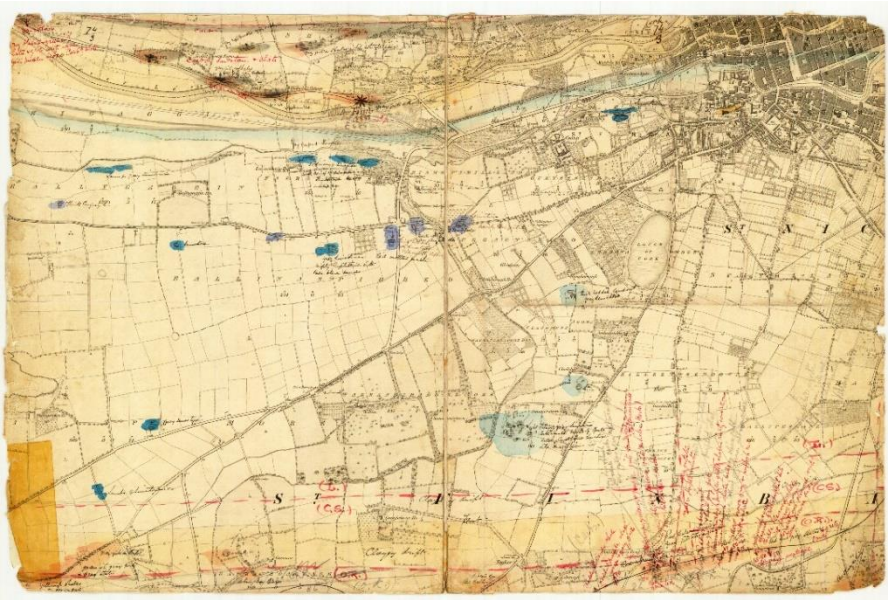
All historical, modern and other mapping deliverables have been compiled into colourful maps and detailed reports that describe the geology of the entire country. Geological Survey Ireland Sheet 25 covers all of Cork City.



Geological Survey Ireland Sheet 25 showing South Cork

19th century 6 Inch to the Mile Fieldsheets

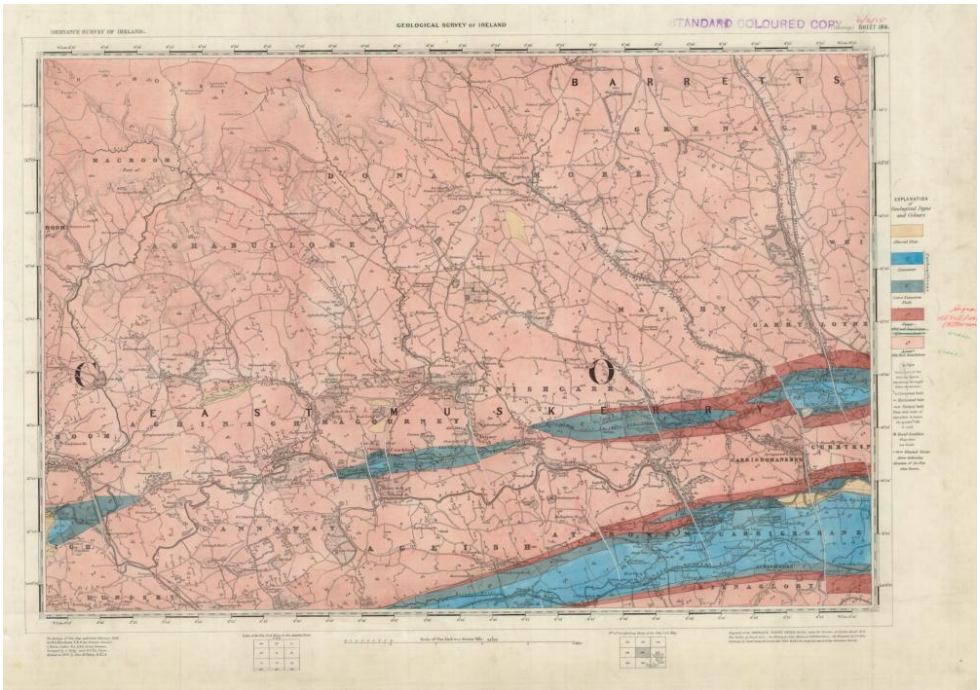
The 6" scale field sheet series provides an important historical and current resource with very detailed observations of the geology of the entire country. Produced in the mid-18th century, these sheets are available to the public in a digital format via GOLDMINE.



Excerpt from Geological Survey Ireland 6 inch to 1 Mile Field Sheet 74.

19th century One Inch to the Mile Maps and Memoirs

Information from the detailed 19th century mapping was distilled into one inch to the mile maps, of which parts of parts of Sheets 186, 187, 194 and 195 cover Cork City. Each sheet is accompanied by a memoir detailing the geology of that area in detail. The memoirs continue to provide valuable records of observations even though interpretations may have changed with better geological understanding. Memoirs are publicly available in scanned PDF format on the GSI GOLDMINE website. https://secure.decc.gov.ie/goldmine/index.html

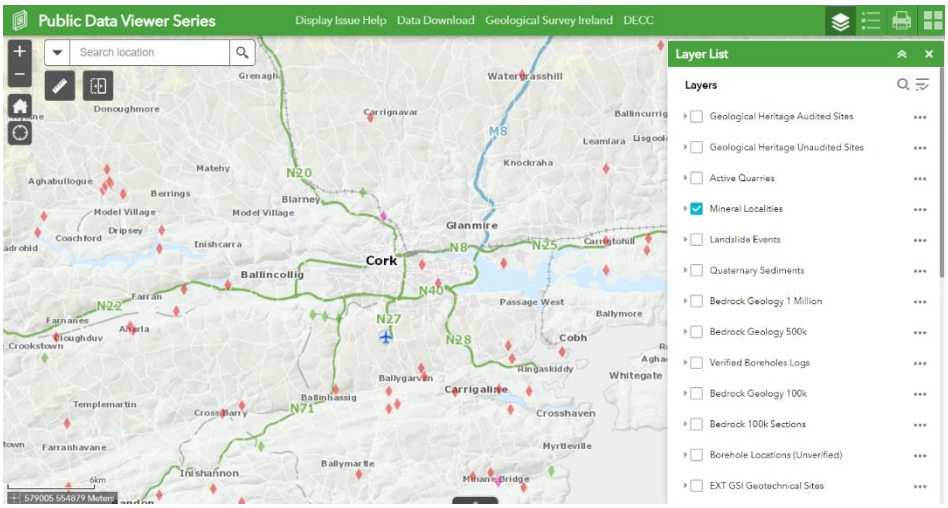


Geological Survey Ireland 1 Inch to 1 Mile Map Sheet 186.

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

MinLocs Data

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



Screenshot of Geological Survey Ireland Data Viewer displaying Mineral localities in Cork City

Open File Data

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

Subsoils Mapping

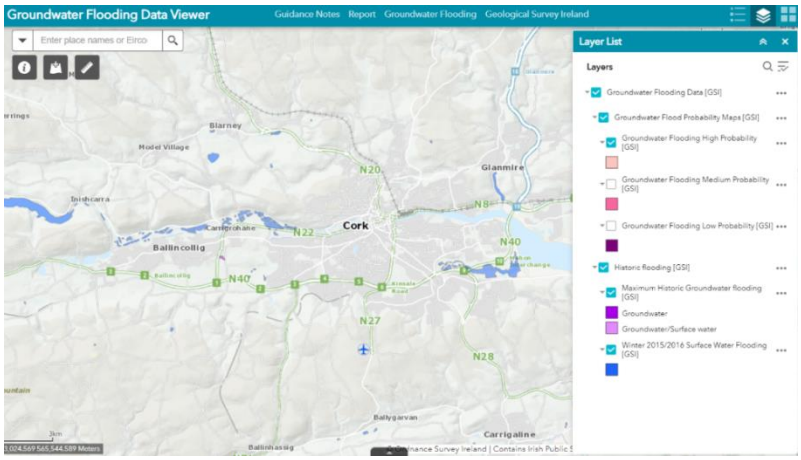
Subsoils are represented on Geological Survey Ireland's national 1:50,000 scaled Quaternary Geology map which indicates the sediment type, sediment origin and geomorphological features. Not only does it show sediments that were laid down during the Quaternary period but also post-glacial sediments, bedrock at or close to the surface, water bodies and made ground. It is continuously updated with findings from ongoing geological mapping campaigns. Digital maps are available on the Geological Survey Ireland public data viewer.

Subsoils may also be visualised in GSI's 3D geological models. These include 3D Quaternary Geology models of Cork and Dublin utilising data from the National Geotechnical Database. They may be accessed here and also viewed in Augmented Reality.

Subsoil mapping is informative about ground conditions for construction activities, ground permeability, groundwater vulnerability and resource (groundwater, aggregates etc) mapping. The Quaternary maps improve our understanding of glacial processes, of how landscapes operate and change and their subsequent susceptibility to hazards and climate change.

Groundwater Flooding

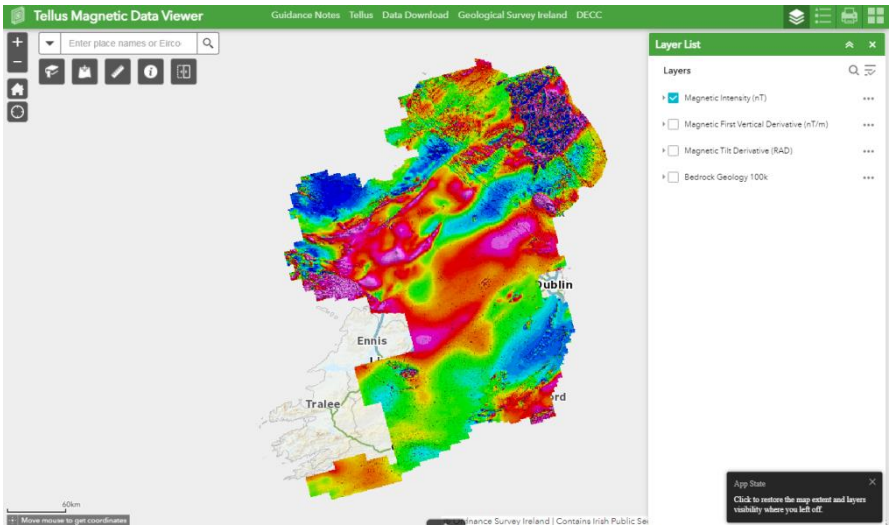
The winter of 2015/2016 saw extensive groundwater flooding in Ireland. The lack of data on groundwater flooding and groundwater flood hazard maps were identified as serious impediments to managing groundwater flood risk. Geological Survey Ireland in collaboration with Trinity College Dublin and Institute of Technology Carlow initiated a groundwater flood project (GWFlood) to address the deficits, and subsequently published (1) a Groundwater Flood Maps Viewer showing historic and predictive groundwater flood maps, (2) a Groundwater Level Data Viewer showing live groundwater hydrometric data and (3) a comprehensive project report (see www.gsi.ie).



GSI Groundwater Flooding Data Viewer.

Tellus Mapping

Tellus is an island-wide mapping project, combining airborne geophysical and geochemical surveys to provide geoscientific information for the island of Ireland. Tellus geophysical surveying of Cork County has been completed, and has been published in 2022, with ongoing surveying continuing across Ireland. All Tellus geochemical and geophysical data is available online free of charge. As of April 2022, the Tellus airborne geophysical survey has mapped over 80% of the country, with plans to extend this to over 90% by the end of the year. The Tellus soil geochemical programme aims to complete over 80% sample coverage by year end. Tellus will look to publish these data over the coming years. The Tellus surveys support mineral exploration, environmental management, agriculture and research activity. Data are freely available at https://www.gsi.ie/en-ie/programmes-and-projects/tellus/Pages/Data-and-Maps.aspx.



Coverage of Tellus Geophysical Survey up to April 2022.

Historic Mine Records in Geological Survey Ireland

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

The EPA, Geological Survey Ireland and the former Exploration & Mining Division undertook a joint project entitled "Historic Mine Site - Inventory and Risk Characterisation (HMS - IRC)". This project carried out detailed site investigations and characterisation on priority historic mine sites in the country. A risk ranking methodology was developed which categorised the sites according to the risks posed to human and animal health and the environment. The project commenced in January 2006 and was completed in December 2008. A final report and a GIS geodatabase was produced on completion of the project. Reports and maps are available at https://www.epa.ie/publications/monitoring--assessment/assessment/historic-mine-sites---inventory-and-risk-classification-volume-1.php and https://gis.epa.ie/EPAMaps/default?easting=?&northing=?&lid=EPA:LEMA_Facilties_Extractive_Facilities. The project provides an understanding of the impacts of historic mining sites in Ireland and their status at the time of the study.

There are no abandoned mines within the Cork City area covered by this audit, recorded in these data sets.

Ordnance Survey Ireland Geohive

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

Heritage Council Heritage Viewer

HeritageMaps.ie is a web-based spatial data viewer, co-ordinated by the Heritage Council, and working with the Local Authority Heritage Officer network, which focuses on the built, cultural and natural heritage around Ireland and off shore. The map viewer allows users to look at a wide range of built and natural heritage data sets online. Boundary data for County Geological Sites are available as a data layer on the online mapping service. http://heritagemaps.ie/

Appendix 6 Further sources of information and contacts

Geoheritage Programme staff at Geological Survey Ireland can be contacted in relation to any aspect of this report. The Cork City Heritage Officer is the primary local contact for further information in relation to County Geological Sites in Cork City. Other contacts include Conservation Rangers of the National Parks and Wildlife Service, currently in the Department of Culture, Heritage and the Gaeltacht. See www.npws.ie for contact details.

Websites of interest

www.gsi.ie	Geological Survey Ireland
www.npws.ie	National Parks and Wildlife Service
www.heritagecouncil.ie	The Heritage Council
https://hardcorecork.ie/	Hardcore Cork, a community project about Cork City's geology
https://sites.google.com/dcscork.ie/corkfossils/home	Cork Fossils, an online resource mapping fossils in Cork
www.geologicalmaps.net	Historical Geological Maps
www.geology.ie	Irish Geological Association
www.iqua.ie	Irish Quaternary Association
www.progeo.ngo	ProGEO – The European Association for the Conservation of Geological Heritage
www.floodinfo.ie	Office of Public Works Flood Plans and Flood Maps
https://secure.decc.gov.ie/goldmine/index.html	Geological Survey Ireland online data archive database

Appendix 7 Technical summaries of Cork City lithologies

Formation name	Age	Lithological summary
Little Island Formation	Chadian – Asbian, Dinantian	The formation is a uniform succession of crinoidal biomicrite limestones and massive unbedded calcilutite limestones from mudbanks. The top of the formation is highly crinoidal.
Cork Red Marble Formation	Chadian, Dinantian	The formation is characterised by cream, pink, and red calcilutite limestones and packstones with pseudo-breccias and a red mudstone matrix. Grey cherty calcilutites both above and below the reddened pseudo-breccias are also included.
Waulsortian Limestones	Tournaisian – lower Visean, Dinantian	Dominantly pale-grey, crudely bedded or massive limestone. Sometimes informally called "reef" limestones, although inaccurate.
Ballysteen Formation	Courceyan, Dinantian	Irregularly bedded and nodular bedded bioclastic limestones with a clay component, interbedded with fossiliferous calcareous shales. It represents a widespread development throughout Westmeath and Longford.
Ringmoylan Shale Formation	Courceyan, Dinantian	The formation is dominated by dark grey to black calcareous shales, with thin bands of shelly and usually crinoidal limestone.
Cuskinny Member (Kinsale Formation)	Courceyan, Dinantian	The member is sand dominant and characterised by alternations of flaser-bedded sandstones, lenticular-bedded (linsen) mudstones, massive sandstones and nodular mudstones. Thin quartz-pebbly sandstones and conglomerates also occur throughout the member.
Castle Slate Member (Kinsale Formation)	Courceyan, Dinantian	The member consists of uniform dark-grey, well cleaved massive mudstones. Crinoidal debris is common in some beds as are phosphatic nodules and disseminated pyrite. Rhythmic upward grading from sediment of medium silt size to fine silt and mud.
Old Head Sandstone Formation	Strunian, Famennian, Upper Devonian	The formation is dominated by grey flaser-bedded sandstones, wavy bedded fine-grained sandstones and minor mudstones and lenticular bedded mudstones.
Gyleen Formation	Strunian, Famennian, Upper Devonian	Fining upwards sequences are siltstone dominant (68%) but with a marked sandstone content (32%), with thinly bedded alternations of green and red sandstones, siltstones and mudstones towards the top. The base is marked by the lowermost erosive medium to coarse-grained sandstones.
Ballytrasna Formation	Famennian, Upper Devonian	In the type area 90% of the formation is composed of dusky-red mudstone while the remainder comprises pale-red fine-medium grained sandstone. The member contains significant quartz-pebbly sandstones at Ballyvoyle and Helvick Heads.

Table with technical summaries of the lithologies found in Cork City, adapted from Geological Survey Ireland Bedrock datasets

Appendix 8 – Geoschol leaflet on the geology of County Cork

CORK

AREA OF COUNTY: 7,457 square kilometres or 2,879 square miles

COUNTY TOWN: Cork

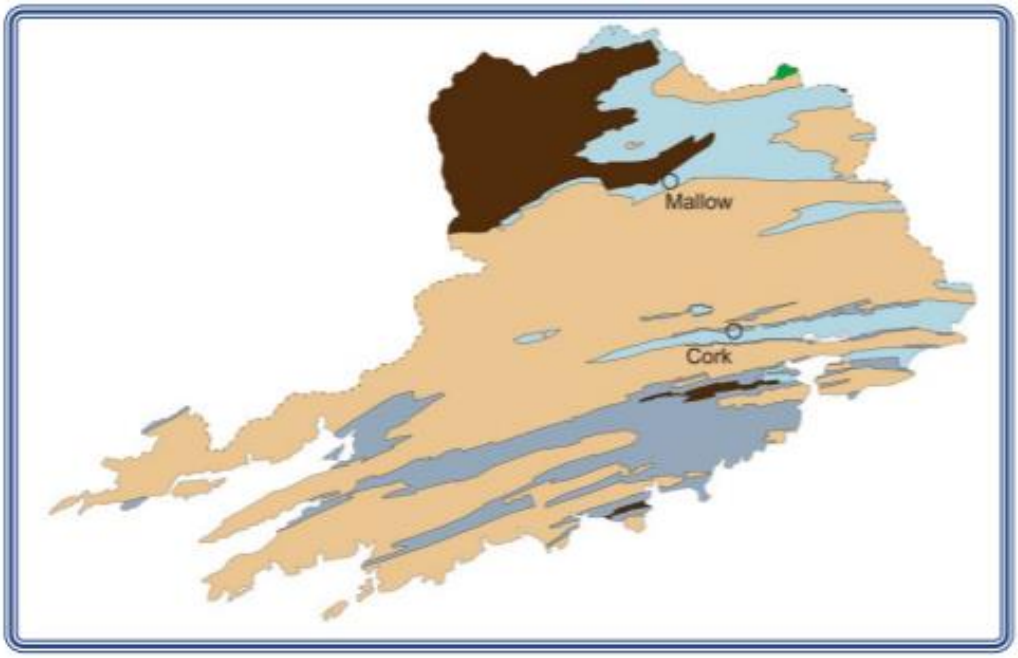
OTHER TOWNS: Bandon, Bantry, Charleville, Cobh, Mallow, Midleton, Millstreet, Skibbereen, Youghal

GEOLOGY HIGHLIGHTS: Copper mines, Cork Red Limestone, Kanturk coalfield, Jurassic and Palaeogene infill deposits.

AGE OF ROCKS: Silurian to Carboniferous; Jurassic; Paleogene

River Blackwater at Banteer, Co. Cork

The River Blackwater as well as the River Lee flow eastwards through Co. Cork in valleys underlain by Carboniferous Limestone. These are hemmed in by ridges of Devonian sandstones and conglomerates



Geological Map of County Cork

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

Geological history

The rocks in Co. Cork largely belong to the Devonian (415-360 million years ago [Ma] to Carboniferous (360-300 Ma] periods. However there is a small occurrence of older Silurian rocks in the northeast of the county on the edge of the Galtee Mountains. For millions of years during the Devonian Ireland was part of a large continent. In general the climate was seasonally wet, and a sparsity of terrestrial vegetation allowed dunes to form in places. Temporary rivers flowed towards the south and in times of rainfall these became torrents with flashflooding and they carried coarse cobbles and pebbles as well as sands downstream. These later were also lithified and are called conglomerates (coarse) and sandstone that collectively make up the Old Red Sandstone.

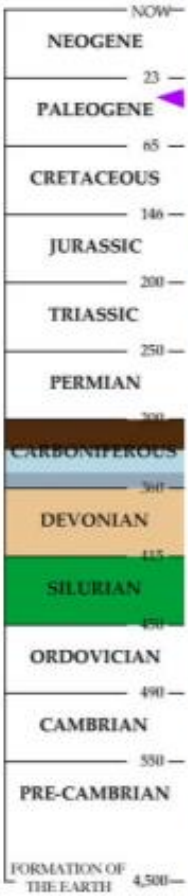
At the beginning of the Carboniferous an ocean began to spread northwards over Ireland. In south Cork a deep marine basin developed called the Munster Basin and this became infilled with shales and mudstones many

Quarry at Ballygiblin showing an orange clay that has infilled a solution hollow or cave in the Lower Carboniferous limestone. Pollen in this clay has proved that it is Paleogene (30 Ma) in age.

of which now contain flattened fossils. Overlying this were deposited limestones which were precipitated in a shallow, warm tropical ocean. Later in the Upper Carboniferous large southwest flowing rivers carried muds and shales into a deepening ocean, while close by at the same time forests in warm swamps thrived. The shales now cover the northwest of the county and the plants which had become compressed by overlying rocks turned into coal that was for many years mined at Kanturk.

Approximately 270 Ma during the Permian period a mountain-building event called the Variscan affected the rocks in Co. Cork. Two continents collided and the rocks were folded into a series of ridges (anticlines) and valleys (synclines) that have an east-west orientation. Across the ridges erosion has removed the younger rocks to expose the Old Red Sandstone while in the valleys the younger Carboniferous rocks still remain. By and large the rivers in Cork flow along the limestone synclines and in the west they have been drowned by seawater to form rias.

Metal deposits such as copper were carried by hot fluids into the rocks of west Cork and these were later mined. During the Jurassic, around 180 Ma, and later during the Paleogene, much of Ireland was land and the exposed limestone became riddled with caves and fissures. Some of these cavities became infilled with clay and are now the only rare evidence for these very young rocks or sediments in the county. Jurassic clays have been found at Cloyne, near Cork, while Paleogene clays are known from Ballygiblin, near Cecilstown.



Geological timescale showing age of rocks in Cork.

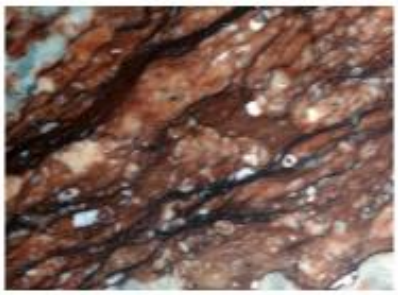
Copper Mining in west Cork

Copper was used by early settlers in Ireland to make bronze weapons. West Cork was an important site for copper mining during the Bronze Age 4000 years ago, and mines were opened at Mount Gabriel (top right). Here miners built fires against the rock and then quenched it with water to break up the stone. The metal ore was then picked out and smelted into useful objects.

Between the 1700s and the 1880s numerous copper mines were opened in the Bearhaven and West Carbury districts where miners came from Cornwall and Wales. The famous Man Engine House at the Mountain Mine, Allihies (centre right) was used to transport the miners down the mine. Other engine houses were used to pump water out of mines.

Cork Red Limestone

This Lower Carboniferous limestone (bottom right) was used for decorative work in churches and other buildings until the 1920s. Quarried at Baneshane, Cobh, and Midleton it contains small circular crinoid fossils and was easily polished. The red colour comes from iron oxides eroded from the underlying Old Red Sandstone.



Suggested reading

• William O'Brien and Anna Brindley: *Mount Gabriel: Bronze Age mining in Ireland* (1994) Galway University Press, Galway.

Map adapted with permission from Geological Survey of Ireland 1:1,000,000 map 2003.
Image credits: Mike Simms 1, 3; Matthew Parkes 4 (top); Mining Heritage Trust of Ireland 4 (centre); Patrick Wyse Jackson 4 (bottom).

Text by Patrick Wyse Jackson & Mike Simms

Appendix 9 Glossary of geological terms

Geological term	Definition
Agglomerate	a rock composed of large, coarse lava fragments, from explosive reactions
Basin	low areas in the Earth's crust, of tectonic origin, in which sediments have accumulated.
Bedding	the layers, or 'beds', of sediments deposited that form the rock.
Bedrock	a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
Bioclast	Biological material, often shells or shell fragments, which act as sedimentary grains.
Biomicrite	A limestone consisting of clasts of bioclasts set in a fine-grained limestone mud matrix.
Bivalve	an aquatic mollusc with a compressed body enclosed within two halves of a hinged shell
Boulder clays	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock or silt. Also known as till.
Breccia	a rock composed of angular clasts or fragments set in a fine-grained matrix
Calcareous	a term describing sediment, sedimentary rock, or soil type which is formed from, or contains a high proportion of, calcium carbonate
Calcite	a pale mineral composed of calcium carbonate, which reacts with dilute hydrochloric acid.
Calcilutite	a type of limestone with either the component of clay-size or both silt-size and clay-size detrital (transported) carbonate grains making greater than 50% rock content.
Channel	a landform formed of the outline of a path of relatively shallow and narrow body of fluid, most commonly the confine of a river, river delta or strait.
Chert	a fine-grained sedimentary rock composed of microcrystalline or cryptocrystalline quartz, the mineral form of silicon dioxide.
Conglomerate	a rock composed of rounded to subangular clasts greater than 2 mm in diameter
Continental shelf	a portion of the continental margin comprising a relatively shallow submarine terrace, before the shelf break
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	sedimentary layering at an angle to the main bedding plane, resulting from progressive movement of sloping ripple or dune surfaces.
Diamict	lithified, poorly-sorted deposits comprising clasts of various sizes in a mud matrix
Dinantian	a series from the Lower Carboniferous of Europe, equal to the lower part of the Mississippian series, lasting from 358.9 to 330.9 million years ago.
Dip/dipping	when sedimentary strata are not horizontal they are dipping in a direction and the angle between horizontal and the inclined plane is measured as the dip of the strata or beds.
Famennian	uppermost stage of the Late Devonian, lasting from 372.2 to 358.9 million years ago.
Fault	planar fracture in rocks across which there has been some displacement or movement.
Flaser bedding	a sedimentary feature formed in bi-directional flows, where troughs of sand ripples are infilled by mud

Fold axis	the geometric straight line that marks the points of maximum curvature of a fold
Fluvial	pertaining to a river or stream.
Geomorphology	the study of the origin, formation and processes of landforms
Glacial	of or relating to the presence and activities of ice or glaciers.
Glaciofluvial	pertaining to the meltwater streams flowing from wasting glacier ice and especially to the deposits and landforms produced by such streams.
Gneiss	coarse-grained, banded rock formed during high-grade metamorphism where lightcoloured and dark-coloured bands are produced by separation of dark minerals (e.g. biotite, hornblende) and quartzo-feldspathic minerals into parallel bands.
Igneous	a rock or mineral solidified from molten or partially molten material i.e. from magma.
Intertidal	the area along a shoreline, which is above low tide and below high tide.
Joint	a fracture in a rock, which shows no evidence of displacement.
Karst	a landscape with distinctive hydrology and bedrock landforms that arise when the underlying rock is soluble
Lenticular bedding	interbedded mudrock and cross-laminated rippled sandstone
Limb	part of a fold with less curvature, found on each side of the fold axis.
Limestone	a sedimentary rock consisting chiefly of calcium carbonate ($CaCO_3$), primarily in the form of the mineral calcite.
Lithology	the description of rocks on the basis of such characteristics as colour, composition and grain size.
Marble	marble forms when limestone is metamorphosed under heat and/or pressure
Meltwater deposits	sediment deposited by meltwaters, including in meltwater lakes and channels. See also Outwash deposits
Meltwater channel	a channel cut by glacial meltwater, either under, along or in front of an ice margin.
Metamorphic	referring to the process of metamorphism or to the resulting metamorphic rock, transformed by heat and pressure from an originally igneous or sedimentary rock.
Mississippian	earlier (first) of the two subdivisions of the Carboniferous Period, lasting from 358.9 to 323.2 million years ago.
Miospore	microfossil pollen grains used to determine the age of the rock in which they were found
Mudstone	a non-fissile sedimentary rock primarily composed of clay or mud particles
Nodule	a rounded mineral concretion that is distinct from, and may be separated from, the formation in which it occurs.
Outcrop	part of a geologic formation or structure that appears at the Earth's surface
Outwash deposits	typically stratified sediments deposited sub-aerially by running glacial meltwater
Packstone	a carbonate rock that is grain-supported (the grains are largely in contact with each other) with a matrix of limestone mud
Palaeoenvironment	an environment from a previous point in geological time
Pegmatite	an igneous rock of approximately granitic composition, formed of very large, interlocking crystals
Pseudo-breccia	a limestone with a coarsely crystalline, apparently fragmented texture resembling that of a breccia, caused by partial and irregular dolomitization.
Pyrite	An iron sulphide mineral, commonly known as Fool's Gold

Sandstone	a sedimentary rock primarily composed of sand-sized grains, cemented together
Sedimentary	a rock formed of sediments, such as muds, sands and cobbles, deposited in aquatic and terrestrial environments and subsequently lithified.
Shaft	a steep sided cylindrical tube formed during karstification
Shale	a fine-grained sedimentary rock, primarily composed of mud and silt, which has developed layering following compaction
Siltstone	a sedimentary rock primarily composed of silt-sized grains, with a low clay content
Slickenlines	a linear structure resulting from friction during movement on a faulted surface, including: striations formed by mechanical forces; and mineral lineations formed by fibrous growth of crystals in a preferred orientation.
Spring	the point where an underground stream reaches the surface.
Storm wave base	the sea depth above which sediments on the sea floor are mechanically disturbed by waves formed during storm events.
Stratigraphy	the study of stratified (layered) sedimentary and volcanic rocks, especially their sequence in time and correlation between localities.
Stromatactis	a sedimentary structure characterized by a nearly flat bottom, and a convex-upward upper surface, consisting of sparry-calcite cement, usually in the central part of a reef
Subtidal	the subtidal zone of the seabed is below low tide, and is rarely, if ever, exposed.
Syncline	a fold where rock layers slope upwards on both sides of a common low point, so the youngest layers of rock are at the centre of the structure
Tectonic	pertaining to the physically deformed crustal rock and the processes that cause such deformation
Till	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock as sand, silt or clay.
Topography	the physical landscape and features of an area
Trace fossils	a fossil of biological activity such as feeding or burrowing, but not the organism(s) that created it
Transgression	an incursion of the sea over land area
Trend	the trend is the orientation of a linear feature, such as a fold axis.
Tributary	a freshwater stream that feeds into a larger stream or river, or a lake
Variscan Orogeny	the mountain building event caused by the collision of Laurussia and Gondwana to form Pangaea, approximately 380 to 280 million years ago
Volcanic Rock	any rock produced from volcanic material, e.g. ash, lava.
Waulsortian	Lower Carboniferous age limestones consisting of skeletal debris and carbonate mud. The sediments commonly form individual and coalesced mounds with depositional dips of 20-40 degrees. Named after rocks in Belgium.
Younging direction	the direction in which layers of rock get progressively younger

Section 2 - Site Reports

Site reports – general points

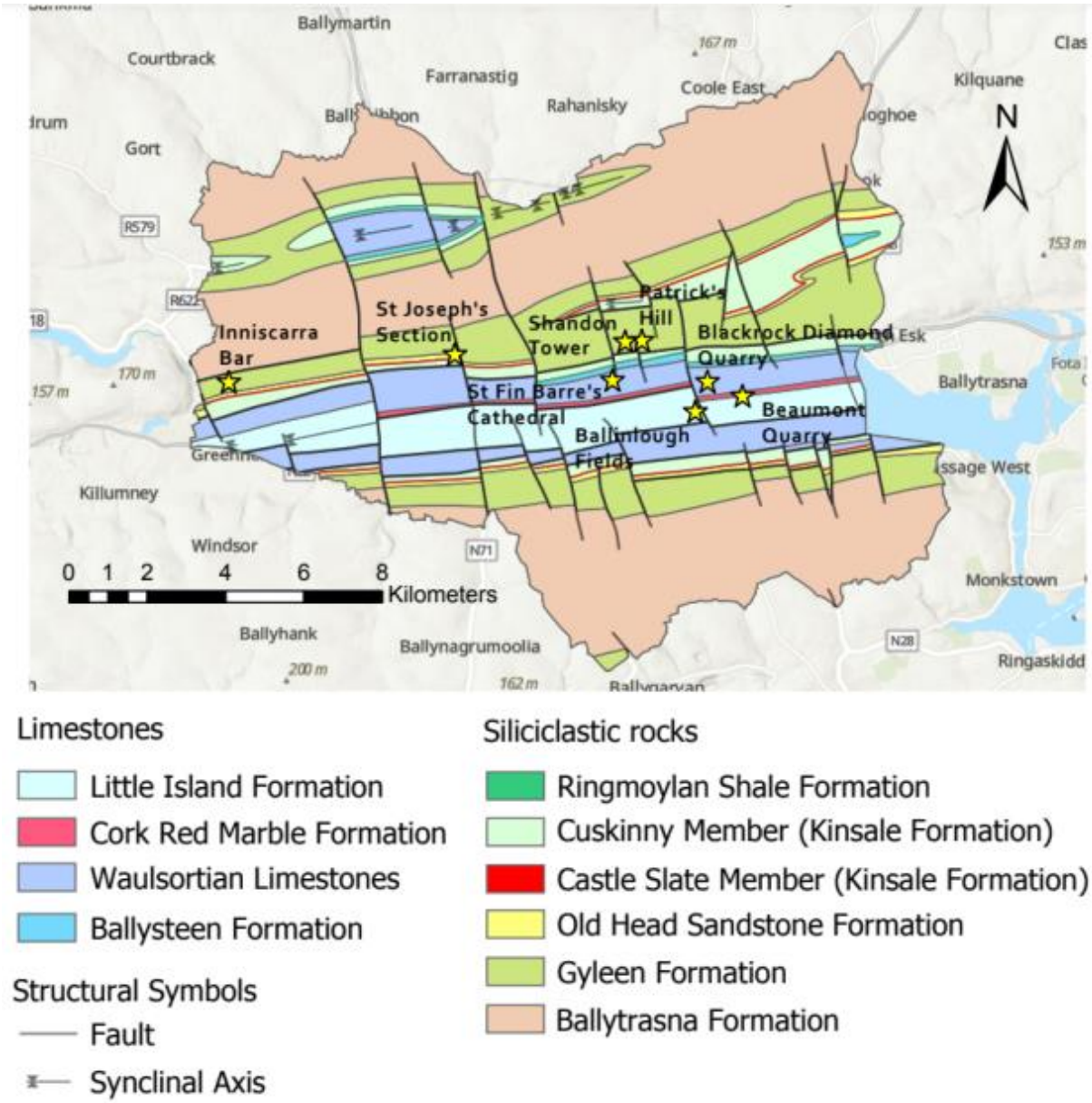
The following site reports are non-technical summaries of the proposed County Geological Sites for Cork City. These have been specially prepared for this report in order to make the information accessible to planners and readers without geological training. Further sites may become relevant as Geoheritage Programme work develops.

Each County Geological Site report has primary location information, a summary of the main rock types and age, and a short description of the key aspects of scientific interest. A brief section outlining any particular management or other issues specific to the site is included, along with low-resolution photographs exemplifying the site. Additional photographs may be made available from the Geoheritage Programme should they be required for an information booklet or leaflet for the public. Site location grid references (Irish Transverse Mercator IRENET95) are given for a central point within the site boundary, as well as the townland in which the County Geological Site is located. Grid references are only indicative of the location, but the site extent is best shown on the included maps. Irish Transverse Mercator (ITM) is the geographic projection co-ordinate system currently used in Ireland (superseding Irish Grid TM65), and has been applied to all site localities in the site reports. Irish Transverse Mercator (ITM) is the standard co-ordinate system for OSI maps.

The site boundary extent is best shown on the included maps, and is also published on the Geological Survey Ireland Public Data Viewer mapping service. **It is important to note that these boundaries have no legal or definitive basis.** The boundaries are only indicative of the limits of exposure, or area of geological interest, and not based on detailed field and boundary surveys, which are outside the scope of this audit. Boundaries are drawn to include the geological or geomorphological interest of the site, and are generally extended to the nearest mappable boundary, such as a field boundary, path, road or edge of built-up area. County Geological Sites are non-statutory and so this should not prove problematic. If any sites are assessed for Natural Heritage Area (NHA) status in the future, boundaries may require small revisions.

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

In terms of any geological heritage site designation as NHA, due process of site reporting, boundary survey and very importantly, consultation with landowners where they can be readily identified, will take place before Geological Survey Ireland finalises recommendations with NPWS on the most important sites to be designated. Any landowner within areas or sites identified in 56 this report with concerns over any aspect of this project is encouraged to contact the Head of the Geoheritage Programme, in the Geological Survey Ireland, Block 1, Booterstown Hall, Booterstown, Blackrock, Co Dublin, A94 N2R6. Phone 01-6782837.



Geological map of Cork City with County Geological Site locations indicated. Map created from Geological Survey Ireland's Bedrock datasets.