

The Geological Heritage of Waterford

An audit of County Geological Sites in Waterford

by Matthew Parkes, Robbie Meehan and Sophie Préteseille

January 2012

The Waterford Geological Heritage Project was supported by

An Chomhairle Oidhreachta
The Heritage Council



This report is an action of the
County Waterford Heritage Plan 2006 – 2011

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Section 2 – Site Reports

IGH 1 Karst

Site Name

Ballynahemery Cave
Ballynameelagh Caves
Ballynamintra Cave
Bewley Caves
Bridgequarter Cave
Cappagh Quarry
Carrigmurrish Cave
Kilgreany Cave
Knockalahara Sink
Oonagaloor and Brothers Cave
Shandon Railway Cutting Cave
Sluggera Crossroads

IGH 2 Precambrian to Devonian Palaeontology

Site Name

Quillia
Raheen Shore
Tramore

IGH 3 Carboniferous to Pliocene Palaeontology

Site name

Not represented in Waterford

IGH 4 Cambrian-Silurian

Site name

The Copper Coast (Stradbally to Tramore)
Garrarus Strand
Kilfarassy Strand

Dunabrattin Head
Tankardstown
Knockmahon and Stage Cove
Bunmahon Head
Ballydowane Bay
Stradbally Cove
Croughaun Hill
Dunhill Quarry
N25 New road cuttings

IGH 5 Precambrian

Site name

Not represented in Waterford

IGH 6 Mineralogy

Site Name

The Copper Coast (Stradbally to Tramore) [see IGH4]

IGH 7 Quaternary

Site Name

Comeragh Mountains
Coumshingaun
Coumfea - Coumalocha
Crotty's Lough Corrie
Coumtay
Mahon Falls
Coumiarthar
Sgilloge Loughs Corrie
Ballyquin shore
Newtown
St. Declan's Stone, Ardmore

IGH 8 Lower Carboniferous

Site Name

Ardmore – Whiting Bay – Goat Island
Ballynacourty
Ballyquin shore [see IGH 7]
Clonea Strand

IGH 9 Upper Carboniferous and Permian

Site Name

Not represented in Waterford

IGH 10 Devonian

Site Name

Ardoginna
Croughaun Hill [see IGH 4]
Comeragh Mountains (volcanics)
Rathmoylan Cove

IGH 11 Igneous intrusions

Site Name

The Copper Coast (Stradbally to Tramore) [see IGH4]

IGH 12 Mesozoic and Cenozoic

Site Name

Not represented in Waterford

IGH 13 Coastal Geomorphology

Site Name

Ardoginna [see IGH 10]

The Copper Coast (Stradbally to Tramore) [see IGH4]

Garrarus Strand

Kilfarassy Strand

Dunabrattin Head

Kilmurrin Cove

Tankardstown

Knockmahon and Stage Cove

Bunmahon Head

Ballydowane Bay

Stradbally Cove

Tramore Burrow

Dungarvan Harbour (including Cunnigar Spit)

IGH 14 Fluvial and lacustrine geomorphology

Site Name

Ballymacart River

Blackwater Bend

Mahon Falls [see IGH 7]

Knockmealdown gullies

IGH 15 Economic Geology

Ardmore Mine

Tankardstown Mine [see IGH 4]

Drumslig

Ross Slate Quarry

IGH 16 Hydrogeology

Ballynamuck Boreholes

Fenor Bog

Appendix 1

Full Geological References for County Waterford

Appendix 2

References to the caves of County Waterford

Appendix 3

References to the mining heritage of County Waterford

Appendix 4

References to the Quaternary geology of County Waterford

Appendix 5

Rejected sites

Appendix 6

Unassessed sites

Appendix 7

Detailed Geological Map of County Waterford

Appendix 8

Geological heritage audits and the planning process

Report Summary

County Waterford is a geologically diverse place with many landscapes, areas and sites treasured by both natives and visitors. The bedrock foundation, with hundreds of millions of years in its formation and shaping, and the more recent history of geomorphological processes such as coastal erosion, limestone solution and scouring by glaciers, are what has created that underlying geodiversity. Geological understanding and interpretation is best done on the ground at sites where the rocks and landforms are displayed. County Waterford has a wealth of such natural and man-made sites.

This report documents what are currently understood to be the most important geological sites within Waterford by the Irish Geological Heritage Programme (IGH) of the Geological Survey of Ireland (GSI). It proposes them as County Geological Sites (CGS), for inclusion within the Waterford County Development Plan. County Geological Sites do not receive statutory protection like Natural Heritage Areas (NHA) but receive an effective protection from their inclusion in the planning system. However, many of the sites described in this report are considered to be of national importance as best representative examples of particular geological formations or features. They will be formally proposed by the Geological Survey of Ireland, for designation as NHAs by the National Parks and Wildlife Service after due survey and consultation with landowners. However, many of these sites fall within existing pNHAs and SACs where the ecological interest is founded upon the underlying geodiversity. The commission of this audit and adoption of the sites within the County Development Plan ensure that County Waterford follows a now established and effective methodology for ensuring that geological heritage is not overlooked in the general absence of allocated resources for progress at national level. It keeps Waterford at the forefront of geological conservation in Ireland.

This report is written in non-technical language (with a glossary for unavoidable geological terminology) as a working document for use by the Heritage Officer and the Planning department of Waterford County Council. It will also be made available via the County Council website for the people of Waterford. A chapter of the report includes recommendations on how to best present and promote the geological heritage of Waterford to the people of the county. It will also inform the work of the IGH Programme and be made available through the GSI website.

The preliminary sections, summary geological history and accompanying map, timescale and stratigraphical column particularly may be used as they stand to preface a booklet or as website information in the development of this work, and for information as seen fit by the Heritage Officer. The contents provide the essential ingredients for a public-oriented booklet on the geological heritage of Waterford.

Waterford in the context of Irish Geological Heritage

This report ensures Waterford is active at the forefront of geological heritage within Ireland, as it is only the eighth county to commission such an audit within the scope of the county based Heritage Plan. It will hopefully encourage other local authorities to follow what is now a tried and trusted methodology. In the absence of significant political and economic resources available to the relevant bodies for geological heritage conservation as Natural Heritage Areas (NHA) at a national level, it represents a significant level of progress in defining and safeguarding Ireland's geological heritage.

It also represents a significant commitment on the part of the Local Authority to fulfil its obligations to incorporate geology into the spectrum of responsibilities under the Heritage Act 1995, the Planning and Development Act 2000, Planning and Development Regulations 2001, and the Wildlife (Amendment) Act, 2000 and the National Heritage Plan (2002). The Geological Survey of Ireland (GSI) views partnerships with the local authorities, exemplified by this report, as a very important element of its strategy on geological heritage (see Appendix 8).

The Irish Geological Heritage Programme (IGH) in the Geological Survey of Ireland complements other nature conservation efforts of the last decade, by assessing Ireland's geodiversity, which is the foundation of the biodiversity addressed under European Directives on habitats and species by the designations of Special Areas of Conservation (SAC) and more recently 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 it fills a void which has been there since the abandonment of the Areas of Scientific Interest scheme, listed by An Foras Forbartha in 1981.

The IGH Programme does this by identifying and selecting the most important geological sites nationally for designation as NHAs. It looks at the whole of Irish geology and geomorphology under 16 different themes. A fundamental approach is that only the minimum number of sites necessary to demonstrate the particular geological theme is selected. This means that our first criterion is to identify the best national representative example of each feature or major sequence, and secondly any unique or exceptional sites. The third criterion, of any sites of International importance, is nearly always covered by the other two.

Designation of geological NHAs is by the GSI's partners in the Programme, the National Parks and Wildlife Service (NPWS) currently operating within the Department of Arts, Heritage and the Gaeltacht. Once designated any geological NHAs will be subject to normal statutory process within the Waterford Planning Department and other relevant divisions. **However, management issues for geological sites are generally less, and somewhat different from many ecological designations. The following section considers these issues.**

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

From a national perspective, as a result of extensive comparison of similar sites to establish which are the best, there is now a good knowledge of many other sites, which are not the chosen best example, but 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. It is these various other important sites that are proposed for County Geological Site (CGS) listing in the County Development Plan, along with the clear NHA selections.

In 2011, a Master List of candidate CGS and NHA sites has been established in GSI with the help of Expert Panels for all the 16 IGH themes. For several themes, the entire process has been largely completed and detailed site reports and boundary surveys have been done along with a Theme Report. Because much of the geology of Waterford happens to coincide with sites from these themes, many of the sites documented here are already selected and proposed for NHA designation, but due to various factors, they have not been formally designated yet. Therefore, inclusion of sites as County Geological Sites (CGS) in Waterford's planning system will ensure that they are not inadvertently damaged or destroyed through lack of awareness of them outside of the IGH Programme in GSI.

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

Geological conservation issues and site management

Since **geodiversity is the often forgotten foundation for much of the biodiversity** which has been identified for conservation through SAC or NHA designation, it is unsurprising that many of the most important geological sites are actually in the same areas. In these areas, the geological case enhances and cements the value of these sites for nature conservation, but requires no additional designation of actual land areas.

There tend to be two broad types of site identified by the IGH Programme. The first are small and discrete sites, which are the most common. They may be old quarries, natural exposures on hilly ground, coastal cliff sections, or other natural cuttings into the subsurface, such as Raheen shore at Newtown Head, Dunhill Quarry, Newtown, Kilgreany Cave or Clonea Strand. They usually have a specific interest such as fossils, minerals or are a representative section of a particular stratigraphical sequence of rocks. **The other type of site tends to be larger areas that represent a geomorphological interest – landscapes that illustrate processes which formed them.** The Coastal Geomorphology theme, the Quaternary theme and the Karst theme include such sites. In Waterford, the Comeragh Mountains with their superb glacial corries are characteristic of the larger sites encompassed under the IGH 7 Quaternary Theme. Long stretches of the coast of Waterford are likewise characteristic of the Coastal Geomorphology theme sites, aside from their other interesting features making them important under IGH Themes such as Precambrian to Devonian Palaeontology (IGH 2), Cambrian to Silurian (IGH4) or Mineralogy (IGH 6).

It is also important from a geological conservation perspective that planners understand the landscape importance of geomorphological features which may not in themselves warrant any formal site designation, but which are an integral part of the character of Waterford. A lack of awareness in the past, has led to the loss of important geological sites and local character, throughout the country. In Waterford a scenic landscape evaluation has been completed (contained in Appendix A9 Volume 3 of the County Development Plan) but it is intended to prepare a full Landscape Characterisation Assessment when resources allow. This will help provide a tool to help future planning decisions maintain the integrity of the County. However, as things currently operate, consultations with GSI, either by the planning department or by consultants carrying out Environmental Impact Assessment are the norm. This now routine pattern, plus strategic environmental assessment (SEA) have greatly improved the situation.

There are big contrasts in the management requirements for geological sites in contrast to biological sites. Most geology is actually 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 for the sites to be known about in the planning department, and more generally, so that consultation can take place if some development is proposed for a site.** In this way, geologists may get the opportunity to learn more about a

site or area by recording and sample collection of temporary exposures, or influence the design so that access to exposures of rock is maintained for the future, or prevent completely inappropriate developments through a strong scientific case.

In some other counties, working quarries may be designated simply because they are the best representative sections available of entire rock sequences, in areas where exposure is otherwise poor. No restriction would be sought on the legitimate operation of these quarries. However, maintenance of exposure after quarry closure would be sought with the operator and planning authority in such a case. At present, one working quarry, Cappagh Quarry, is included as a site in Waterford. These issues are briefly explored in a set of Geological Heritage Guidelines for the Extractive Industry, issued jointly by the GSI and the Irish Concrete Federation in 2008.

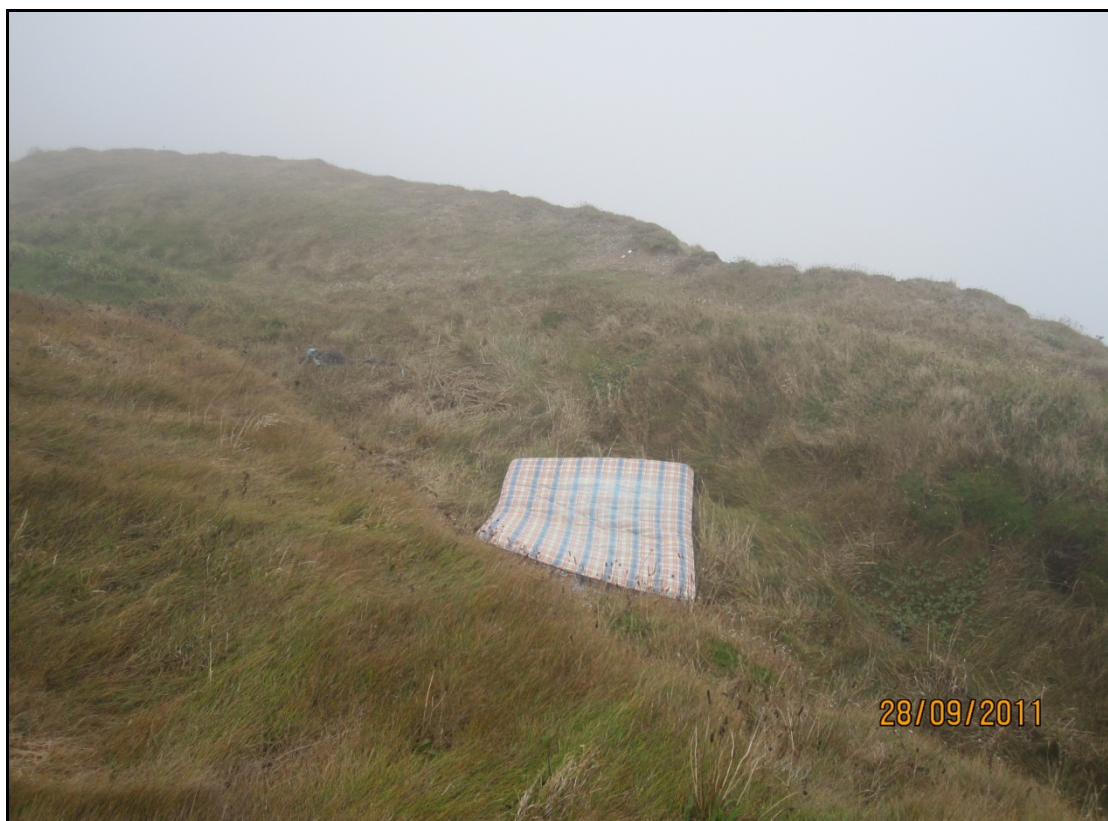
A new quarry may open a new window into the rocks below and reveal significant or particularly interesting features such as pockets of fossils or minerals, or perhaps a karstic depression or cave. Equally a quarry that has finished working may become more relevant as a geological heritage site at that stage in its life. It would possibly need regular maintenance to prevent overgrowth of vegetation obscuring the scientific interest.

Nationally, specific sites may require restrictions and a typical case might be at an important fossil locality or a rare mineral locality, where a permit system may be required for genuine research, but the general opportunity for collecting may need to be controlled. However, Waterford's palaeontological and mineralogical sites are not likely to require such an approach.

Waste dumping

A lesser problem, but one which does still occur, is the **dumping of rubbish in the countryside, but especially in closed depressions (dolines), collapsed caves or in active sinkholes in karstic areas**. The karstic areas of Waterford are relatively restricted to the valley floors inland westward from Dungarvan and to a much lesser extent near Ardmore. Long tradition of 'out of sight out of mind', is unacceptable today, and requires attention wherever it occurs.

The Copper Coast also suffers from waste dumping associated with abandoned mine shafts and former mining areas, such as the Tankardstown Mine area near Bunmahon, and along the R675 coast road. The mistaken expectations of people dumping, that the sea will take care of it, can only threaten the marine environment and the bird life such as choughs, for which these cliffs are designated as an SPA.



A dumped mattress opposite Tankardstown Engine House, September 2011.

The dumping of waste is not only unsightly and messy, but when waste materials are dumped in area where rock is exposed, such as quarries or karstic depressions, they may leach into the groundwater table as they degrade. This can cause groundwater pollution and can affect nearby drinking water supplies in wells. 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. Such a scheme has been completed for Waterford County Council by the Geological Survey of Ireland, thus ranking the county land surface into vulnerability categories of 'Extreme', 'High', 'Moderate' and 'Low', and helps planners in assessing which developments are suitable in some areas of Waterford, and which are not.

New exposures in development

One less obvious area where the Local Authority can play a key role in the promotion and protection of geology is in the case of new roads. **Wherever major new carriageways are built**, such as around the M9 and its intersection with the N24 and N25 northwest of Waterford City (largely in County Kilkenny), or in other major infrastructural work, it should be a policy within the Planning Department that **where new rock exposures are created, that they be left open and exposed** unless geotechnical safety issues occur (such as bedding dips prone to rock failure). The grading and grassing over of slopes in cuttings is largely a civil engineering convenience and a mindset which is hard to change. However, it leads to sterile and uninteresting roads which look the same throughout the country. By leaving rock exposures along the routeway, where they are intersected, it provides an

improvement in character and interest, reflecting the geology and landscape of the locality. Sympathetic tree or shrub planting can still be done, but leaving bare rocks, especially where they show interesting features, not only assists the geological profession, but creates new local landmarks to replace those removed in the construction of the roadway. This can also potentially save money on the construction. Waterford County Council has been successful in implementing this approach in the construction of new road sections, for example on the N25 between Waterford City and Dungarvan. Three of these new cuttings are treated as a County Geological Site in this report, since they provide valuable new windows into the sedimentary geology of the Waterford volcanic belt.



New cutting in N25
near Kilmeaden

Geoparks

An extremely interesting development in geological heritage, not just in Europe but internationally, has been the rapid recent growth and adoption of the 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 used to develop sustainable tourism opportunities**. Initially it was largely a European Geoparks Network (EGN) but has now expanded worldwide as the Global Geoparks Network (GGN) since 2004 and is fully assisted by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) [see www.globalgeopark.org and www.europeangeoparks.org]. A fundamental theoretical basis of the Geopark is that it is driven from the bottom up – the communities in the Geopark, are the drivers of the project and are the main beneficiaries. It therefore provides protection of the geological heritage resource so that the community can benefit from it.

In Ireland there are already two members of the Geopark Network. One is the Copper Coast in Waterford and the other is the cross-border Cuilcagh-Marble Arch Geopark in Fermanagh and Cavan [see www.marblearchcaves.net]. A recent active application for the Burren and Cliffs of Moher in County Clare to become a Geopark, has just been successful (September 2011), strongly supported by Clare County Council. In addition there are aspirant groups

exploring the work and infrastructure required for applications in other areas such as Joyce's Country in Mayo and Galway, and the Mourne Mountains and Carlingford area.

The Copper Coast Geopark has been a member of the network since 2001 and a reappraisal in the summer of 2011 has just confirmed (September 2011) that it still meets the fairly stringent requirements of the Geopark Network membership criteria, and has a valid membership for 4 more years.

This audit project may contribute to ongoing promotion of the geological heritage, and local commitment to the cause as well as firmly demonstrating Waterford County Council's support. In addition, the Copper Coast Geopark is preparing an application to extend the Geopark to include the Comeragh Mountains.

[see www.coppercoastgeopark.com]

Proposals and ideas for promotion of geological heritage in Waterford

The clear and significant inclusion of geological heritage in the Heritage Plan for County Waterford is a most welcome and positive step, for a topic that is often undervalued and poorly known in the wider community. This section examines the existing points in the plan relating to geological heritage and provides specific suggestions of how these may be implemented, supported or enhanced by the audit of geological heritage sites in the county.

AIM 1.0 Collect and disseminate information on the heritage of County Waterford and make it available

Objective 1.1 Establish and publish baseline information on heritage in County Waterford

1.1.17 Compile a database the industrial and engineering heritage of County Waterford.

Audit Action: any mining heritage information not included in the database can potentially be supplied by Matthew Parkes, through the Mining Heritage Trust of Ireland

1.1.20 Protect the geological sites listed in the County Development Plan and review the list where appropriate.

Audit Action: The audit will provide a robust and detailed report and dataset to achieve this objective in the Heritage Plan. However, ongoing review in future years for additional sites will be required. Some vigilance on the ground at sites will be required to ensure they are not damaged. The GSI should be consulted on any planning application that is potentially impacting upon an identified County Geological Site.

Objective 1.2 Add to the body of knowledge on the county's heritage

1.2.2 Continue to assemble images for the online Waterford Image Archive

Audit Action: The audit images can contribute to this objective.

1.2.7 Continue the Dungarvan Caves Project which is researching the archaeology of caves in the Dungarvan Valley.

Audit Action: The audit may contribute to the Dungarvan Caves Project through better integration of geological data with archaeological data.

AIM 2.0 Raise the level of awareness of heritage in County Waterford

Objective 2.1 Production of interpretative material; organisation of public events etc, on heritage in County Waterford

2.1.6 Prepare appropriate exhibitions on County Waterford's heritage for display in various centres throughout County Waterford. Use prepared ENFO exhibitions.

Audit Action: This objective is fulfilled in relation to geological heritage by the inclusion of draft content for a panel based exhibition (provided as supplementary to tender specifications).

2.1.9 Add to the existing stock of County Waterford heritage-related books, journals etc., digitally available on

the County Library website.

Audit Action: *Selected geological and speleological titles will be made available digitally to build this collection, from the authors' own connections (as Speleological Union of Ireland Librarian) and resources.*

Objective 2.2 Provide access to heritage in County Waterford

2.2.2 Continue to develop an infrastructure on the Copper Coast for sustainable tourism.

Audit Action: *The content of the report and ancillary deliverables (i.e. an exhibition) can be used as resources for educational products and in raising awareness of the geological heritage value of the Copper Coast.*

2.2.3 Implement and review the Walking Strategy in County Waterford, observing best practice with regard to heritage management and interpretation.

Audit Action: *The audit can serve as a basis for developing new walking routes, and associated information leaflets and signage if required.*

2.2.4 Prepare and implement a strategy for access to heritage sites and routes, to include the provision of signage.

Audit Action: *Strategy should include adding geological information on signage where geological sites have been identified along routes.*

2.2.5 Develop a walking route along the old Dungarvan to Waterford railway and consider developing further walking routes.

Audit Action: *The audit can serve as a preliminary basis for developing this new walking route, and associated information leaflets and signage if required. However, the survey of the route should be completed by a geologist to further develop this*

Objective 2.3 Promote heritage in County Waterford's education sector.

2.3.2 Provide content in the County Heritage webpages aimed at schools.

Audit Action: *Exhibition panels included as part of this audit project can be made available as a handy resource. In addition, the Geoschol 4 page leaflet on the geology of Waterford, aimed at primary level, can be made available or through a link to it on the Geoschol website (www.geoschol.ie).*

2.3.3 Consider a heritage course for in-service training of teachers in County Waterford.

Audit Action: *The Copper Coast Geopark would be in a strong position to assist as they have experience in running geology courses. The authors could also be available to contribute an earth science component to such a course, utilising much of the material in this audit.*

2.3.6 Continue the Copper Coast GeoPark education work for schools.

Audit Action: *The authors will continue to support Copper Coast Geopark education work in whatever ways are feasible. At present, Matthew Parkes supplies copies of the magazine Earth Science Ireland to Copper Coast Geopark and to the Heritage Officer, as well as to individual teachers on request. Other supports will be provided as appropriate opportunities arise.*

AIM 4.0 Promote best practice with regard to our heritage

Objective 4.1 Management of Heritage

4.1.11 Pilot biodiversity-enhancing practices in the creation and maintenance of road verges etc.

Audit Action: *It is advised that some consideration of geology and soil types is required in such schemes.*

4.1.16 Develop a County Waterford policy document on Water as a Heritage, to address the management of rivers, floodplains, lakes, wetlands, and other water bodies; in line with the requirements of the EU Water (framework) Directive.

Audit Action: *Material herein may act as a reminder to fully include karstic and other groundwater bodies in such a policy. Authors could potentially assist in developing a water policy document and ensuring that the groundwater component is fully addressed.*

4.1.24 Integrate Heritage management with the protection and enhancement of Tramore Dunes and Back Strand.

Audit Action: *Tramore dunes and back strand is included here as a site, and the report may provide assistance with this action.*

Objective 4.2 Heritage and the Development Process

4.2.3 Carry out Landscape Character Assessment in County Waterford.

Audit Action: *Landscape Character Assessment utilises geological characteristics as a fundamental defining factor and the content of this audit and report may provide useful input to the LCA process.*

Specific ideas for projects

Guides

There are only a few existing guides to the geology of parts of County Waterford, and even less aimed at a general audience (e.g. *The Copper Coast; Dunabrattin to Benvoy Strand; Stradbally to Ballydwane*. Landscapes from Stone: Geological Survey of Ireland, 1998). There is scope for many others, and for guides at different levels of detail and accessibility to non-specialists. A wide range of leaflets, booklets, books and other media are all feasible, but the research and production of appropriate text and images is a difficult task to do well without appropriate experience, and adequate time and resources. **It is suggested that with only modest editing and reorganisation the content of this report would comprise a good general guide to the geological heritage of County Waterford, in similar style to that produced in Sligo as a follow-on from the audit of sites conducted there in 2004.**

Signboards

Simple explanatory or interpretive signboards may be advisable at key geological heritage locations, but if these are considered, their locations and individual siting should be very selective, since a proliferation of different interest groups may provoke a 'rash' of panels all over the county. The Planning Section should clearly have a controlling input, in conjunction with the Heritage Office. It is most likely that a panel combining various heritage

interests at a place is preferred to single interest panels. It is important to consult with potential partners such as the Copper Coast Geopark in the planning stage so that duplication does not occur.

The subject of panels, and the integration of text and graphics are a fine art to complete successfully, and the IGH Programme can offer input if signs are planned for key visitor localities. The authors of this report are also able to write, review or provide content on geological heritage for any proposed panels.

At present the Copper Coast Geopark, the Mahon Falls and the Comeragh driving route are signed with directional brown tourism signs at several key junctions along the Waterford to Dungarvan route and at many points elsewhere, which is a prominent endorsement and recognition of geological heritage sites by Waterford County Council.



Museum exhibitions

As a result of the work to produce this report, the material for a panel based exhibition has been largely compiled. With some extra research covering human dependence on geology and resources, an interesting exhibition can be put together for display in the Museum, Council offices or County Library branches. The model followed was that produced for Carlow and for Dun Laoghaire-Rathdown. Images of these can be seen on the geological heritage section of the GSI website [www.gsi.ie].

Geoparks

Whilst there exists an active group, based in the local communities, developing Copper Coast Geopark projects and actions, the continued excellent support of the Heritage Office and the local authority is essential to the success and growth of the brand and the tourism potential, both for Irish and foreign visitors.

TV programmes

It is suggested that further short features within existing regular magazine style programmes (e.g. Nationwide on RTE1, EcoEye), or one-off

documentary programmes, may be the best avenues to seek Waterford coverage. With sufficient resources consideration could be given to making a specific programme or even a series on the geological heritage of Waterford. The IGH Programme and the GSI could advise on the development of this idea. Some existing programme concepts developed during International Year of Planet Earth but which did not get funded, are national in scope. The making of a specific programme or series on Waterford would need to be led from the county, and would require considerable drive and initiative to overcome prejudices and disinterest amongst media circles.

New media

There are increasing numbers of examples of new methods of promoting earth sciences, via mobile phones and other electronic media. Self guiding apps on specific sites would be one of these, such as those produced by Ingenious Ireland for Dublin city geology and for other sites. Plans for such products and many other exciting developments have been included in Copper Coast Geopark Interreg funded projects and new project applications, but other parts of Waterford could also benefit from such approaches.

Earth Science Ireland Group and magazine

[\[http://www.habitas.orguk/es2k/index.html\]](http://www.habitas.orguk/es2k/index.html)

The group Earth Science Ireland is an all-Ireland group promoting awareness of earth sciences and supporting educational provision in the subject. A main vehicle for the efforts is the twice a year magazine *Earth Science Ireland* and this is distributed free to thousands of individuals, schools, museums, centres and organisations. The editor would welcome more material from the Republic of Ireland and Waterford's geological heritage is featured in a major article in Issue 9, Autumn 2011. A second article on the Copper Coast is planned for issue 10 in the Spring of 2012.

Geoschol website [\[www.geoschol.com\]](http://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 summarising the geology and some highlights of Waterford is already part of the available material. If no material is available to add, then at least working links to the Copper Coast Geopark website and to the county council website (when the results of this audit are available) should be established.

A summary of the Geology of Waterford

1) Paragraph summary

The rocks of Waterford include three main types. A complex of volcanic rocks mixed in with sediments, mostly from about 460 million years ago, dominates the eastern part of the county, and is represented by the Copper Coast. Devonian rocks from around 400 million years ago dominate the western half of the county and are normally red sandstones and conglomerates. These are best seen in the Comeragh Mountains. Around 330 million years ago warm tropical seas flooded low areas of Ireland and deposited the generally fossiliferous Carboniferous limestone. Both it and the Devonian rocks were 'squeezed' into large scale folds at the end of the Carboniferous Period. Subsequent erosion has left limestone as the bedrock in the downfolds of the Dungarvan and Ardmore synclines while Devonian sandstones form the ridges of high ground. Following erosion over several hundred million years, the last two million years have had a profound impact on the landscape with glaciers eroding the high ground leaving corries in the Comeraghs and blanketing much of the lower ground with till.

AGE (Million Years Ago)	ERA	PERIOD	EVENTS IN WATERFORD	IF THIS TIMESCALE WERE A DAY LONG ...
2	Cenozoic	Quaternary	Several ice ages smothering Waterford, followed in the last 10,000 years by the spread of vegetation, growth of bogs and arrival of humans. Sculpting of corries in Comeraghs.	The ice ages would begin 38 seconds before midnight
65		Tertiary	Erosion, especially of limestone. Caves, cavities and underground streams developing in the Dungarvan and Ardmore synclines.	The Tertiary period begins at 11.40 pm
145	Mesozoic	Cretaceous	<i>Erosion. No record of rocks of this age in Waterford.</i>	11.15 pm
205		Jurassic	<i>Uplift and erosion. No record of rocks of this age in Waterford.</i>	The age of the dinosaurs, starting at 10.55 pm
250		Triassic	<i>Desert conditions on land.</i>	10.42 pm
290	Palaeozoic	Permian	<i>No record of rocks of this age in Waterford.</i>	10.30 pm
355		Carboniferous	Land became submerged, limestones with some shales and sandstones deposited in tropical seas across much of Waterford. Limestones remaining today are pure and unbedded in the central portions of the valleys, with muddier limestones at the edges.	Much of Waterford's current rocks (limestone, sandstone and shale) deposited around 10.10 pm
410		Devonian	Caledonian mountain building. Sandstones deposited throughout west Waterford.	'Old Red' Sandstone deposited at 9.52 pm
444		Silurian	Shallow seas, following closure of the Iapetus Ocean. Slates, greywacke and shales deposited between Carrick-on-Suir and the Comeraghs.	Starts at 9.42 pm
488		Ordovician	Slates, siltstones and volcanic rocks form across much of east Waterford.	Begins at 9.28 pm
542		Cambrian	Opening of the Iapetus Ocean. Mudstones and siltstones deposited east of Tramore.	Starts at 9.11 pm
2500	Proterozoic	Precambrian	<i>Some of Ireland's oldest rocks deposited in Mayo and Sligo.</i>	Beginning 11.00 am
4000	Archaean		<i>Oldest known rocks on Earth.</i>	Beginning 3.00 am
4600			<i>Age of the Earth.</i>	Beginning 1 second after midnight

2) Simple summary

The Precambrian rocks in Waterford are 600 million years old [Ma] and are now metamorphosed or altered sediments that were first deposited into an ocean and later changed during a later mountain-building event. During the Ordovician period (488-444 million years ago) shallow water limestones and some deeper-water muds were laid down in the Iapetus Ocean, that divided Ireland into two at that time. The Tramore Limestone dates from this time and contains bell-shaped fossil bryozoans called *Diplotrypa*. Some brachiopods (shells) and trilobites (arthropods, like Horseshoe Crabs) have also been found. As this ocean slowly closed, the continents on either side were subjected to great stress and volcanoes produced lavas and ash during eruptions. Along the coast at Kilfarrasy and Bunmahon these volcanic rocks can be seen. During the Silurian period, sediments continued to be deposited in the ocean that finally closed. This closure caused another mountain building event to take place causing many of the Silurian rocks to be tilted and then eroded away.

A new continent was created in the Devonian Period, around 400 Ma, when the Iapetus Ocean was finally closed. Large rivers drained from the newly formed mountains and deposited great thicknesses of sand and gravel on the flood plains. These sediments lithified (hardened) and in a few places these Devonian rocks can be seen lying on an ancient erosion surface on steeply tilted older rocks. The boundary between them is called an unconformity. These sandstones and conglomerate (pebble beds) now form all of the higher ground above 200 metres in the county, such as in the Comeragh and Knockmealdown mountains. By about 360 Ma, at the start of the Carboniferous Period, sea level was slowly rising and it drowned the flood plains. The fossiliferous limestones deposited in this warm, shallow equatorial sea now form much of the low ground across the county.

Both it and the Devonian rocks were 'squeezed' into large scale folds at the end of the Carboniferous Period. Subsequent erosion has left limestone as the bedrock in the downfolds of the Dungarvan and Ardmore synclines while Devonian sandstones form the ridges of high ground. Following erosion over several hundred million years, the last two million years have had a profound impact on the landscape with glaciers eroding the high ground leaving corries in the Comeraghs and blanketing much of the lower ground with till.

After the Ice Age the rivers in southern Ireland flowed north to south. As they eroded downwards, the upstream parts of rivers were reorientated by the underlying east to west trend of the landscape in south Munster. The River Blackwater flows for most of its length eastwards but at Cappoquin makes a marked right-hand turn and flows south to Youghal.

The coast between Fenor and Kilfarrasy is a European Geopark called 'The Copper Coast', and with good reason. In the nineteenth century, copper was mined at a number of localities by miners, some of whom brought their skills from Cornwall. Along the coast rocks can be seen with the tell-tale staining of copper minerals. Bunmahon was the centre of mining where the Mining Company of Ireland started to extract ore in 1826. A thriving industry needed engine houses with their square outlines and tall chimneys to pump water out of the mine shafts deep underground. Water wheels and dressing floors were used to remove the ore from the surrounding rock, and slipways were needed to transport the ore to ships that carried it to Swansea for smelting into metal ingots. By the late 1800s copper mining had ended in Waterford.

3) Extended summary

The oldest rocks in Waterford are of Precambrian age, dating from 600 million years ago (Ma) and are now metamorphosed or altered sediments that were first deposited into an ocean and later changed during a later mountain-building event. They underlie the low ground inland from Tramore and are not well exposed.

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The long coastal sections of the Copper Coast give an excellent cross section through the geology. There are intrusions of rhyolite and andesite, some like at Knockmahon with columnar shapes like a mini Giant's Causeway. The sediments were often not consolidated so intrusions created complex interactions and different degrees of deformation. The site at Dunhill Quarry provides proof that at times the volcanoes built up above the ocean surface and subaerial eruptions deposited ash and tuffs into the sea.

During the Silurian Period, sediments continued to be deposited in the Iapetus Ocean that finally closed at the end of this time. This closure caused another mountain building event to take place causing many of the Silurian rocks to be tilted and then eroded away. Today these rocks occur in the northeast of the county, to the south of Carrick on Suir, but they are not well exposed.

A new supercontinent was created in the Devonian Period, around 400 Ma, as the Iapetus Ocean closed. Large rivers drained from the newly formed mountains and deposited great thicknesses of sand and gravel on the flood plains. In a few places, like Ballydowane, these Devonian rocks can be seen lying on an ancient erosion surface on steeply tilted older rocks. The boundary between them is called an unconformity. These sandstones and conglomerate (pebble beds) now form all of the higher ground above 200 metres in the county, such as in the Comeragh and Knockmealdown mountains. By about 360 Ma, at the start of the Carboniferous Period, sea level was slowly rising and it drowned the flood plains. The fossiliferous limestones deposited in this warm, shallow equatorial sea now form much of the low ground across the county.

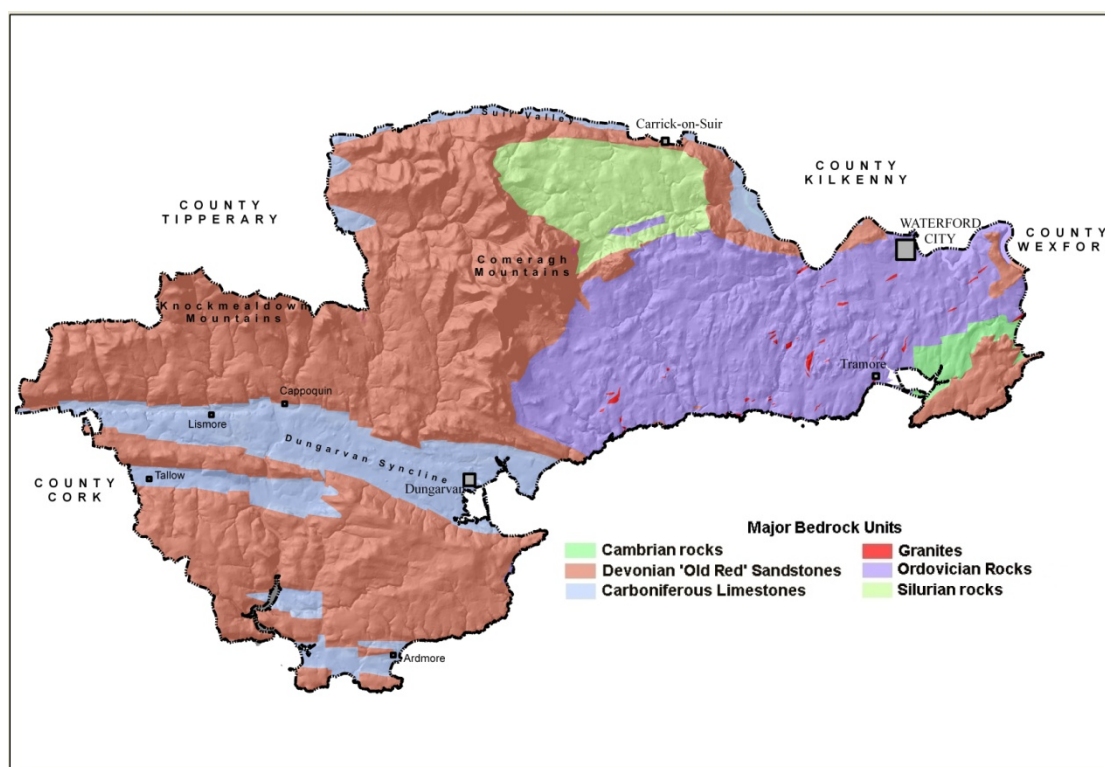
The Carboniferous limestone and the Devonian rocks were all folded into broad east west fold structures across Munster, as part of the Hercynian orogeny or mountain building episode, at the end of the Carboniferous Period. The downfolds, or synclines, now run along valleys from Dungarvan to Fermoy, and also at Ardmore, with a lesser syncline through Tallow. From this time, around 300 Ma, the land surface was subjected to erosion, but was generally stable.

The Pleistocene Period or Ice Age began about 2 Ma and several cold periods interspersed with warm periods saw Waterford smothered with ice. The ice sculpted

the county's landscape and glaciers formed in corries in the Comeragh Mountains and carved out superb features like Coumshingaun. The rock the ice ground down was deposited as an unsorted mixture of debris called till, in thick blankets over much lower ground, and now seen at sites like Ballyquin and Newtown.

The River Blackwater flows for most of its length eastwards, but at Cappoquin makes a marked right-hand turn and flows south to Youghal. This is probably an inheritance of a pre-glacial pattern but still provides an enigma for geologists. Drainage in the Dungarvan Syncline east of Cappoquin is often underground, with a number of caves present. Many of these were formed during the Ice Age as they have bones of extinct animals from warm and cold periods in them.

The coast between Fenor and Kilfarrasy is a European Geopark called 'The Copper Coast' and with good reason. In the nineteenth century, copper was mined at a number of localities by miners, some of whom brought their skills from Cornwall. Along the coast rocks can be seen with the tell-tale staining of copper minerals. Bunmahon was the centre of mining where the Mining Company of Ireland started to extract ore in 1826. A thriving industry needed engine houses with their square outlines and tall chimneys to pump water out of the mine shafts deep underground. Water wheels and dressing floors were used to remove the ore from the surrounding rock, and slipways were needed to transport the ore to ships that carried it to Swansea for smelting into metal ingots. By the late 1800s copper mining had ended in Waterford. Humans continue to remodel the landscape in our time, in what some people are now calling the Anthropocene.



A simplified geology map of Waterford outlining the main geological units.

Geological heritage versus geological hazards

Ireland is generally considered to be a country with very low risk of major geological hazards: there are no active volcanoes, stable tectonic plates mean earthquakes are relatively rare and human history is not peppered with disastrous landslides, mudflows or other geological hazards. Yet there are of course risks of one-off events, and this section briefly looks at the specific record and nature of geological hazards in Waterford 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 they can be suddenly active with major events, and quiet periods in between. Many of the sites in this audit represent evidence of past environments and geological processes, such as volcanic activity, tropical coral seas, glacier erosion of mountains and so on. However, some sites represent the active geomorphological or land-forming processes of today. These sites, generally coastal, are dynamic environments and are subject to constant or intermittent change.

Landslides and bog flows

The Geological Survey of Ireland has been compiling national data on landslides in the past decade. However, no identified landslips or bog slides are recorded in Waterford. Given the thick blanket bogs, variable slopes and extensive peat coverage of the Comeragh Mountains it seems unlikely that there have been no bog slides there, but the remoteness of the uplands would mean that they could easily go unnoticed and unrecorded.

Minor landslips are often the result of human interference with slopes causing destabilisation. An example of this is the road beneath Dunhill Castle which has been closed due to a minor collapse of the embankment (see below).



Small roadside collapse below Dunhill Castle.

Flooding

There are three types of flooding which need consideration.

Coastal flooding is potentially only a problem in low lying areas when a combination of high tides and weather conditions may cause the sea to overtop barriers or coastal defences, whether man-made or natural. Where natural systems exist different habitats adapt to and absorb occasional inundations, but when people build in vulnerable areas or channelize rivers (remembering that geological time is far greater than human lifespans) problems can occur.

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. This has not been a widespread issue in the county except occasionally in Waterford City and south and east of Clonmel. The OPW website www.floods.ie can be consulted for details of individual flood events in Waterford. Floodplains at Bunmahon, Annestown and along the River Blackwater in Lismore are also known flooding locations.

Karstic flooding can occur when underground passages are unable to discharge high rainfall events. The karst in the Dungarvan Syncline has largely relict or inactive caves, yet there are signs in some that the phreatic zone (the water table) does rise significantly. There are no known turloughs in Waterford, which are seasonal lakes where the water table intersects the land surface. The Ordnance Survey of Ireland six inch to the mile mapping does not record any areas 'liable to flooding' in the karstic landscapes. However, the potential exists for karstic flooding to occur along the valley floor.

Coastal erosion

Whilst much of the Waterford coastline is composed of hard rocks such as Ordovician volcanics or Devonian sandstones, erosion is generally slow and not a significant hazard. However, in some areas there are relatively unconsolidated glacial tills and head deposits. These are much more prone to erosion by the sea and can constitute a hazard. The cliffs, at sites such as Ballyquin, retreat by slumping of the cliff faces. The slumped material gets removed by the sea, further undermining the stability of the till, and causing renewed slumps. This only normally becomes a hazard to landowners or property on the cliff-top when assets are threatened.



Slumps at Ballyquin Shore.



Coastal protection techniques include placing of large boulders at the toe of slumping areas, which are a significant modification of local landscapes. This photo of a boulder barrier is at Ballyquin.



Bunmahon beach has been treated the same way.

Karstic collapse

This is a very real, but localised hazard in parts of Waterford. In the flat valley west of Dungarvan, there is limestone a few metres beneath the surface. The number of known caves in the limestone suggest that there are cavities and indicate that there are risks, since some cave entrances such as Carrigmurish and the two caves called Oonagaloor, are collapses into large chambers. The fluctuations of groundwater in the limestone can remove sand and mud fill in some caves and cause sluggera collapses. These actually

occur quite frequently in some areas such as south east of Cappoquin, but collapses are often filled in quickly by farmers.

The recent example of a collapse in the entrance road at the industrial estate in Cappoquin illustrates this hazard quite spectacularly. In late autumn 2010 a 50m by 10m section of road subsided. Although it has been filled and the road repaired, it is still clearly visible in the photograph below, as a dip in the land surface and from the footprint of the replanted juvenile trees.



Glossary of geological terms

Geological term	Definition
Adit	A horizontal or only gently inclined mine tunnel dug to access ore, or to drain, ventilate or further develop a mine.
Alluvial Deposit	unconsolidated clay, silt, sand and gravel, deposited by a body of running water.
Alluvium	a term for unconsolidated clay, silt, sand and gravel, deposited by a body of running water.
Andesite	a volcanic rock of intermediate composition (between rhyolite and basalt).
Anticline	a structural geological term meaning an upfold of sedimentary strata in a linear arch shape.
Aquifer	a water saturated rock unit.
Arete	A thin, almost knife-like, ridge of rock which is typically formed when glaciers erode two adjacent corries or valleys.
Backwall	the cliffs at the rear section of a corrie.
Bedding Plane	the contact between individual beds of rock.
Bedrock	a general term for the rock, usually solid, that underlies soil or other unconsolidated, superficial material.
Biostratigraphy	using fossils to define the succession of rocks.
Blanket Bogs	bog covering a large, fairly horizontal area, which depends on high rainfall or high humidity, rather than local water sources for its supply of moisture.
Boulder Clay	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock or silt. Also known as till.
Brachiopods	a marine invertebrate of the phylum Brachiopoda - a type of shellfish. Ranging from Lower Cambrian to present.
Braided River	a river that consists of a network of small channels separated by small and often temporary islands.
Bryozoa	invertebrates belonging to the phylum Bryozoa, ranging from Ordovician to present, often found as frond-like, net-like or stick-like fossils.
Calcareous	containing significant calcium carbonate.
Calcite	a pale mineral composed of calcium carbonate, which reacts with dilute acid.
Carbonate	a rock (or mineral), most commonly limestone (calcite) and dolomite.
Cave	a natural underground space large enough for a human to enter, which is usually formed in either soluble limestone by karstic processes, or in exposed rock along the coastline, where the sea erodes natural rock fractures.
Clast	an individual constituent, grain or fragment of a sediment or rock, usually produced by mechanical weathering (disintegration) of a larger rock mass.
Cleavage	a finely spaced, flat plane of breakage caused by compressive deformation of rocks. e.g. the splitting of slate.
Conglomerate	sedimentary rock comprising of large rounded fragments in a finer matrix.
Corrie	a horseshoe-shaped, steep-walled valley formed by glacial erosion.
Crinoid	a variety of sea-urchin, with a long flexible stem, usually anchored to the sea-floor and a body cup with arms which may be branching (a sea lily).
Cross-bedding	layering in sedimentary rocks at an inclined angle to bedding formed by current-ripples.
Crust	the outermost, solid, layer of the Earth.
Dip/dipping	when sedimentary strata are not horizontal they are dipping in a direction

	and the angle between horizontal and the inclined plane is measured as the dip of the strata or beds.
Doline	circular/oval closed depression found in karst terrain.
Dolomite	calcium and magnesium bearing carbonate mineral; also a rock composed of the mineral.
Dressing floor	in 19 th century mines cobbled yards or dressing floors were used to break down lumps of ore by hand to minimise the waste rock included.
Dune slacks	the hollow between dunes, sometime long and linear like a valley, sometimes a round trough.
Epikarst	the shallow layer, near surface, of highly karstified rock, with many voids included.
Erratic	a rock fragment, often large, that has been transported, usually by ice, and deposited some distance from its source. It therefore generally differs from the underlying bedrock, the name "erratic" referring to the errant location of such boulders. Tracing their source can yield important information about glacial movements.
Facies	the character of the rock derived from its original sedimentary environment and process of deposition.
Fault	planar fracture in rocks across which there has been some displacement or movement.
Fault Zone	a tabular volume containing many faults and fault rocks (rocks broken up by fault movement).
Fauna	collective term used to group all animal life.
Floodplain	a flat or nearly flat land area adjacent to a stream or river that experiences occasional or periodic flooding.
Flowstone	calcite or other minerals deposited as a surface crust by water flowing over cave or mine walls and floors.
Fluvial	pertaining to a river or stream.
Fold(ing)	flexure in layered rocks caused by compression.
Formation	a formal term for a sequence of related rock types differing significantly from adjacent sequences.
Fossiliferous	rich in fossils.
Fossils	any remains, trace or imprint of a plant or animal that has been preserved in the Earth's crust since some past geological or prehistorical time.
Geo	a narrow, near vertical sided linear coastal erosion feature, usually exploiting some fracture or fault zone. A particularly Scottish term.
Glacial	of or relating to the presence and activities of ice or glaciers.
Gossans	the highly weathered zone, often with brightly coloured oxidised minerals, above a buried mineral deposit.
Grading	a sorting effect with the coarsest material at the base of the bed and finest grained material at the top.
Granite	a coarsely crystalline intrusive igneous rock composed mostly of quartz and feldspar.
Graptolite	extinct organism of the phylum Hemichordata with colonies consisting of one or more fine branches with cups. Ranging from Middle Cambrian to Devonian, but particularly important in dating Ordovician and Silurian rocks.
Greywacke	an impure sandstone, characterised by poorly-sorted, angular grains in a muddy matrix, that was deposited rapidly by turbidity currents (submarine avalanches).
Gully	a deep valley created by running water eroding sharply into bedrock or subsoil.
Haematite	a mineral form of iron oxide, which is the main ore mined as iron.
Head	weathered rock fragments accumulated on lower slopes from periglacial

	freezing and thawing action acting with gravity.
Hummock	a small hill or knoll in the landscape, which may be formed by many different processes.
Ice margin	The edge of an ice sheet or glacier.
Igneous	a rock or mineral that solidified from molten or partially molten material i.e. from a magma.
Interglacial	the time interval between glacial stages, or pertaining to this time.
Irish Sea Till	clay-rich till found along the eastern seaboard of Ireland, and occurring as much as 12km inland, which was deposited by an ice stream which occupied the Irish Sea Basin during the last glaciation.
Joint	a fracture in a rock, which shows no evidence of displacement.
Karst	general term used for landscapes formed by weathering of soluble rocks, usually limestone, by surface water and/or groundwater.
Knoll	a small hill or hillock sticking up from generally flat terrain.
Laminated	the finest example of stratification or bedding, typically exhibited by shales and fine-grained sandstones.
Lapilli	pyroclastic fragments between 2mm and 64mm in size.
Lava	magma extruded onto the Earth's surface, or the rock solidified from it.
Limestone	a sedimentary rock consisting chiefly of calcium carbonate (CaCO_3), primarily in the form of the mineral calcite. It is mostly formed by the accumulation of calcareous shells, cemented by calcium carbonate precipitated from solution.
Lithification	the process of rock formation from unconsolidated sediment.
Lithology	the description of rocks on the basis of such characteristics as colour, composition and grain size.
Lodgement	process by which debris is released from the sliding base of a moving glacier/ice sheet and plastered or 'lodged' onto the glacier bed; also describes tills emplaced by this process (i.e. lodgement till).
Maze cave	a cave formed in an extensive grid pattern when slow moving water.
Melt-out	process by which glacial debris is very slowly released from ice that is not sliding or deforming internally; also describes tills emplaced by this process (i.e. melt-out till).
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.
Micaceous	rich in mica (shiny, flaky silicate minerals).
Misfit stream	a stream which is too small to have eroded the valley in which it flows, as is often the case with streams now flowing in meltwater channels.
Moraine	any glacially formed accumulation of unconsolidated debris, in glaciated regions, such as during an ice age.
Mudmound	Waulsortian limestone of Carboniferous age is characterised by forming as massive mounds or ridges or sheets of carbonate mud on the seafloor of the time. Mudmound is a general term to describe the varieties of forms.
Mudstone	a very fine grained sedimentary rock, containing quartz and clay minerals. Similar to shale, but not as easily split along the plane of bedding.
Ore	a mineral which is concentrated enough to be exploited by mining.
Orogeny	the creation of a mountain belt as a result of tectonic activity.
Outcrop	part of a geologic formation or structure that appears at the surface of the Earth.
Peperite	Peperites form when hot magma interacts with unconsolidated water-saturated sediment.
Periglacial	very cold but non-glacial climatic conditions.

Phreatic	below the water table.
Phreatic	when a cave passage or void space in limestone rocks is filled with water it is said to be phreatic or in the phreas. When later found without water in them such passages have a characteristic cylindrical shape from solution in all directions and are called phreatic tubes.
Phreatic Zone	the area below the water table, where the rock is completely saturated with water.
Plate Tectonics	a theory that states that the crust is divided up into a number of plates, whose pattern of horizontal movement is controlled by the interaction of these plates at their boundaries with one another.
Pyrite	iron sulphide, pale yellow/gold coloured mineral, commonly occurring as cubes and often called 'fool's gold'.
Pyroclastic	fragmented rock material formed by a volcanic explosion.
Quartzite	a hard, metamorphosed sandstone, composed mostly of recrystallised quartz grains that are tightly interlocking. Quartzite is formed through heat and pressure usually related to tectonic compression.
Rhyolite	an igneous, volcanic (extrusive) rock of acidic composition. The mineral assemblage is usually quartz and alkali and plagioclase feldspars.
Sand spit	a linear coastal sedimentation feature where sand accumulates in a spit across a bay or along a coast.
Sandstone	a fine to coarse sedimentary rock, deposited by water or wind, and composed of fragments of sand (quartz grains), cemented together by quartz or other minerals.
Sedimentary	a rock formed by the deposition of sediment, or pertaining to the process of sedimentation.
Shaft	a vertical hole dug in a mine for access, ventilation, for hauling ore out or for pumping water out.
Shale	a very fine-grained mudstone, containing quartz and clay minerals, that splits easily along the plane of bedding.
Siltstone	is similar to mudstone but with a predominance of silt-sized (slightly coarser) particles.
Sink	another name for a swallow hole, the point where a stream passes underground.
Slate	is a fine-grained metamorphic rock produced from a sedimentary mudstone by pressure, imposing a cleavage along which the slate easily splits.
Sluggera	a tube-like collapse of the Earth's surface into an underground cavity, which has formed by the dissolution of limestone.
Slumping	the movement of a mass of unconsolidated sediment or rock layers down a slope, or pertaining to contorted sedimentary bedding features.
Solution pipe	a karstic feature of solution in a vertical narrow chimney or pipe shape.
Spring	the point where an underground stream reaches the surface.
Stratigraphy	the study of stratified (layered) sedimentary and volcanic rocks, especially their sequence in time and correlation between localities.
Sub-aerial	refers to processes occurring above ground level, such as the weathering of rocks.
Subduction	the sinking of one crustal plate beneath the edge of another through the process of plate tectonics.
Subsidence (zone)	the sudden sinking or gradual downward settling of the Earth's surface with little or no horizontal movement.
Swallow hole	the point where a stream passes underground, sinking below the ground surface.
Syncline	a structural geological term meaning a downfold of sedimentary strata in a linear trough shape.
Terrestrial	pertaining to the Earth's dry land.

Till	unconsolidated, unsorted glacial deposits consisting of boulders and cobbles mixed with very finely ground-up rock as sand, silt or clay also known as boulder clay.
Transgression	an incursion of the sea over land area.
Trilobites	extinct arthropods.
Tuff	rock formed from pyroclastic volcanic ash material usually composed of silt-sized to sand-sized particles.
Tuff(aceous)	consolidated rock formed from the ash ejected from a volcano.
Turbidite	deposit of a turbidity current.
Turbidity Current	underwater density current carrying suspended sediment at high speed down a subaqueous slope. The resulting deposit is called a turbidite.
Unconformable	a sedimentary rock that is not following in sequence from the one below but has a significant time gap present between them.
Unconformity	a buried erosion surface separating two rock masses or strata of different ages, indicating that sediment deposition was not continuous.
Vadose Zone	the area between the surface and the water table.
Vein quartz	white thin veins of quartz injected in rock fractures during episodes of stress. Also found as durable beach pebbles, once it has been eroded.
Volcanic Arc	a linear belt of volcanoes formed on the overlying plate at a subduction zone, resulting from subduction of the underlying plate.
Volcanic Ash	very fine rock and mineral particles ejected from an erupting volcano.
Volcanic Rock	any rock produced from volcanic material, e.g. ash, lava.
Volcanism	the process by which magma and its associated gasses rise into the crust and are extruded onto the Earth's surface and into the atmosphere.
Volcano	a vent in the surface of the Earth through which magma and associated gasses and ash erupt.

Data sources on the geology of County Waterford

This section is a brief summary of relevant GSI datasets, to assist any enquiry concerning geology and to target possible information easily. The GSI has very many datasets, accumulated since it began mapping Ireland's geology in 1845. A Document Management System (DMS) is freely available to any person at the GSI Customer Centre, into which about half a million documents and maps have been scanned. This means that any user can visit the GSI Customer Centre themselves and search on screen for data of relevance to them. High quality colour and black and white print-outs can be made or data supplied on CD, or via USB keys etc. **Data is available free of charge.**

Key datasets include:

1:100,000 Map Report Series

All historical, modern and other mapping has been compiled into very useful maps and reports that describe the geology of the entire country. Parts of Sheets 22 and 23 cover Waterford.

19th century 6 inch to the mile fieldsheets

These provide an important historical and current resource, with very detailed observations of the geology of the entire country.

19th century one inch maps and Memoirs

Information from the detailed 19th century mapping was distilled into one inch to the mile maps, of which parts of Sheets 167,168,178, 179, 188 and 189 cover County Waterford. Each sheet or several sheets were accompanied by a Memoir which described the geology of that area in some detail. These still provide valuable records of observations even though interpretations may have changed with better geological understanding. Memoirs are in the Customer Centre library and scanned on the DMS.

Historical geological mapping is now available via a website:
<http://www.geologicalmaps.net/irishhistmaps/history.cfm>

Open File Data

Each Mineral Prospecting Licence issued by the Exploration and Mining Division of the Department of Communications, Energy and Natural Resources (currently) carries an obligation on the exploration company to lodge records of the work undertaken, for the common good. These records are held by the Geological Survey and are available as Open File Data, once a period of time has expired. They may include geological interpretations, borehole logs, geophysical and geochemical surveys and so on.

MinLocs Data

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

Historic Mine Records

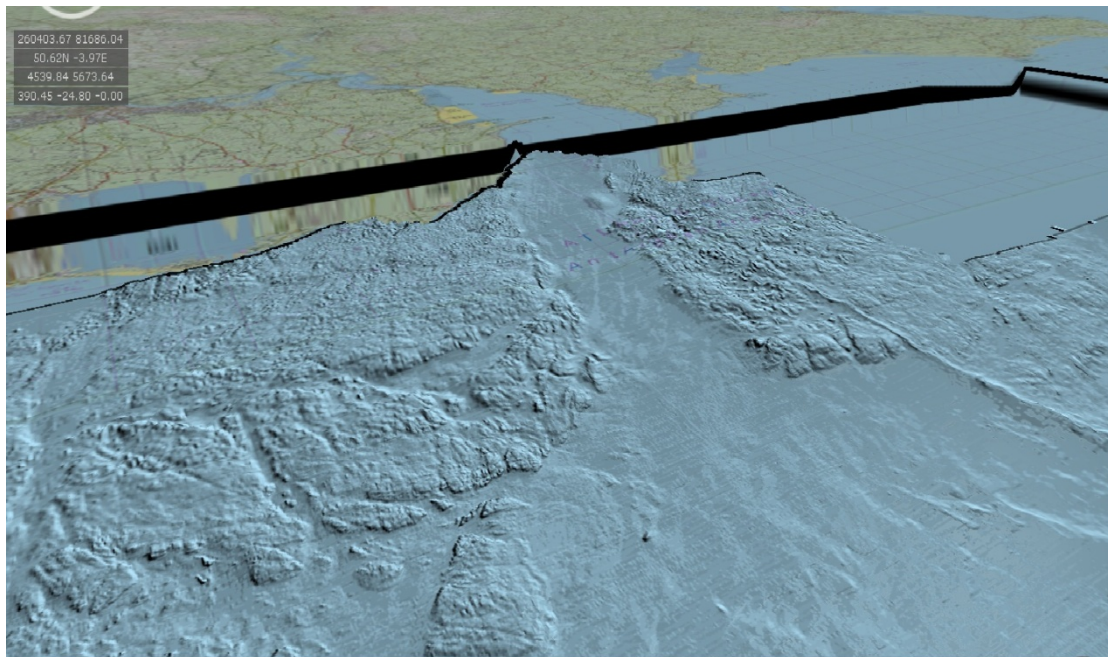
Abandonment plans and varied other material exists for the various mining ventures in the county, at places like Tankardstown Mine, near Bunmahon.

Subsoils Mapping

Since a Groundwater Protection Scheme has been done for County Waterford by GSI, a recently completed map of the subsoils of Waterford exists, as well as the previously completed bedrock mapping. This provides a significant resource in general terms as well as for groundwater protection. Customised output is possible.

Digital mapping of many different datasets is now available via the GSI website: www.gsi.ie

Since 1999 the National Seabed Survey and the INFOMAR project, between the GSI and the Marine Institute, have been mapping Ireland's marine territory. Initial years were focused on the vast extent of deep water offshore. More recent years have seen the emphasis change, with the acquisition of purpose built research vessels, to the shallow inshore waters. During the summer of 2011 an inshore survey of Waterford Harbour took place. This identified many riverbed features including whirlpool scour marks, sand waves, shoals and igneous dykes. It provides a level of continuity between onshore landscape features and the offshore drowned versions of them.



Shortlist of Key Geological References

This reference list includes a few **key** papers, books and articles on the geology and geomorphology of Waterford that are recommended as access points to Waterford's fabulous geological heritage. A full reference list of papers relating to the bedrock geology of County Waterford is included at the back of this report (Appendix 1), plus a list of caving references which are kept separate (Appendix 2). Appendix 3 is specific literature on the mining heritage of County Waterford. Appendix 4 covers the literature on the Quaternary geology of Waterford.

DALY, D., DREW, D.P., DEAKIN, J., PARKES, M. and WRIGHT, J. 2001. *The Karst of Ireland; Limestone Landscapes, Caves and Groundwater Drainage Systems*. Karst Working Group Dublin, 37pp.

HOLLAND, C.H. (ed.). 2001. *The Geology of Ireland*. Dunedin Academic Press, Edinburgh.

MORRIS, J.H. 1999. *The Copper Coast*. Landscapes from Stone, Geological Survey of Ireland,

SLEEMAN, A.G. and McCONNELL, B.J. 1995. Geology of East Cork - Waterford. A geological description of east Cork, Waterford and adjoining parts of Tipperary and Limerick to accompany the Bedrock Geology 1:100,000 map series, sheet 22, East Cork - Waterford. Geological Survey of Ireland.

STILLMAN, C.J. and SEVASTOPULO, G. 2005. Leinster. Classic geology in Europe 6. Terra Publishing, Harpenden, Herts, England.

TIETZSCH-TYLER, D. and SLEEMAN, A.G. 1994. Geology of south Wexford. A geological description of south Wexford and adjoining parts of Waterford, Kilkenny, and Carlow to accompany the bedrock geology 1:100,000 scale map series, Sheet 23, South Wexford. Geological Survey of Ireland, Dublin.

Full Geological references

See Appendix 1 for the full reference list of all papers, books, articles and some unpublished reports etc relating to the geology and geomorphology of Waterford that could be traced.

Caving References

The references in Appendix 2 relate significantly to caves and caving within the Waterford area. They may only be brief reports or newsletter items. They are generally available within the Speleological Union of Ireland Library which is housed in the Geological Survey of Ireland and is managed by Matthew Parkes.

Mining heritage references

Appendix 3 lists references specifically pertaining to the mining heritage of County Waterford. Assistance with locating these references may be provided by the Mining Heritage Trust of Ireland if required.

Quaternary References

The references in Appendix 4 are all covering the Quaternary, or Ice Age, geology of Waterford. They are split into the specific ones covering Waterford sites or features and a section of national or regional papers with some Waterford data included.

Further sources of information and contacts

Sarah Gatley of the Geological Survey of Ireland, who is the Head of the Geological Heritage and Planning Section, can be contacted in relation to any aspect of this report. Bernadette Guest, the Heritage Officer of Waterford County Council, or Aisling Gleeson, Senior Executive Planner in the County Council are the primary local contacts for further information in relation to this report. Other contacts include the Conservation Rangers of the National Parks and Wildlife Service, currently in the Department of Arts, Heritage and the Gaeltacht. The names and phone numbers of current staff may be found in the phone book, or at www.npws.ie. Tina Keating, Geologist at the Copper Coast Geopark, Bunmahon, County Waterford, is an important local contact, along with Paula McCarthy, the CCG administrator as of 2011 (see www.coppercoastgeopark.com for contact details).

Web sites of interest

www.gsi.ie - for general geological resources

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

<http://www.habitas.org.uk/es2k/index.html> - for general geological information of wide interest

<http://www.tcd.ie/Geography/IQUA/Index.htm> - for information, fieldtrips, lectures etc in relation to Ireland's Ice Age history

<http://www.cavingireland.org/> - for information on caves and safe caving

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

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Section 2 - Site Reports

Site reports – general points

The following site reports are brief non-technical summaries of the proposed County Geological Sites for County Waterford. These have been specially prepared for this Report in order to make the information accessible to planners and others without geological training. For most sites more detailed reports and information files are held in the IGH Section in the Geological Survey of Ireland. These are available for consultation if required. Further sites may become relevant as IGH Programme work develops.

Each site report has primary location information, a mention of the main rock types and their age, and a short description of the key aspects of scientific interest. A section outlining any particular management or other issues specific to the site is included, along with one or two low resolution photographs exemplifying the site. **A CD accompanying this report will include further pictures of most sites at higher resolution, should they be required for a glossy booklet or leaflet for the general public.** Grid references are given normally for a central point in the site if the site is small, or two extreme points at opposite ends of the site if the site is extensive or linear. They are only indicative of the location, but the site extent is best shown on the included maps.

A series of maps are provided with an outline of the site boundary. It is important to note that no legal or definitive basis should be based on these boundaries. They are indicative only of the limits of exposure or of geological interest, and not based on detailed field and boundary surveys, which were outside the scope of this contract.

For sites that have been proposed or will be proposed for NHA designation detailed site boundary maps will become available to the Local Authority, through NPWS as the designation process is undertaken. Some areas may already be available if they are proposed NHAs (pNHA), under the Wildlife (Amendment) Act 2000. 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 the wider area 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 GSI makes recommendations to NPWS on the most important sites to be designated. Any landowner within areas or sites identified in this report with concerns over any aspect of this project is encouraged to contact Sarah Gatley, Head of the Heritage and Planning Section, in the Geological Survey of Ireland, Beggars Bush, Haddington Road, Dublin 4.

Phone 01-6782837. Email: sarah.gatley@gsi.ie

Simplified Geological Map of Waterford with site locations indicated

