Islands

Coast

and Quarries

The geological heritage of Fingal

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By Matthew Parkes

Comhairle Contae Fhine Gall
Fingal County Council

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This book is a visual exploration of the geological heritage of Fingal. Using data gathered during a 2007 audit (by Aaron Clarke, Matthew Parkes and Sarah Gatley) of 21 sites of geological and landscape importance in Fingal, it presents some of the fascinating stories told by the rocks and fossils in these special places. In concise and non-technical language, illustrated with stunning contemporary photography, it provides an insight into the forces that have created the landscape of Fingal. The book is an Action of the Fingal Heritage Plan 2011-2017, and we hope that it will open readers' eyes to the wonders that are right on their doorstep.

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Foreword

When we hear the word heritage my guess is that very few of us think about geology. We may think about family and local history or about nature and landscape, but we probably do not think at all about the underlying rocks and the geological processes which have literally shaped Fingal. We're also not used to thinking in terms of the very long time periods involved in geological processes. Typical geological time periods extend over millions of years and are hard for us to begin to imagine. Yet geology and geological processes provide us with vital resources every day. For example, Fingal's rich agricultural soils are formed from the glacial till deposited by retreating glaciers. Our quarries continue to provide building materials which sustain the modern construction industry. And our coastline, which is a valuable resource and amenity for us all, continues to be shaped and changed by geological processes such as erosion and deposition.

In 2007, because we had little information on important geological heritage sites in Fingal, the Council commissioned the Geological Survey of Ireland to undertake an audit of geological heritage sites in the county. The resulting audit report identified 21 geological heritage sites and recommended that these sites become County Geological Sites. County Geological Sites are geological heritage sites of local or regional importance which do not have formal statutory protection but are considered by the local authority in performing its functions, including making planning decisions. The County Geological Sites are included in the Fingal Development Plan 2011–2017 together with policies which seek to maintain and enhance the geological heritage values of the sites and to provide access to them where feasible. In the future some of the sites may also be designated by the Department of Arts, Heritage and the Gaeltacht as Natural Heritage Areas (NHAs) because they are of national importance.

The superb folds at Loughshinny can best be seen from the end of the pier

What is Geology?

Geology is the study of the Earth, including the rocks and minerals that it is composed of. It includes the study of life on Earth, also known as palaeontology, or the study of fossils. There are many specialised disciplines within geology, including geophysics, geochemistry, mineralogy, petrology and dozens more. One study, sometimes regarded as a geography discipline, is geomorphology — the study of the physical processes that form the landscape. Stratigraphy is the critical framework of time, which in the case of the Earth and our solar system, is about 4,600 billion years!

Rock types

In this book you will encounter some familiar rock types, such as granite and limestone. These rocks — as with every type of rock — are formed in different ways.

Original molten magma from below the Earth's surface sometimes erupted as volcanic rocks like basalt or andesite lavas. Magma that crystallises as a rock below ground is most commonly found as granite. All these rocks are classified as igneous.

Sedimentary rocks are very diverse and include conglomerate, which has large rounded lumps; breccias, with large angular fragments; and — going down in particle size — sandstones, siltstones and mudstones or shale. Limestone can be formed in many different ways, but it generally contains a lot of shell debris from living animals, as well as chemically precipitated lime sediment.

Both igneous and sedimentary rocks may be altered by strong heat and/or pressure. The resulting metamorphic rocks include slate (from mudstone), marble (from limestone), and schist, quartzite and gneiss. Volcanic lavas and limestone are the most common types of rock found in Fingal.

Some basic terms

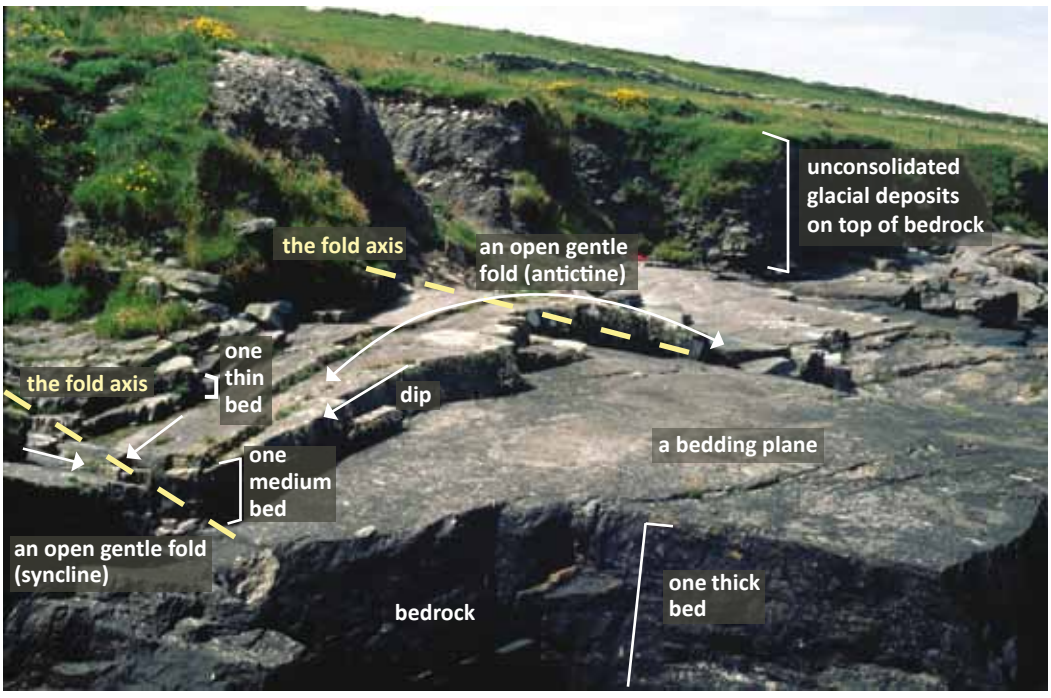
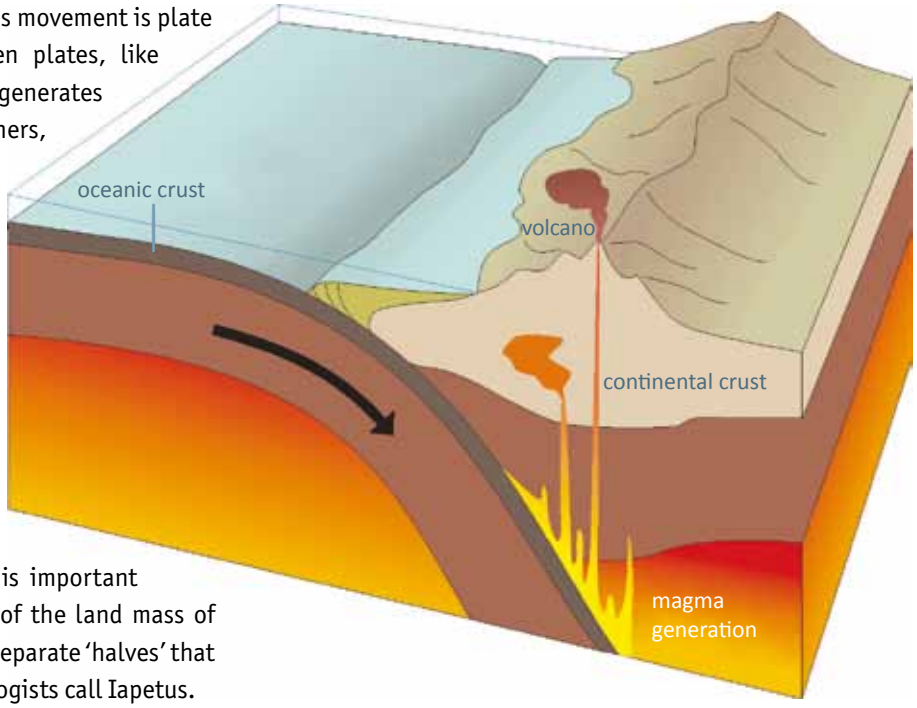


Plate tectonics

Around 50 years ago there was a radical leap forward in our understanding of how the Earth works. The skin or crust of the Earth is made up of mobile plates which move around. The term used to describe this movement is plate tectonics. At some margins between plates, like in the mid-Atlantic Ridge, magma generates and rises to create new crust. At others, one layer of crust slides beneath another in a subduction zone (see diagram – right), often creating volcanoes in the process. Usually, oceanic crust is subducted beneath thicker continental crust. At other plate boundaries there is sideways displacement, such as the San Andreas Fault in California. Any of the slow movement of plates or volcanoes can cause earthquakes and even tsunamis. Plate tectonics is important for understanding the development of the land mass of Ireland. Ireland was once in two very separate 'halves' that were separated by an ocean that geologists call Iapetus.



These 'snapshot' reconstructions of palaeogeography of the Earth through time show the Iapetus Ocean which once separated the two 'halves' of Ireland. Starting from the Cambrian (about 500 million years ago (Ma)) the plate tectonic movement of continents can be tracked, from left to right, through the Ordovician (465 Ma), to the Silurian (420 Ma) when Ireland was virtually combined, and into the Devonian (390 Ma) when Ireland was on the margin of a supercontinent

Cambrian

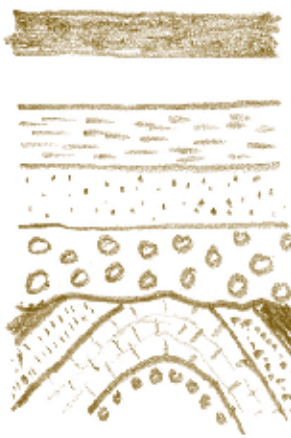
Ordovician

Geological time

Stratigraphy is the cornerstone of geology. We need to understand not only what events and environments have occurred on the Earth, but the sequence in which they happened. Stratigraphy helps us place different rocks into a framework of time, and we can then correlate sequences and events that occurred in different places. Geological time is subdivided into many different periods, some of which are familiar from popular films such as Jurassic Park. The chart on page 57 shows the main time periods and what was happening in Fingal in each period, and the last section of the book provides an overview of the different events through time in the area.

Two key periods are relevant for almost all the sites described here. The Ordovician Period (about 510 to 438 million years ago) was when volcanoes erupted at Lambay Island, Portrane and Balbriggan, among other places. The majority of sites in Fingal formed in the Carboniferous Period, from around 355 to 290 million years ago. In the early part of this period, Ireland was inundated by a warm tropical sea, with limestone deposited widely.

Stratigraphy helps us reconstruct past environments and how they changed through time. This shows what environments existed in what we know as Ireland today, but about 330 million years ago in the Carboniferous Period



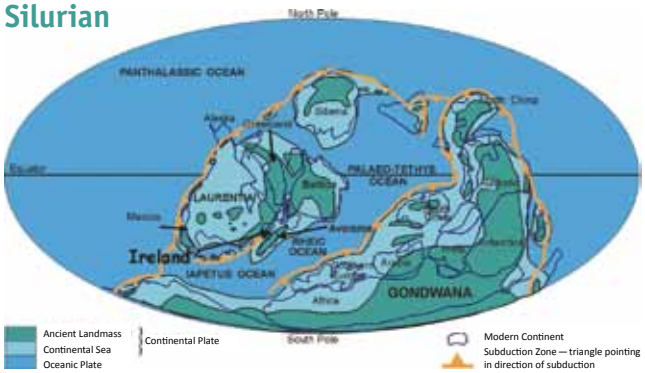
sedimentary beds are flat-lying

unconformity

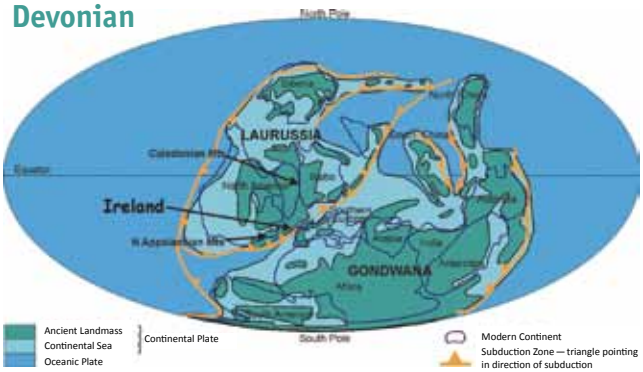
sedimentary beds are folded and tilted

An unconformity represents a time period and the events that deformed, folded and eroded the lower rock sequence. Younger rocks lie flat on top of them

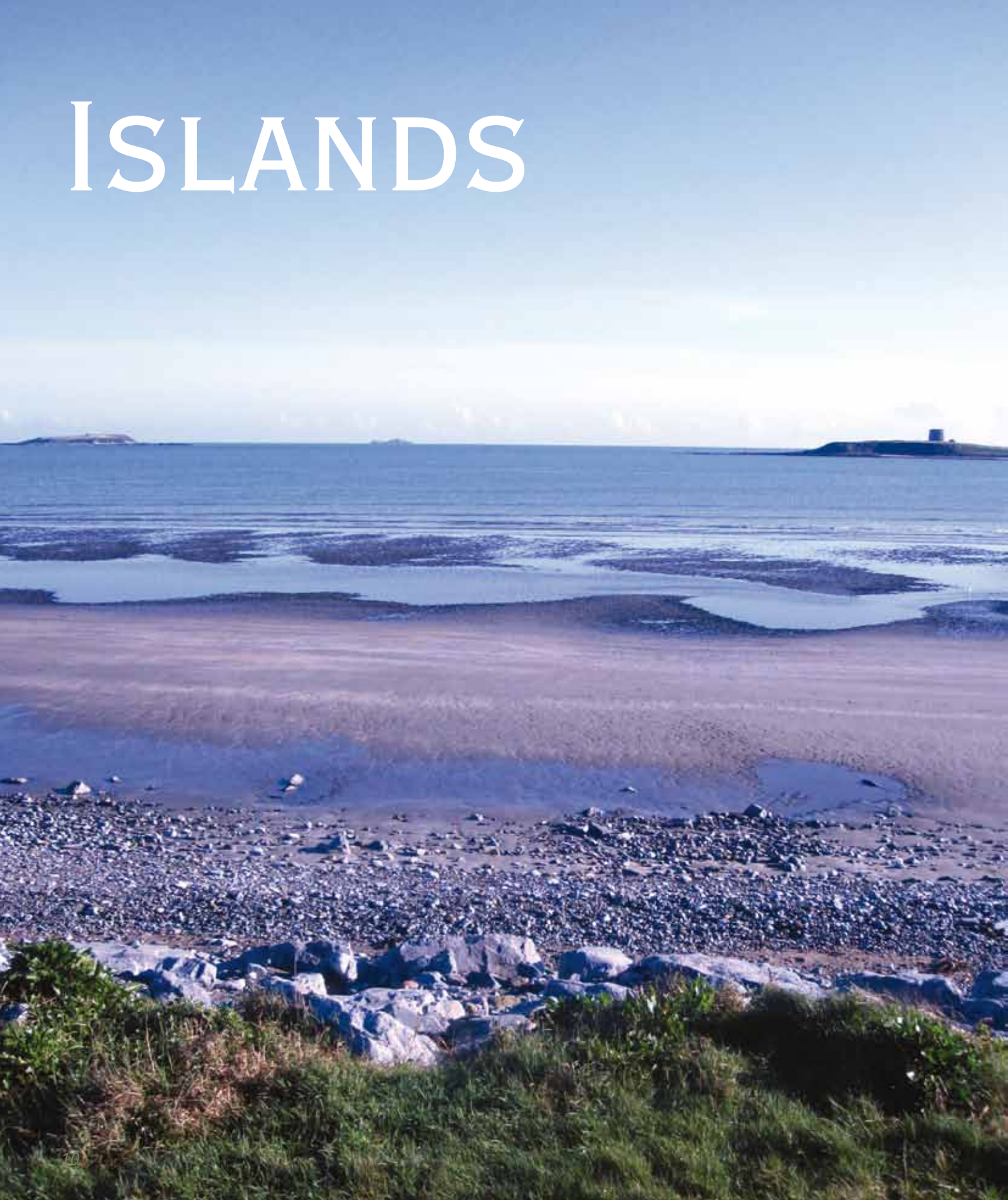
Silurian



Devonian



Islands



Kiln Point (on left) and Heath Hill (middle high ground) are where fossils have been found on Lambay

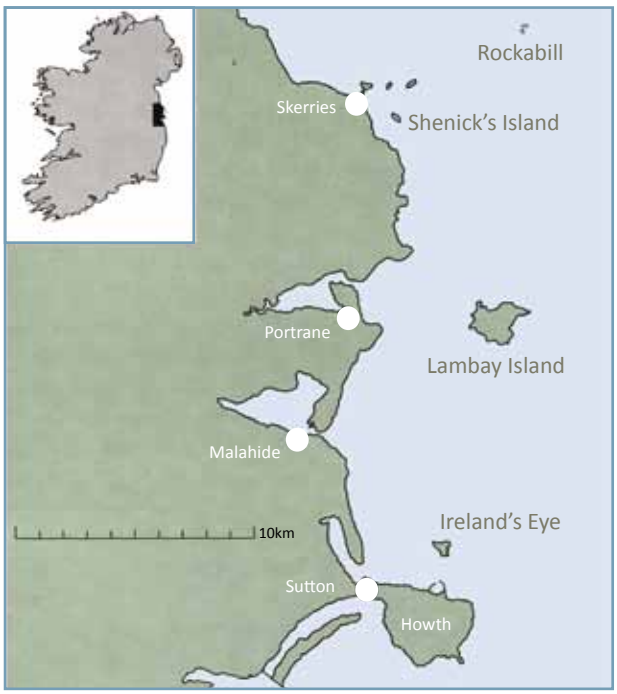
Rockabill is an internationally important breeding place for Roseate Terns

Looking across the causeway to Shenick's Island

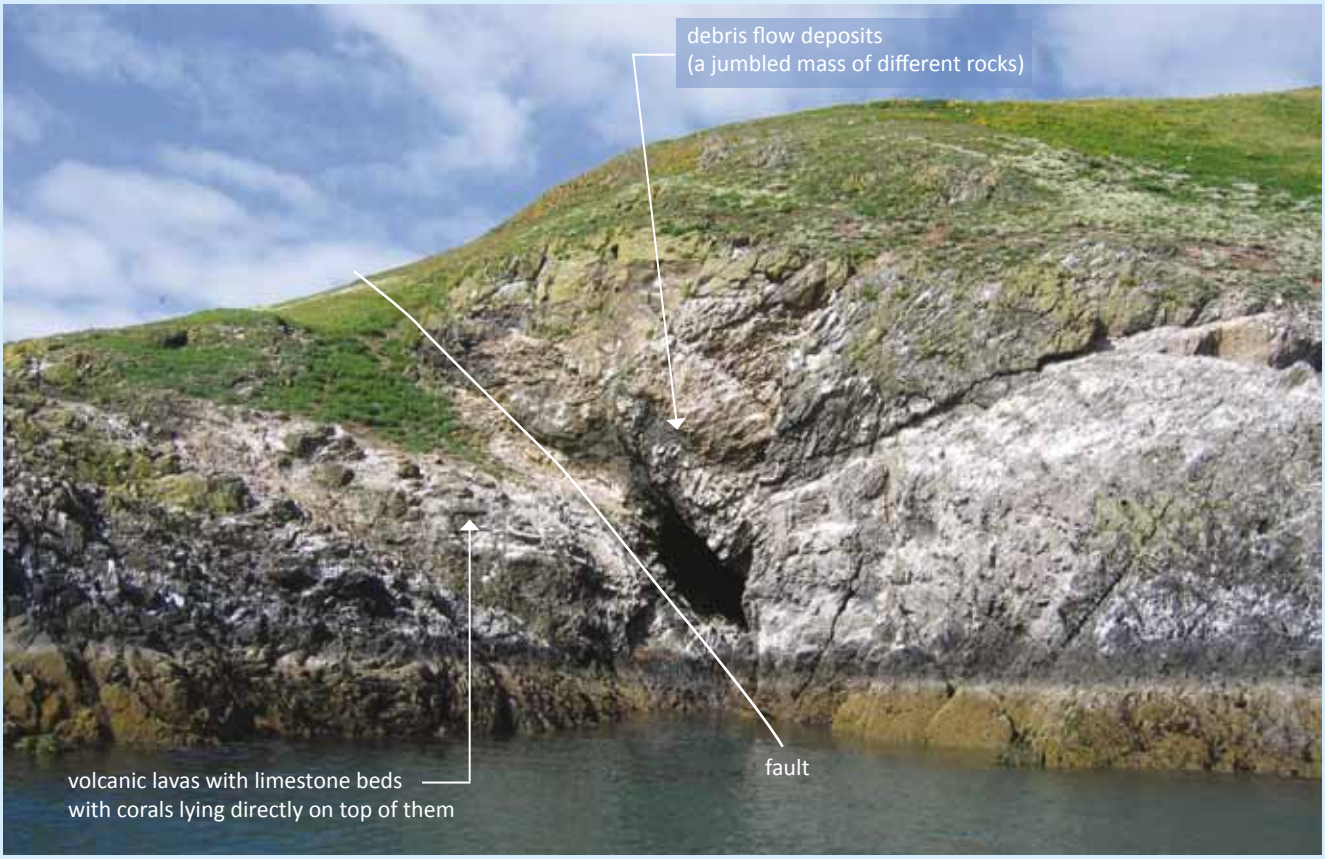
Left: Offshore from Skerries are St Patrick's Island (left), Rockabill (centre) and Shenick's Island (right) among other small islands closer inshore

For a small county, Fingal has a wealth of islands just off the coast. They are all geologically interesting, and they are also quite different from each other in their geology. Many of them have been selected as County Geological Sites (CGS). As islands, they have a special place in maintaining our biodiversity. The biodiversity of these islands—the animals and plants that live there—is strongly related to their geological character, which determines the types of habitat that have developed on each island.

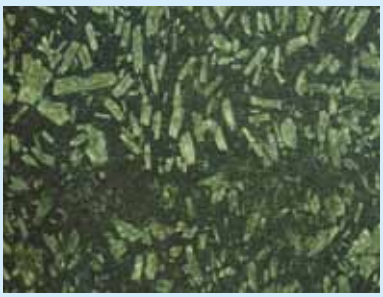
All of Fingal's islands are protected areas for nature conservation. A range of national and European designations protect important habitats and species which occur on the islands. Recognising their geological identity and importance completes the picture in providing for appropriate management, awareness and education about the islands.



Lambay Island



Kiln Point from the sea, with limestone beds directly on lavas on the left, and a fault at the base of the cliff of a massive debris flow



Lambay porphyry in a polished section in the National Museum collections

Main Geological or Geomorphological Interest

The island is important as the remains of an Ordovician volcano. It forms one of several such complexes which resulted from the closure of the Iapetus Ocean and the subduction of one tectonic plate beneath another. This took place around 450 million years ago, and it resulted in the two 'halves' of Ireland joining together (see the Iapetus story panel on facing page). There is a diversity of rock types, which include the well-known Lambay porphyry—an attractive greenish-grey stone that can be polished for ornamental use.

The area around Kiln Point and Heath Hill is particularly important. Here a variety of fossils have been collected that provide evidence about the age of the rocks and information about what the environment was like at the time. Corals and other shells indicate that there was a warm tropical sea around the extinct volcanic island. Much of the original volcano has been eroded away over 460 million years, and now Lambay Island remains as a remnant.

Archaeologists have discovered a prehistoric axe factory on Lambay, and a few axe heads made of the porphyry are known to exist (see *Axes, Warriors and Windmills* published by Fingal County Council for a detailed account by Gabriel Cooney).

Site Importance

Lambay is an important site because here we find fossils associated with volcanic rocks that help us understand how volcanoes and tectonic movement of the Earth's crust formed Ireland as we know it. The island's biodiversity is already recognised and protected. The geological heritage is equally significant and the island is a County Geological Site. The Kiln Point and Heath Hill area may be designated as a Natural Heritage Area (NHA) in the future for their palaeontology.

Visiting Lambay Island

The island is privately owned and is not open to the public. Sailors and sea kayakers can get close-up views from the sea. The geological story on Lambay is mirrored at Portrane, which is easy to visit, and where you can see a microcosm of Lambay's geology.

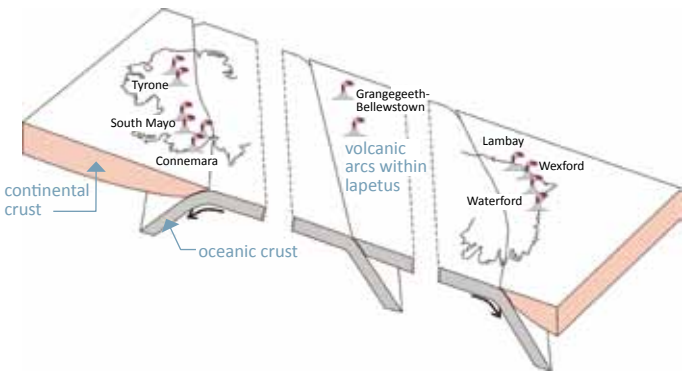
A small section of Devonian 'Old Red Sandstone' also outcrops on the northwest corner of Lambay Island

The Story of Iapetus

Ireland is made up of two 'halves', which were originally separated by an ocean that geologists call Iapetus. The northwestern half was on the margins of a North American continent; the southeastern half was on the margins of the European continent. Plate tectonic movement throughout the Ordovician Period gradually forced the land masses on either side of the Iapetus Ocean together. Ireland's two halves converged and eventually combined in Silurian times. Fingal's rocks tell part of this story.

In plate tectonic movements of the Earth's crustal plates, new crust is generated at ocean spreading ridges (for example in Iceland and down through the Mid-Atlantic Ridge). When this happens, it is balanced by the destruction of crust at a subducting plate elsewhere. Subduction involves a plate, usually of thinner oceanic crust, sliding under another plate and being melted back into the Earth's mantle. This happens at depths of 30km or more. Where continental crust occurs, it is less likely to subduct: instead, the plates push together and buckle up into mountain ranges. The Alps and the Himalayas were formed in this way.

Many of Ireland's rocks are slivers of crust that slid together along transform faults (like the famous San Andreas Fault in California), which compensate for various stresses and allow plates to move sideways.



Ireland's Eye

Sea stacks, including Thulla, at the southeastern end of Ireland's Eye

Dramatic cliffs are seen on the island

Main Geological or Geomorphological Interest

The island is composed entirely of Cambrian age rocks from about 510 million years ago. These rocks are greywacke, sandstone and quartzite, which were all sandy sediments in a marine environment when they were deposited. The geology is essentially the same as that of Howth Head and Bray Head, but better exposed. The rocks were formed when the Iapetus Ocean (see story panel on page 13) was young and had not long before opened up as an ocean. This was caused by the sea-floor spreading as continents moved apart. In the same way, today's Atlantic Ocean split apart 65 million years ago, and is still getting wider.

Impressive sea stacks and islets, such as Thulla at the southeastern end, are evidence of the erosive power of the sea. Whilst they may appear not to change, even durable and resistant rocks like these ancient quartzites are constantly changing through time. The cliffs and stacks give Ireland's Eye its distinctive appearance from the mainland.

Site Importance

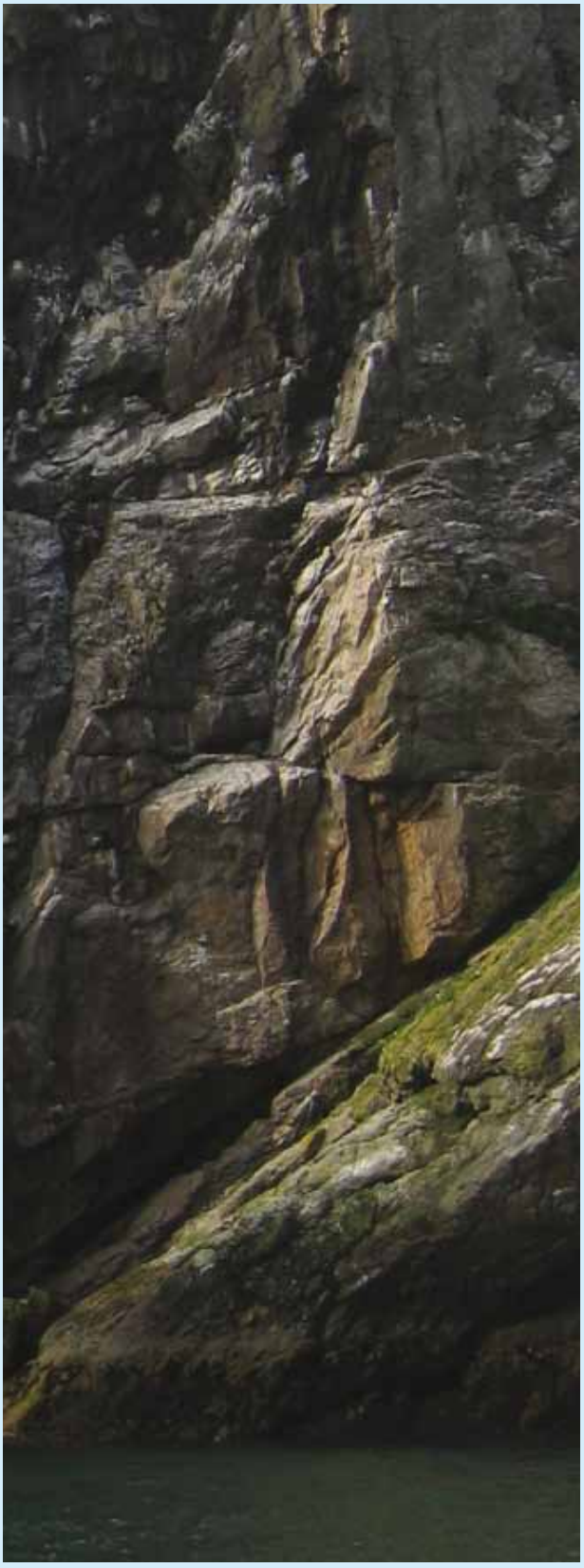
The island is important for its representative Cambrian geology and is a County Geological Site (CGS).

Visiting Ireland's Eye

Access to the island is by regular local boat service from the East Pier in Howth Harbour, mainly during the summer months. It is important to avoid disturbing nesting birds when visiting.

The sea stack Thulla

The beach on the western side of the island



Massive, hard quartzite rocks produce steep cliffs

Shenick's Island

Shenick's Island from Skerries. The island is briefly accessible at low tide via a sand causeway (do not get trapped on the island!)

Main Geological or Geomorphological Interest

Three main geological elements are exposed on Shenick's Island. The foreshore around the island displays the oldest rocks, a mix of volcanic ashes and lava and sedimentary shales, which collectively are similar to and related to the Ordovician volcanic rocks at Balbriggan. They are not dated because no fossils have been found in them, but their close relationship is a good indication that they are part of the same volcanic episode of Earth's history as Balbriggan's rocks, but just a little further away from the source of the eruptions.

The second rock type is composed of broken angular rock fragments and is called a breccia. It was formed about 110 million years after the oldest rocks. It is found only at the southern end of the island. It sits on top of the volcanics and includes broken pieces of them in a red sandy matrix.

The third element is till (also known as boulder clay) from the last Ice Age, which covers the centre of the island and is well exposed below the Martello Tower on the west side.

Site Importance

Shenick's Island is a jigsaw piece filling a gap in the picture of Ordovician volcanoes in north Leinster, and is a County Geological Site (CGS).

Visiting Shenick's Island

Access to Shenick's Island on foot, across a sand bar, is possible at low tide, but is not advisable. If you do visit, take care not to get cut off by the rising tide – you would have a long wait for the next low tide!

At the southern end of Shenick's Island an unconformity can be seen (the dotted line) with shallowly dipping beds of red conglomerate (on the right) lying directly on top of steeply dipping beds of Ordovician slate (on the left). This represents a time gap in the rock succession of about 100 million years

In detail, the Ordovician slates, seen running across the foreground here, are smeared with a jumbled mix of angular and rounded fragments of weathered and eroded slate set in a matrix of red sand

The cliff under the Martello Tower on Shenick's Island shows a cap of glacial till on top of the ancient rocks

Rockabill

Rockabill is better known for the sight and sound of terns flying than for its geology, but it represents the tip of a deeply buried granite body poking up at the Earth's surface and extending inland under County Meath

The guano of nesting sea birds has all but obscured the granite rock

Main Geological or Geomorphological Interest

The two islands together—the larger Rock, with its lighthouse, and the smaller Bill—are composed of granite. This very localised occurrence is rare proof of the existence of one or more large bodies of granite which are believed to underlie north Fingal and southern parts of County Meath. It continues from Rockabill underneath Balbriggan, deep underground, and on towards Navan. Its existence has been suspected from geophysical evidence since 1952, although a small occurrence was also found in a deep excavation in Drogheda in recent years.

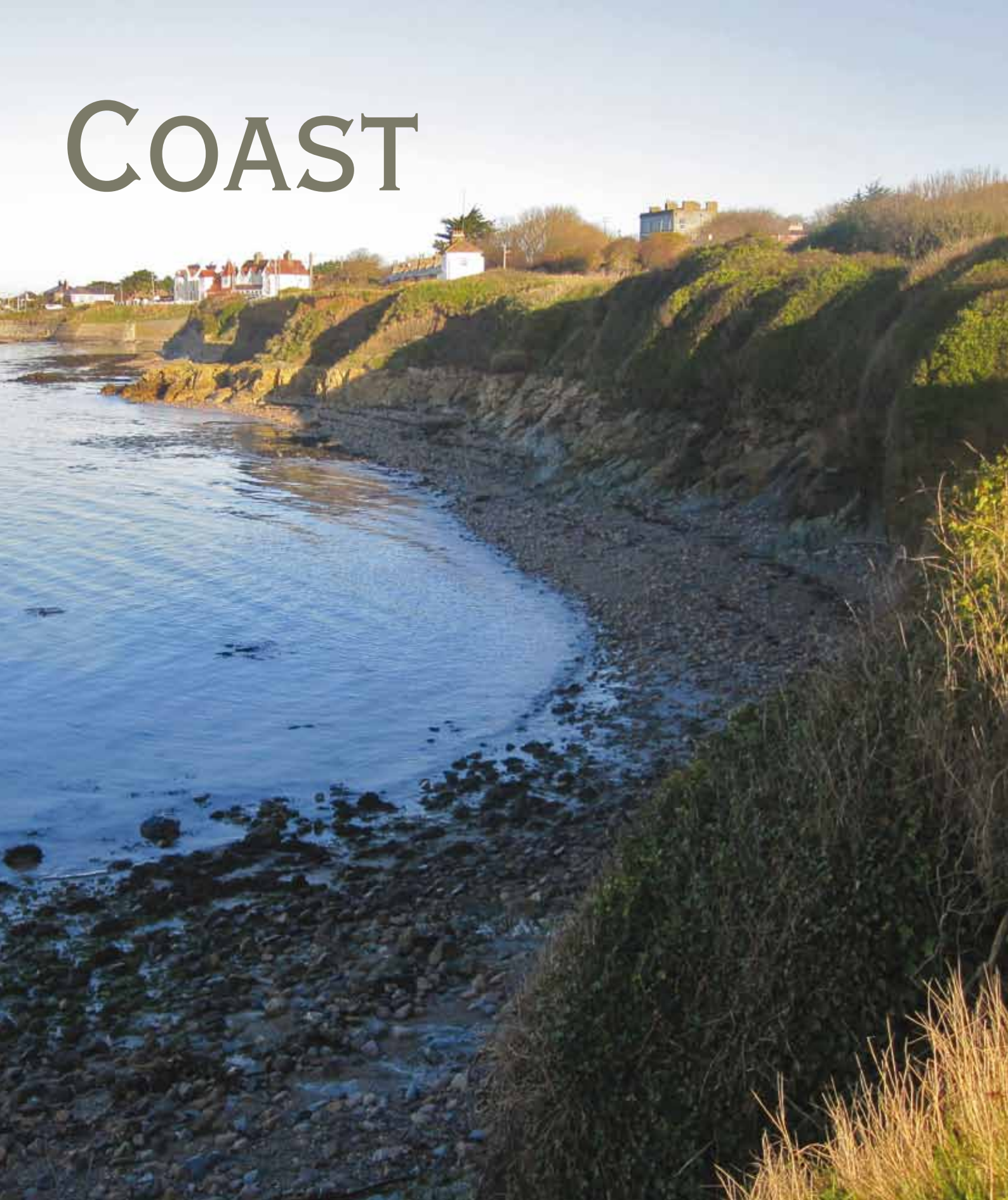
Site Importance

Rockabill is a County Geological Site for its importance as a surface example of a deeply buried granite known from geophysical evidence to underlie the region.

Visiting Rockabill

Access to Rockabill is not normally possible. As the island is of global importance as a breeding site for the roseate tern it is protected as a Special Protection Area (SPA), and birds must not be disturbed during the breeding season. For its geology, unless you have a serious research interest in granites, there is actually very little to see as most of the rock is well coated with guano!

Coast



Fault breccias at Balscadden Bay, Howth

Inside Pollnagollum cave at Portrane

A crinoid stem in cross section, a typical fossil from Carboniferous rocks, seen here at Malahide

Left: Cambrian aged rocks, of types such as quartzite and slate, are seen along the shore at Bottle Quay, strongly folded with a top surface planed off by ice sheets, and then covered with a veneer of glacial till or sand and gravel washed along by glacial meltwater

Fingal is long and narrow, which means that for its size it has quite an extensive coastline. Along with all its islands and river estuaries, this makes it a diverse and fascinating area. The coast is a highly dynamic place because the sea is constantly changing the land.

- It is contested ground — the sea tries to remove the rocks of the land, but some rock types are rugged and resistant and survive as headlands, stacks and islands.
- It is a place of balance — erosion and removal of rocks in one place is always balanced by sediments being deposited somewhere else.
- It is a harsh environment — only a few specialist plants and animals can survive.
- For humans, it is a frontier territory — people normally avoid building houses, except in sheltered harbours.

All of this makes the coast a special place for geology: the best places to see geology exposed are mainly on the coast, where there is no soil, vegetation or urban development.

Most of the sites identified as County Geological Sites in Fingal are in coastal locations. From Bottle Quay on the south side of Howth to Fancourt Shore just south of Balbriggan, Fingal's coastline has varied underlying geology, and also varied geomorphology — the landforms created by different Earth processes.

Fancourt Shore

The view northward over most of the Fancourt Shore section

The beds all dip fairly steeply to the south, although there are some small faults, thus providing a thick section of early Silurian rocks

Main Geological or Geomorphological Interest

A coastal section of rocks at Fancourt, south of Balbriggan town, has yielded the most complete succession (a group of rock strata in a chronological sequence) of Irish Silurian rocks. These have been dated by the graptolite fossils in them (see panel on facing page). This section is therefore an important reference point against which other fossil-containing sites can be compared.

Fossils in rocks can be used as a timescale. A biozone that contains a particular fossil species is used as a unit of 'time', and this provides a way of correlating rocks from different places based on the species found in them. The Fancourt Shore section also includes graptolitic black shales of upper Ordovician age. A fault separates these from the Silurian succession at the north end of the shore section. Local faulting means that not every single Silurian graptolite zone is recognisable, but a nearly complete succession of the older half of the Silurian Period has been established.

Site Importance

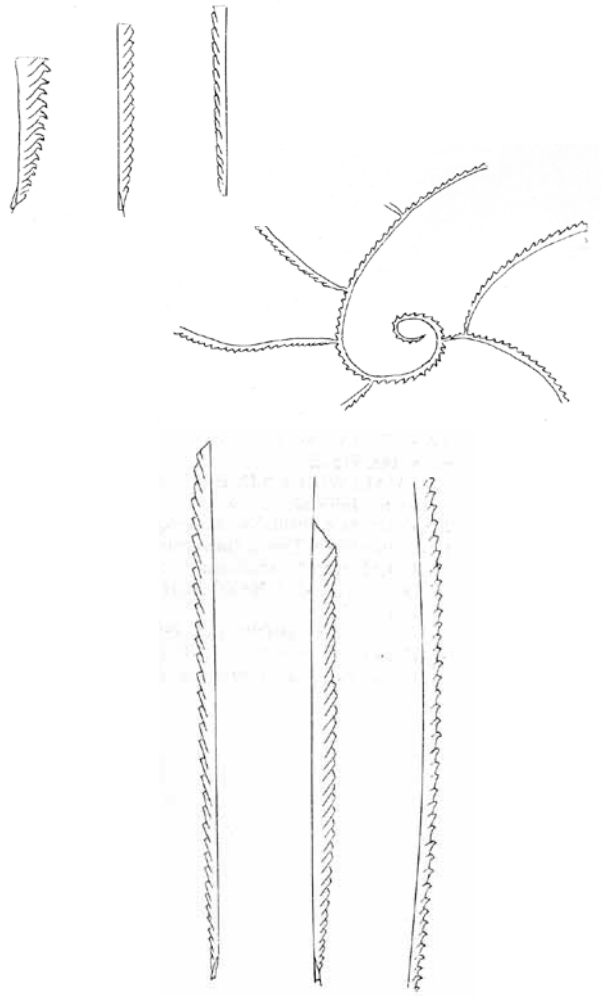
The area is a County Geological Site (CGS), but it has also been put forward by the Geological Survey of Ireland for Natural Heritage Area (NHA) designation by the National Parks and Wildlife Service on account of the completeness of the graptolite fossil succession. Most places with graptolites in Ireland tend to represent only snapshots of one particular time and graptolite biozone.

Visiting Fancourt Shore

Access to the shoreline is from the green space in Hampton Cove housing estate, off the Skerries Road southward out of Balbriggan. This site is publicly accessible as it is nearly all foreshore, but it is only safely reached when the tide is out. Due to the arduous work required to extract graptolites, and their rather dull appearance (except to the specialist), this site is not recommended as the place to start if you have an interest in fossils!

Graptolites

Graptolites are an extinct group of animals that lived in the sea. They first appeared in the Cambrian era, were abundant all over the world during the Ordovician and Silurian, and then disappeared in the Devonian. Their name comes from the Greek words *graptos* (written) and *lithos* (rock): they look rather like doodles on rock. Typically they are preserved as carbon films in slaty rocks, with grey or pyrite streaks and a saw-blade appearance. Most were shaped like single or double sticks, but rarer forms were spiral, multi-branching or bushy. In life they were planktonic and may have been able to float rather than just drifting in the sea. Most were only a few centimetres long.



Skerries to Rush

At Loughshinny the folds in the beds of limestone rock are picked out on the foreshore

Main Geological or Geomorphological Interest

The coast between Skerries and Rush exposes six different geological formations, representing different geological time periods and changing environments when they were deposited. This is one of the best continuous successions of Lower Carboniferous age rocks anywhere in Ireland or Britain. These rocks show many different sedimentary structures, tectonic structures and fossils. They are strongly deformed by compression, with zig-zag or chevron folds especially visible at Loughshinny. Many of these folds are picked out in three dimensions — as a section in the cliff; and in plan form (like a map) — on the foreshore platform. North of Loughshinny is the Smugglers Cave, which is actually an old copper mine dating back to the 1800s.

Site Importance

The whole section of coast is a County Geological Site and may be designated as a Natural Heritage Area in the future. It is of national importance — and maybe regarded by geologists as of international importance.

Visiting Skerries to Rush

Much of the coastal section has high cliffs and is not easily accessible. Other parts can be traversed safely at low tide, but caution must be exercised at all times. The most accessible sections for walkable beaches are around the towns of Rush, Loughshinny and south of Skerries.

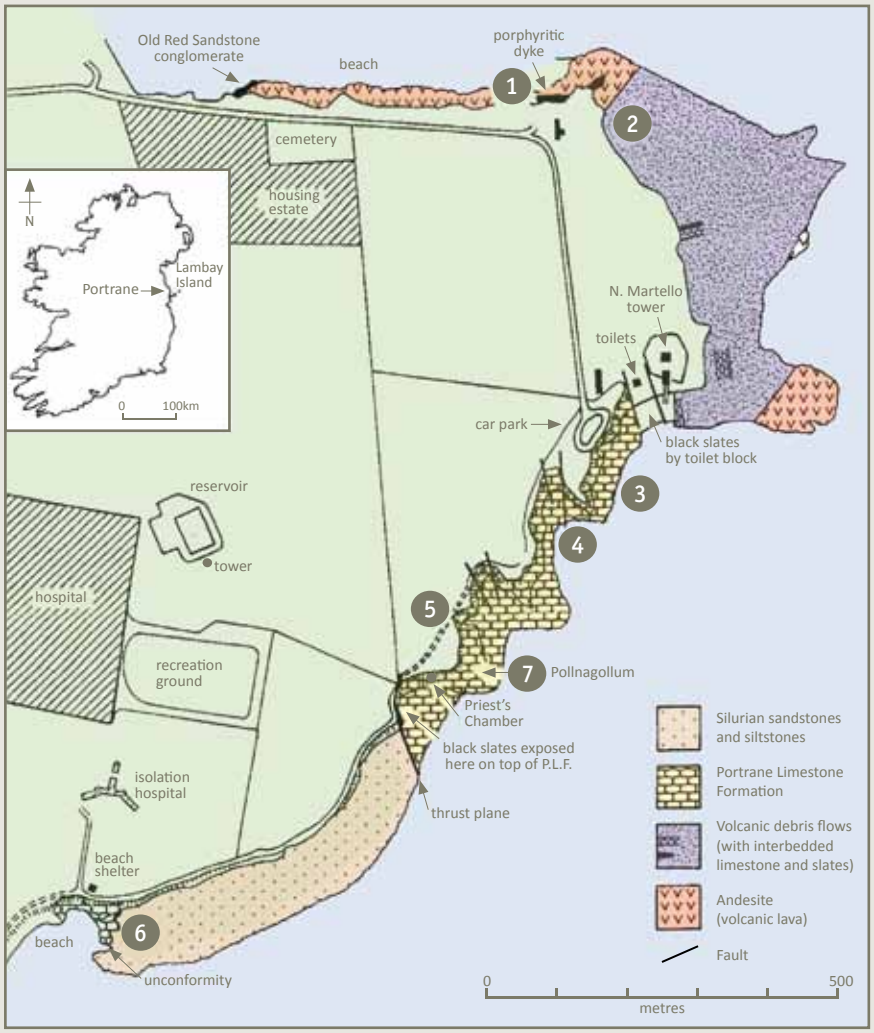
A section of the tight angular folding seen at Loughshinny

An old copper mine is known locally as the Smugglers Cave. It was worked mainly in 1807-8 and yielded over 100 tons of copper ore

Along the limbs of folds, flat but tilted bedding surfaces are seen at Loughshinny

Some folds are more rounded, like this one

Portrane Shore



Main Geological or Geomorphological Interest

Portrane Shore has an immense geodiversity in a very small area. The main elements are described below:

1. Andesite lavas of the Ordovician volcano of Lambay Island from about 460 million years ago along the northern shore.

2. Along the east-facing shore north of the Martello Tower there is a complex mix of debris flow deposits.

3. Fossiliferous limestones that formed as lagoons around the dormant volcano, mostly found south of the car park, have silicified fossil shells and corals in them.

4. Widespread soft-sediment deformation – it was not fully lithified or converted to hard rock when it was disturbed by small earthquakes.

5. A doline (enclosed depression) formed in the limestone when it was exposed at the end of the Ordovician Period during an Ice Age – massive ice sheets locked up masses of water resulting in a sea level at least 45m lower than before.

6. Unconformable sandstones of Silurian age at the southern side of the promontory – there was a period of erosion of the limestone and tilting before the Silurian rocks were deposited, with a time gap of perhaps only 17 million years.

7. More recent caves, including Pollnagollum, in the limestone that were created by underground rivers – but most have been modified by sea erosion.

The walls and the passage shape show that Pollnagollum cave at Portrane was formed by normal cave solution, and not by sea erosion

Brownish-grey Silurian rocks on the blueish-grey Ordovician limestones at the southwest end of the section represent a time gap of about 17 million years

Site Importance

This County Geological Site is also of national importance for several different geological themes and is highly valuable for research and for teaching geology, as well as general appreciation by visitors.

Visiting Portrane Shore

The headland is quite accessible. There are beach car parks at the north and south sides and on the headland itself; easy access by bus from Dublin; and a train station at Donabate, only 2km away. A clifftop path around the headland allows views of most parts. Access to some individual coves is via difficult paths or scrambles. It is possible to get cut off by the rising tide in some small inlets, so care is necessary to avoid this. At low tide most parts are accessible at beach level.

The karstic doline at Portrane which formed around 440 million years ago when an ice age lowered sea level and the limestone emerged as land

Most of the limestone beds at Portrane were still soft-sediment when they were folded and disrupted

Silicified fossils

Most marine animal shells are made of calcium carbonate (calcite). During the process called diagenesis, which is the conversion of soft, wet sediments into hard rock, these shells can be preserved in various ways. Sometimes they stay the same. Sometimes the shell structure is dissolved and then replaced by crystalline calcite (which you can often see as white curved shapes in sawn slabs of limestone on modern buildings). More rarely, the shell is dissolved but then replaced by a form of silica. This is what has happened to many of the fossils at Portrane — they have been silicified. Since silica is not soluble in rainwater (which limestone is), the fossils of shells and corals can be seen sticking out of the limestone. This property is useful in palaeontological research — dissolving bucketloads of rock in weak acid can yield a range of fossils.

A short section of fossil bryozoan, replaced by silica

A cross section through a solitary coral, but it is not silicified

A silicified brachiopod shell

Malahide Coast

Fossiliferous Carboniferous limestones are well displayed along the shore between Portmarnock and Malahide, in a gently dipping sequence

A colonial coral fossil in cross section

Main Geological or Geomorphological Interest

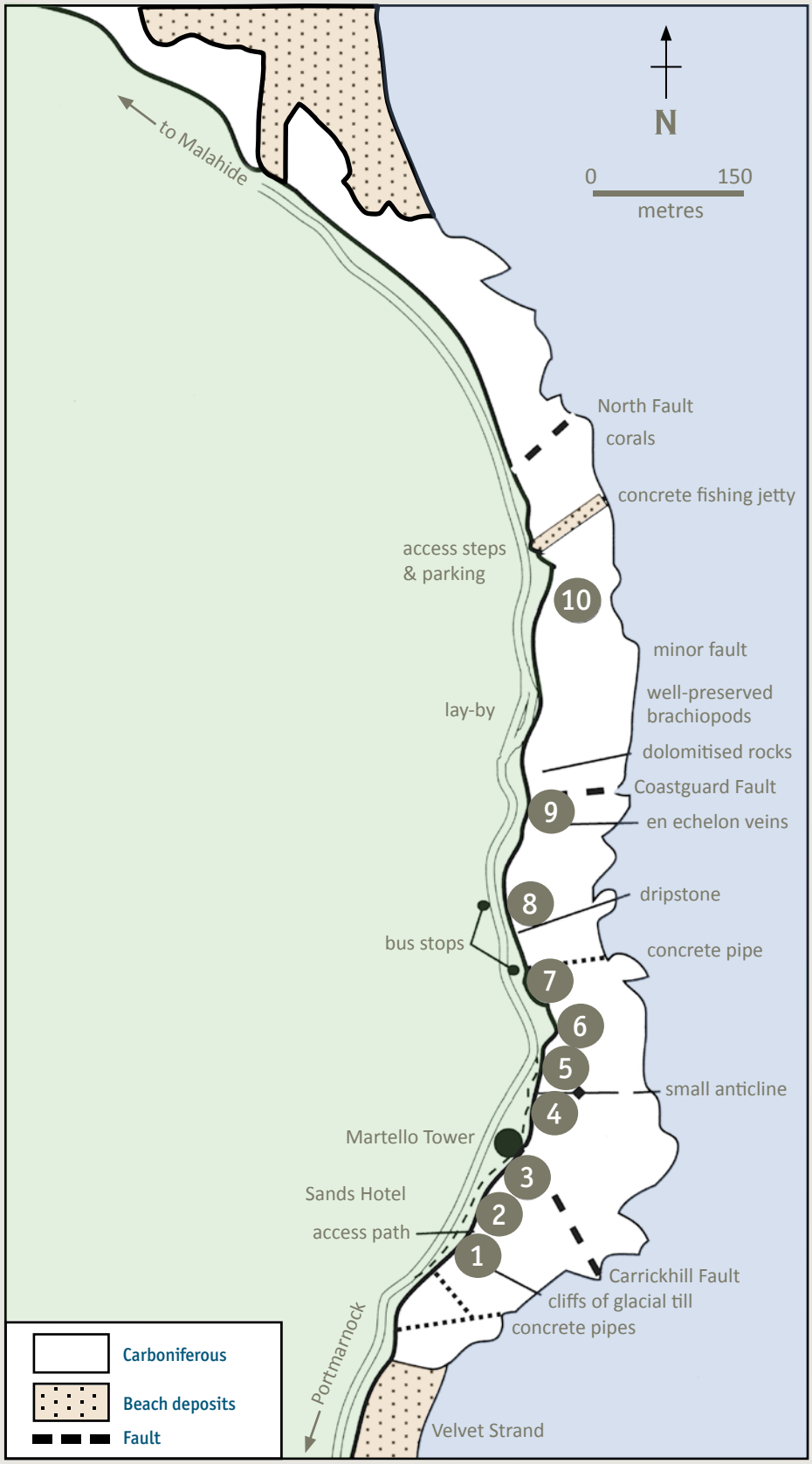
This coastal section of Carboniferous limestone rocks shows a diverse range of fossil fauna. There are three faults in the section, but this is the only near-continuous section of fossiliferous Lower Carboniferous age rocks near Dublin, and the large quantity and variety of fossils make this a very interesting location.

Site Importance

The site is a County Geological Site for its interesting succession of Carboniferous rocks. It may be of national importance, and is likely to be put forward as a geological Natural Heritage Area in the future.

Visiting the Malahide Coast

This entire section is easily accessible from the public path along the coast road between Malahide and Portmarnock. Care must be taken: the best time to visit safely is at low tide and in calm weather.



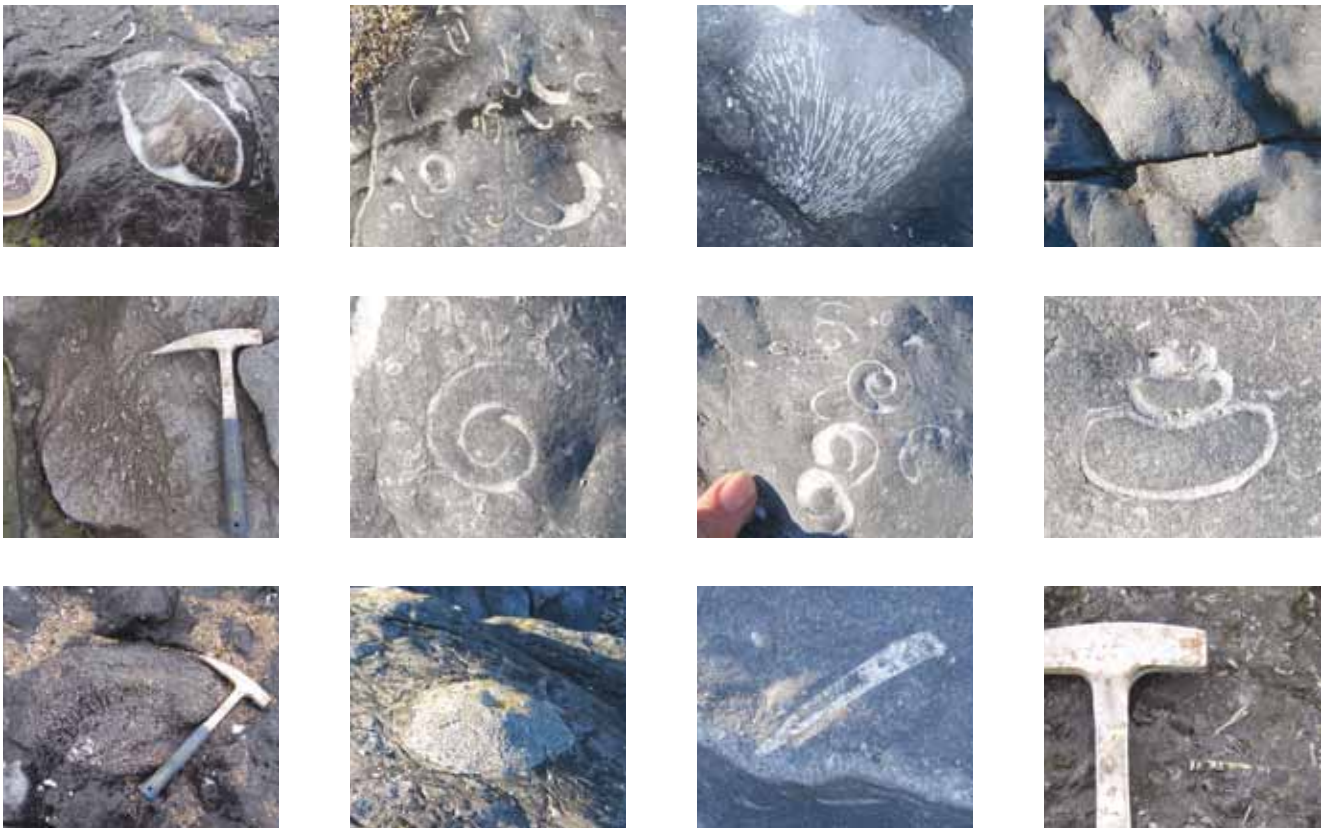
Highlights along the Malahide Coast

1. Crinoid and bryozoan fossils common in this area.
2. Cliffs of glacial till on top of the limestone.
3. White calcite veins indicate the fault.
4. Finely laminated limestone beds were probably formed in very shallow or tidal water depths.
5. An anticlinal fold is seen here – rocks dip away from the axis.
6. A single limestone bed is rich in brachiopod shell fossils.
7. Rich coral and gastropod (snail) fossils in this area.
8. Where lime-rich waters seep out from the junction of the glacial till on the limestone beds, a spongy deposit called tufa is formed, similar to stalactites in caves.
9. Disruption, veins and breccia of a fault line are seen here.
10. Bryozoan, brachiopod and crinoid fossils well seen on water-washed surfaces.

Collecting fossils – do's and don'ts

If you get bitten by the fossil bug, and find yourself collecting some, here are a few pointers:

- At sites like the Malahide coast, do not collect fossils in situ as there will be nothing left for the next visitor to appreciate. Unless you are experienced and have the right tools, you will not be able to get fossils out of water-worn surfaces. So please avoid hammering at the obvious visible fossils!
- Take photographs, and include a scale such as a ruler or coins.
- Preferably collect only loose rocks that are getting battered by the tides anyway.
- Make notes and take photographs of where you collected the fossils.
- Wrap fossils in newspaper or tissues and put them in a bag. Resealable-type food bags are good for this. Write a label on paper or card and put it in the bag, or use a good permanent marker to write on the bag or on the other side of the rock containing the fossil. You won't always remember the details later!
- Try to identify your fossils using books, websites and museum displays.
- If you cannot identify your finds you can ask for help from the geological curator at the Natural History Museum in Dublin.



Some of the marine fossils you might see in cross section on the wave-washed rock surfaces. **From left to right, top row:** brachiopod shell with hints of the internal spiral structures that supported the soft parts; brachiopods and gastropods (snails); colonial coral in side section; colonial coral in top view. **Middle row:** colonial coral in side view section; a gastropod, with hints of spines off the outside; a cluster of gastropods; a single gastropod. **Bottom row:** a colonial coral; a colonial coral viewed obliquely to show the typical dome shape of a whole colony; a straight-shelled nautiloid; a straight-shelled nautiloid clearly showing the separate chambers

Malahide Point also known as Balcarrick Beach, Donabate

The sand spit at Malahide Point (just behind Balcarrick Beach) provides fine beach walks, but the dunes behind have long been a links golf course

The one inch to the mile Geological Survey of Ireland map from the mid 1800s shows a much smaller spit than aerial photographs from 2000

Main Geological or Geomorphological Interest

The sand spit at Malahide is a landscape feature that was created by a build-up of sand deposits in Malahide Estuary. The feature is sustained by a combination of longshore drift of sediment southwards on the coast, water from Broadmeadow River and Ward River flowing out into the estuary and the impact the embankment for the Dublin to Belfast railway line has on sand deposition.

The feature is a particularly broad sand spit. When compared to historical maps it appears to be growing wider (accreting), building up ridges at the southeast corner.

Site Importance

The site is a County Geological Site and is a good example of an accreting sand spit.

Visiting Malahide Point

This may be geological heritage that is normally studied using maps and aerial photos, but it is best enjoyed on a bracing walk along the beach or a summer swim! The dunes in the centre of the spit are now a links golf course, but public access to the beach is from the north end via the Balcarrick Road out of Donabate.

Bottle Quay

A view of the Bottle Quay section looking northwest from near the Martello Tower at the southern end

Main Geological or Geomorphological Interest

Excellent exposures of some of Howth's Cambrian rocks are found at Bottle Quay on the south side of Sutton. The rocks here are quartzite and mudstone rock types. The site shows some evidence of disruption that happened in Cambrian times when they were still soft sediments. Then there are tectonic fractures that happened much later, mostly shown up by white quartz veins. In addition, the Cambrian rocks are covered with high cliffs of Ice Age (Quaternary) till. This mixed deposit of sand, gravel and clay also shows some evidence of the ice shearing away the surface of the Cambrian rocks, illustrating the erosive power of glaciers.

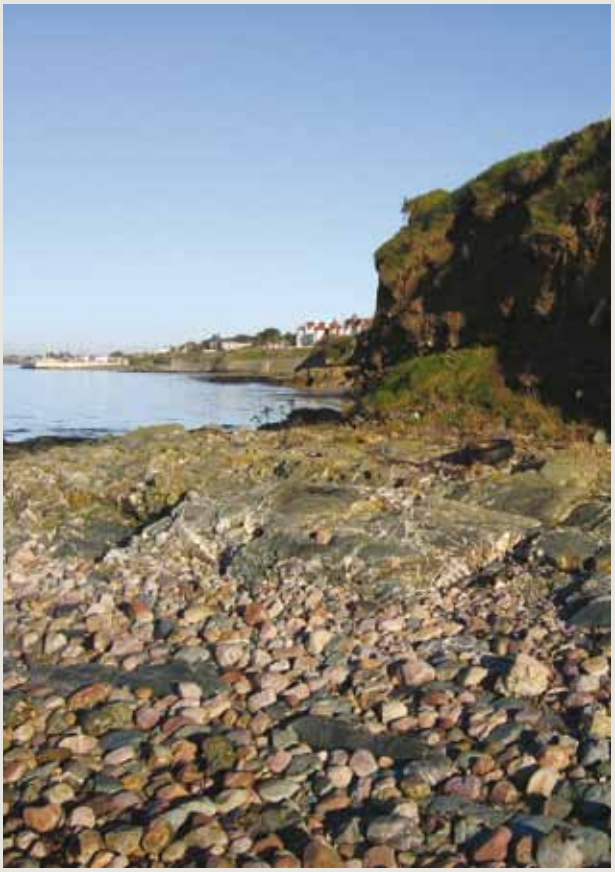
Site Importance

The coastal exposures are a County Geological Site as an accessible and clear representation of the Cambrian rocks of Howth, with their glacial modifications.

Visiting Bottle Quay

Access is possible from the cliff walk, though most features are best observed from the rocky beach. It is best to visit at low tide.

Slaty mudstone rocks are interbedded with the quartzites



Foreshore exposures of quartzite are heavily veined with white quartz veins where they have been fractured and folded

A mixed deposit of cobbles, sand and mud, called till, is left on top of the bedrock by ice sheets which topped the Hill of Howth

Claremont Strand

A view westward along the main section of rocks at Claremont Strand

Main Geological or Geomorphological Interest

This short section of rock headland between beaches includes a good example of Waulsortian limestone from the Carboniferous Period. Waulsortian limestones are normally massive and without obvious layers (beds). They formed as mounds of lime-mud on the sea floor, probably with mats of bacteria or algae binding them together. They are also characterised by having calcite-filled irregular cavities distributed widely through them. They often had lots of animals living on them as they created shallower and sheltered environments under the water. Today they often show fossils in cross section. In addition, there is a good section of till, left after the Quaternary Ice Age at Claremont Strand.

Site Importance

This is a place of County Geological Site importance as a reasonable example and accessible place to see the particular type of Carboniferous limestone known as Waulsortian, which was originally discrete sea floor mounds of lime-mud, bound together. See page 41 for a distribution map of this special limestone.

Visiting Claremont Strand

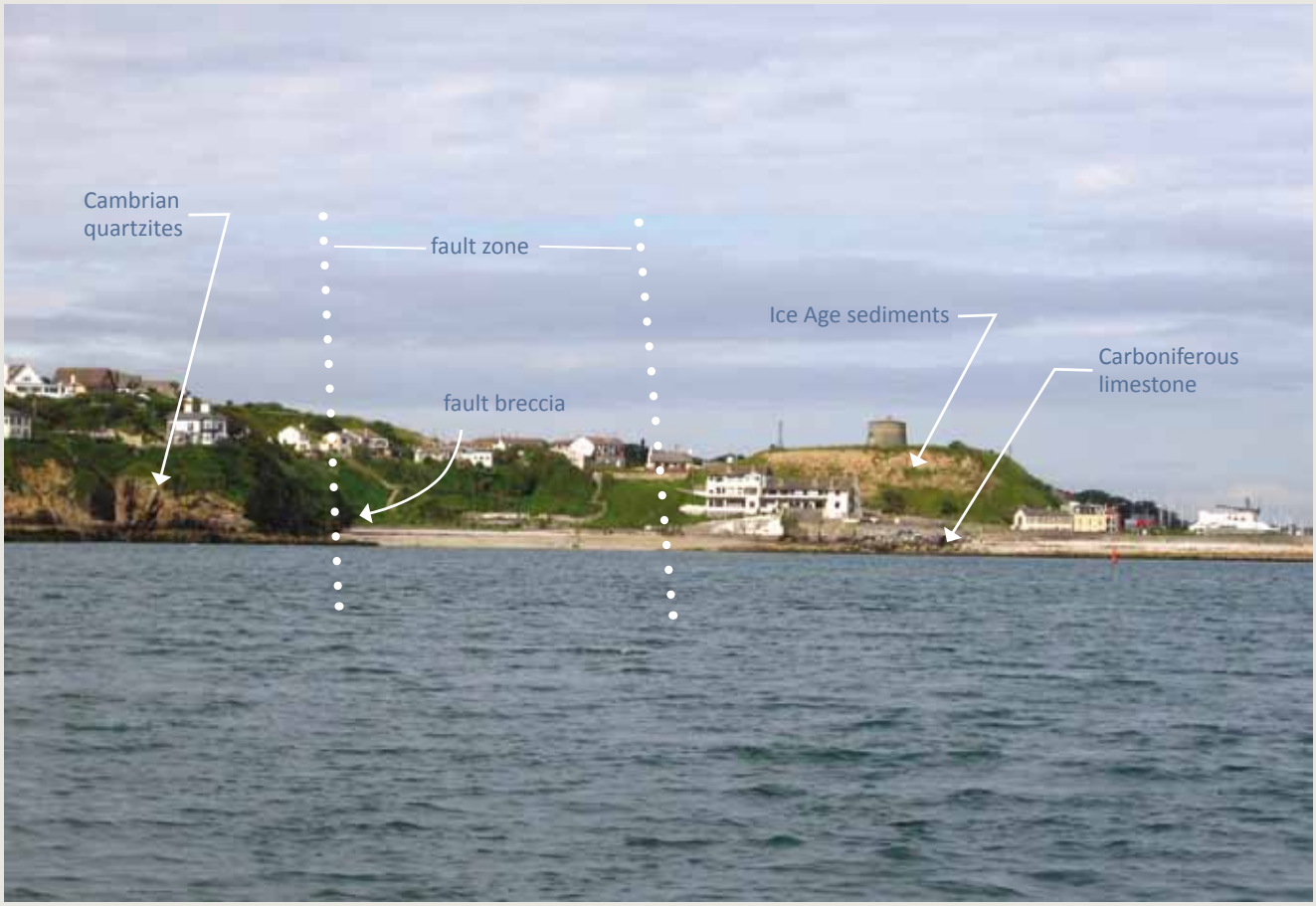
The site is really only exposed at low tide, so time your visit carefully. The chances of getting cut off are low, as the section is only about 500m long, although some of it is backed by high garden and sea walls. There are public beaches at each end of the site.

A pillar of glacial till stands like a last bastion of the natural coast here

The limestone bedrock shows classic mottled textures of Waulsortian limestone

A close-up view of the Waulsortian limestone textures

Balscadden Bay



A view eastward into Balscadden Bay from the sea. Cambrian rocks occupy the left-hand side. The fault is a wide zone spanning the back of the beach. Some exposures of broken-up rock (fault breccias) appear in the far left corner of the beach. Carboniferous limestone rocks appear in the bottom right below the Martello Tower, at sea level, whilst the tower sits on glacial sediments

Main Geological or Geomorphological Interest

In Balscadden Bay there is a significant fault zone. There are Cambrian rocks on the south side of the bay, typical of the Howth peninsula. The north side of the bay, toward Howth harbour, shows dark Carboniferous limestone rocks. They have been placed side by side by a large fault. The fault is a wide zone across the bay, made up of broken fragments of rock (called a breccia). The Carboniferous rocks are seen only on the north side of the bay as gently dipping beds. Above the bay, in steep roadside slopes, are exposures of thick sands and gravels, which were deposited by glacial meltwaters. There is then a layer of till on top, showing that an ice sheet advanced over the sands as a last blast of glaciation.

Site Importance

The site is a County Geological Site for its structural geology, displaying a significant fault, and it has good potential for teaching geology.

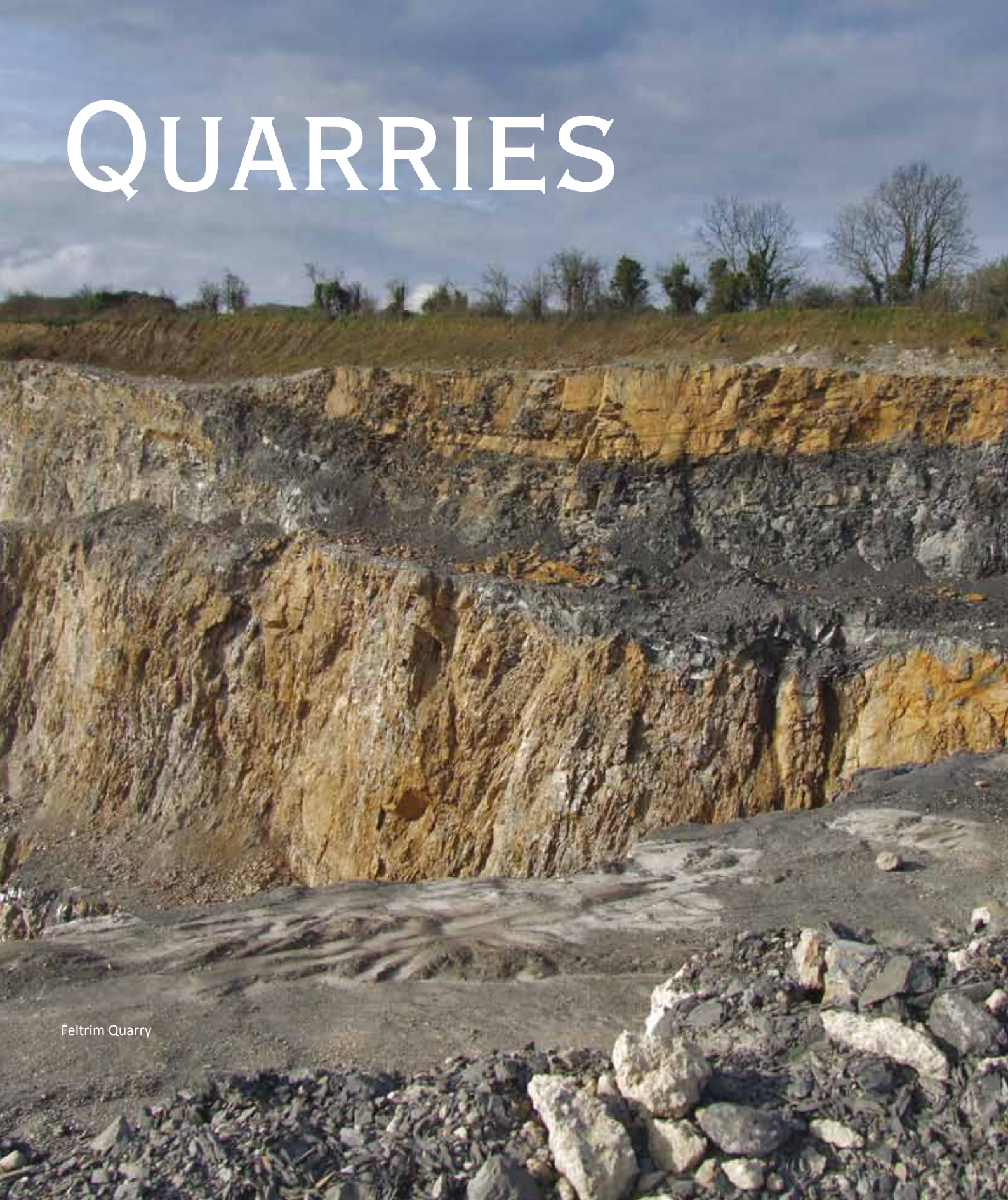
Visiting Balscadden Bay

The rock exposures along the waterline on the south side of the bay are Cambrian rocks which are 500 million years old, with Carboniferous rocks (200 million years younger) on the northern side of the beach. A wide fault zone runs through the back of the bay, with fault breccia visible in the corner. The shingle beach is accessible by uneven steps and footpath, but beware of rough weather and tides.

The rocks in the corner of the bay comprise a breccia — a broken-up mess of fragments in a fault zone

A view southward into Balscadden Bay from beside the Martello Tower. Cambrian rocks occupy the far side. A fault breccia appears in the right-hand corner. Carboniferous limestone rocks are not seen in the bottom left due to the house roof

Quarries



Feltrim Quarry

Fingal has a long history of quarrying to provide stone for building, both locally and throughout Dublin. The construction boom of the Celtic Tiger years fuelled a massive increase in quarrying activity and in output from individual quarries, but selecting and extracting suitable stone for the construction of buildings has a long tradition going back over many centuries.

Historically, important buildings in towns and communities were constructed using dimension stone. Dimension stone was quarried out and dressed by stonemasons with chisels and hammers to get it to the precise shape and size that was required. Older quarries were often worked intermittently and many small older quarries are found scattered throughout the county. Many of the historical fossil collections in the National Museum and the Geological Survey of Ireland came from these older, now inactive quarries across the country.

Modern construction has changed the face of quarrying. Stone is now crushed as aggregate and reconstituted as blocks or as concrete for modern buildings. Crushed rock or gravel aggregate is essential for modern development, whether in homes, offices, factories, harbours or roads. Cut stone is now really only used as decorative sheets cut for cladding steel-framed concrete structures, and for minor conservation-based works and specialist projects. The development of machinery and extraction techniques have also made it much easier to extract large volumes of rock, and some of Fingal's quarries are massive. For example, quarrying activity covers approximately 50 ha at Huntstown Quarry near Finglas.

Quarries have had an image problem in modern times. In former decades, when there was little regulation, quarries generated noise and dust and lots of lorry traffic, and not many people would have regarded them as good neighbours. Many have been abandoned and have become dumping grounds, which has further damaged their public image. Yet many people do not make the connection that if they want material goods, economic development and services, they must live with quarries. Nearly everything we produce, apart from food and timber, has originally been derived from a quarry or a mine or an oil well.

Today, quarries are well regulated and only permitted when environmental assessments have been completed. Consideration must be given to the end-use as part of the planning process. In Fingal, quarry sites that are County Geological Sites (CGS) are mainly modest, disused sites such as Curkeen Hill Quarry and Balrickard Quarry, which are useful reference sites for geologists. However, active working quarries such as Feltrim Quarry and Milverton Quarry are also included as County Geological Sites. These are superb places to see particular aspects of geology. Nags Head Quarry has moved from extraction to end-use in recent years. It will eventually be backfilled, but the operators have been co-operating with efforts by the Geological Survey of Ireland to maintain access to some key sections and to support educational opportunities in relation to quarrying (see also pages 48 and 49).

Quarries provide a window into the Earth's structure

Quarries provide a window into past sedimentary environments

Quarries provide a window into the groundwater and karstic weathering

Curkeen Hill Quarry

A face has been left accessible to geologists at Curkeen Hill Quarry, even though most of the quarry has been landfilled

Main Geological or Geomorphological Interest

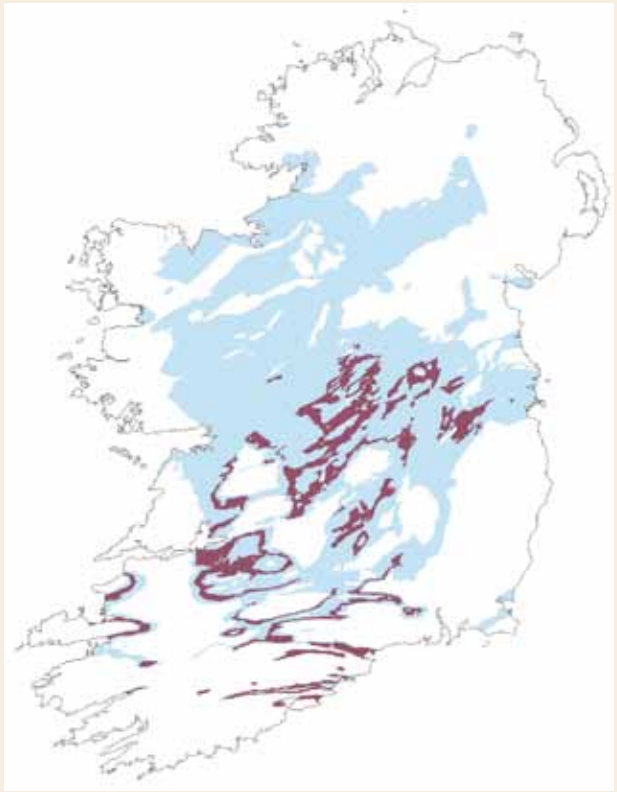
The small open face of a disused quarry lies 2.5km south of Skerries. Lower Carboniferous lime-mud mound rocks are exposed here. These mud mounds and banks are classified by geologists as Waulsortian, named after the place in Belgium where they were first described. However, they are best understood from widespread study in Ireland, where they occur across the southern half of the Midlands especially. As at Claremont Strand (pages 34–35), these mottled limestones are characterised by calcite-filled irregular cavities, and were originally mound structures on the sea floor of lime-mud bound together by bacteria or some biological agent.

Site Importance

Curkeen Hill Quarry is a diverse fossil locality with many recorded species, which are comparable to fossils found on the coastline at Loughshinny. This is an important Lower Carboniferous exposure, which has been studied in the past and is a County Geological Site as a representative example of only local importance. It is also an early example of accommodation for geologists: when the area was backfilled, a small face to the north was left open by negotiation with the Geological Survey of Ireland (GSI).

Visiting Curkeen Hill Quarry

The site is privately owned and is not open for public visits.



Carboniferous limestone distribution with Waulsortian limestone in red

In most quarries, if left to their own devices and not actively managed for geoconservation, plants become established and can quickly obscure the geology

Feltrim Quarry

A view into part of Feltrim Quarry from the rim. Although Feltrim Hill is slightly higher than surrounding land, the quarry has been excavated to some depth below the general level. Quarrying is done in stepped benches for stability and safety of the faces

Main Geological or Geomorphological Interest

Feltrim Quarry is contained within a Waulsortian mudmound complex where quarrying has been active since the eighteenth century. Due to the quarry's constant activity through the years it has provided excellent exposure of the Dublin Basin Waulsortian rocks and Lower Carboniferous shale. This site has a diverse range of fossils and is a type locality for some fossil species. This means it is the place from which came the type, or first described, specimens on which the species is based.

Site Importance

The extensive exposures of Feltrim Quarry, showing Lower Carboniferous stratigraphy with its diverse fauna, make this site nationally important. Many fossil species are widely distributed in the limestone. This County Geological Site lies within the existing Feltrim Hill proposed Natural Heritage Area (pNHA).

Visiting Feltrim Quarry

This is a large working quarry and is therefore a hazardous environment. It is not possible to access the site unless arrangements are made with the operators.

Large exposures in a quarry can show large-scale lateral changes in the sediments and the original environments that they represent

Piles of crushed rock aggregate ready for use are stockpiled on the quarry floor

Milverton Quarry

A view into Milverton Quarry

Main Geological or Geomorphological Interest

This small quarry is just south of Skerries. It shows good exposures of Lower Carboniferous limestone with occasional shale beds. There are also karst weathering features, such as pipes and caves. Karst is the general term for features of limestone rocks formed by solutional weathering, including caves, swallow holes, limestone pavement and many others. The karstic pipes at Milverton are mostly filled with orange-brown gravelly clay. Some are up to 8m high, and are found in the upper levels of the quarry. Limestone from this quarry was extensively used locally as well as to build the Rockabill Lighthouse.

Site Importance

It is a County Geological Site as a good example of exposed Lower Carboniferous rocks that otherwise can only be partially viewed along the Fingal coastline, just south of Skerries. The presence of karst weathering features along some of the quarry walls may also make this site a good teaching locality.

Visiting Milverton Quarry

Although this is a small, relatively quiet working quarry, it is still a potentially hazardous environment and is not suitable for general public access. As with any working quarry, geological groups must seek permission from the operators for any potential access.

A karstic solution pipe is apparent vertically in the rock face directly above the person's head

The quarry faces show near-horizontal bedding planes, near-vertical joints (fractures) and changes in thickness of beds

Some of these solution pipes and weathered fractures are infilled with red-brown clays which can sometimes provide environmental or fossil data

Balrickard Quarry

An exposed face at Balrickard Quarry shows thick beds of sandstone, with thin sandstones and shale beds above

A single very thick sandstone bed forms a distinct sloping feature in the back of the quarry

Main Geological or Geomorphological Interest

Sandstone and shale from the Upper Carboniferous Namurian Period are seen in this disused quarry, 6km east of Naul. It displays some good exposures of thickly bedded coarse-grained sandstone interbedded with dark grey shale, all dipping gently towards the west.

A cattle shed constructed up against the walls of the disused quarry at Balrickard

Site Importance

This old quarry exposes rocks of the Balrickard Formation, which would otherwise not be accessible. It is one of the few places in Fingal where this rock formation is so easily observed and because of this it has been recognised as a County Geological Site.

Visiting Balrickard Quarry

The site is privately owned agricultural land and is not accessible to the public.

Moss and vegetation quickly obscure rock faces in disused quarries such as Balrickard

Interbedded sandstone and shale of the Balrickard Formation. The thicker beds are made up of the coarse sandstones while the darker, thinner beds are the shale

Sandstone beds exposed at Balrickard Quarry, with very thin shales in between beds. Note mobile phone for scale

Sandstone beds are seen to dip gently to the southwest

The cattle can appreciate the geology from under their shelter

Nags Head Quarry

A view northeast into Nags Head Quarry, which will eventually be filled with waste in environmentally engineered cells

Main Geological or Geomorphological Interest

This large quarry, 5km south of Naul, exposes Lower Carboniferous rocks of the Loughshinny Formation – mixed beds of limestone and shale. The folds of the rock strata seen here are related to those also visible 12km away on the coast at Loughshinny. The Nags Head structures are more visible than those on the coast, because of the extensive rock faces in the quarry. In the northern part of the quarry there was one of the very few exposures of Upper Carboniferous sandstones in North Leinster, but this section has been backfilled.

Site Importance

The site shows impressive large-scale structural features in the bedrock that can only otherwise be observed along the coastal section at Loughshinny. It is an excellent teaching locality and a County Geological Site.

Visiting Nags Head Quarry

This former quarry, now a waste-disposal facility, is a potentially dangerous environment and is not suitable for general access without first contacting the owners. The facility management may allow supervised educational groups to visit, on request.

The Nags Head Quarry showed the Loughshinny style folds continued inland

What do we do when the quarry is finished?

Nags Head Quarry illustrates just how fast circumstances can change. In a few short years its purpose has changed from extraction to waste disposal. It also provides an example of constructive co-operation between operators and the Geological Survey of Ireland (GSI). In this case, the operators consulted with the GSI about their plans. As a result, although the quarry will eventually be filled with fully licensed waste, key exposures of the rocks will be left accessible, at least until the final stages, for access by geologists. The owners have also proposed an information panel and a safe viewing area for the non-technical visitor.

The role that quarries can play in society extends far beyond their original function of supplying rock material, and can include waste disposal, biodiversity havens, water sports facilities, industrial or residential development, recreational resources such as rock climbing, concert venues, and much more.

Other County Geological Sites

Small quarries have provided building stone for local use around Howth and are seen near the top of the Hill of Howth

Not every County Geological Site in Fingal is an island, coast or quarry. The following sites are inland, but each tells us about different aspects of the geology of Fingal. Read their stories to round off your exploration into deep time in Fingal.

Use of local stone gives a distinct character to areas such as the Hill of Howth where the angular blocks of rich orange-tinged quartzite are widely used in walls and gate pillars

Ardgillan House Boulder

Main Geological or Geomorphological Interest

This single large boulder is composed of Ordovician pillow lavas. After underwater volcanic eruptions about 470 million years ago, lava interacted with seawater to form globular 'pillow' shapes. The water quenched the outside of the lava, forming a crust, but hot molten lava under pressure continued to flow out, creating these classic structures. Subsequent weathering has picked out concentric rings of cooling structures and trapped gas bubbles within the lava.

This boulder also has an interesting recent history. First found on the shore near Ardgillan, it was thought to be an archaeological artefact showing prehistoric stone carvings, like those at Newgrange. Initially stored in OPW premises in Trim, it was later saved from disposal and moved to Ardgillan by Michael Lynch, Senior Parks Superintendent with Fingal County Council at the time.

Site Importance

The boulder, which is a County Geological Site, tells several fascinating stories. It reveals not only its geological origin as volcanic lava that erupted underwater – evidence of the amalgamation of the two 'halves' of Ireland millions of years ago (see Iapetus story box, page 13), but also a more recent history of movement at the hands of people. It is sited in a publicly accessible, eye-catching spot, where many visitors can see it.

Visiting the boulder

The boulder is situated alongside the access path to Ardgillan House from the closest car park. It can be visited any time Ardgillan is open.

Walshestown Stream Section

Main Geological or Geomorphological Interest

A small, deeply incised stream at Walshestown has exposed long sections of dark shale, occasionally interbedded with thicker, more resistant beds of limestone and sandstone (see picture below). These are Upper Carboniferous rocks. The rocks here show several stages of erosion by the stream. There are a number of small waterfalls, with plunge pools, along the length of the stream. These are formed wherever a resistant bed occurs. A small tunnel, which allows the stream to flow under a local road, displays some of the best exposed rocks of this section.

Site Importance

Natural well-exposed outcrops such as this stream section are rare. They can be used by earth scientists as teaching localities and for mapping purposes. This stream section is therefore a County Geological Site.

Visiting Walshestown Stream Section

The land is heavily forested and is private property, so it cannot be visited without permission.

Mulhuddart Holy Well

Main Geological or Geomorphological Interest

Natural springs occur all over the country, where the water table intersects the land surface. The water may come either from shallow bedrock or from the Ice Age (Quaternary) deposits which overlie them. If these are sand and gravel they can act as aquifers for water supply. Mulhuddart Holy Well is typical of many natural springs in that it was considered to have religious significance. A small chamber was built over the spring.

Site Importance

Mulhuddart Holy Well is simply a good example of a natural spring in a publicly accessible space and recognised as a County Geological Site for that reason.

Visiting the well

The Holy Well is right beside a busy road, so care should be taken when visiting.

Hill of Howth

Main Geological or Geomorphological Interest

The Hill of Howth is a dominating presence in the Fingal landscape. It is composed of Cambrian quartzite and mudstones, which have resisted the erosion of the landscape over millions of years. Near the summit of Howth Hill, between Muck Rock and the Ben of Howth, is a heavily vegetated, steep-sided valley, formed along the line of a large fault plane. A large number of rock exposures are found across the hill, showing structures associated with faulting. Some also show glacial features referred to as gouges and striations (see grooves in the picture above) which prove that ice overrode the hill during the Ice Age. When sea levels were higher, Howth would have been an island, but today it is joined to the mainland by a tombolo — a sand bar — underlying Sutton.

Site Importance

This is an important County Geological Site. It clearly demonstrates both small- and large-scale structural deformation in Cambrian rocks, making this an excellent teaching locality.

Visiting the Hill of Howth

Access to the site is by numerous public footpaths that criss-cross the area. It is well served by public transport to Howth. This site lies within the existing pNHA and SAC of Howth Head and is well used by local people as a walking route.

What is a County Geological Site?

The National Heritage Plan of 2002 adopted the proposal for County Geological Sites as a non-statutory designation in local authority development plans. The aim of this measure was to provide awareness and information on geological heritage sites of local, or national, significance as a second tier of protection after the proposed network of geological Natural Heritage Areas (NHAs), which would encompass the best national examples of geological phenomena under 16 different themes.

All local authorities in the Republic of Ireland have now taken steps to include information supplied by GSI's Irish Geological Heritage Programme on the counties' geological heritage sites in their County Development Plans (CDPs). At this stage, some counties have been through a second revision of their CDP.

Several counties, including Fingal, Sligo, Clare, Kildare, Kilkenny, Meath, Carlow and Waterford, have now completed audits of their geological heritage. The reports and documentation of these county audits is available from the GSI website (www.gsi.ie) and from some of the county councils' own websites. The audits follow an established methodology and use the same general format, although they may differ in details depending on the geology of the county and the specific requirements of the local authority.

While County Geological Sites are a very important means of both protecting and promoting the most important geological sites in a county, there are many other places with interesting Earth Science aspects. Public sculpture can often be a particularly good means of generating interest, either in the rock materials used or with the design, such as this sculpture at Portmarnock

A summary geological history of Fingal

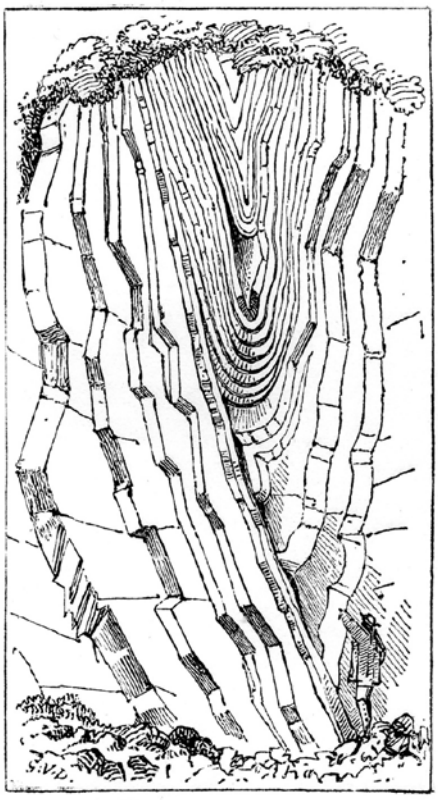
This book has avoided the conventional geological approach of starting with the oldest events or sites and working through to the modern day in a linear time-based fashion. The focus has been on the places and what can be seen, rather than the processes that created the featured rocks and fossils, and when each occurred in relation to the next. However, for readers who wish to understand a little more of the different places in a more rounded geological context, there follows a summary geological history of Fingal.

Rocks can be divided into three main groups: sedimentary; igneous; and metamorphic. Sedimentary rocks are laid down, generally in water, as particles of material such as sand or mud and then hardened by compaction and lithification (the process of becoming rock) into sandstones, siltstones, mudstones and limestones. Fossils preserved in these rocks can give us an idea of when the rock formed and what the climate and environment were like at that time. Igneous rocks crystallise from magma originating deep beneath the Earth's surface and may include volcanic lava flows at the Earth's surface. Metamorphic rocks are sedimentary or igneous rocks that have been altered by changes in temperature and/or pressure.

The predominant rock types in Fingal are sedimentary rocks, particularly limestone of Carboniferous age. These sedimentary rocks retain many of their original sedimentary and depositional structures. There are older volcanic rocks at Lambay Island, Portrane, Balbriggan (and Bellewstown in Meath).

At any one locality there is usually more than one rock type, or lithology. Rock types over a small area are largely consistent and types can be identified which often share common characteristics, allowing them to be grouped together as geological units. The most important of these 'units' is a 'formation'.

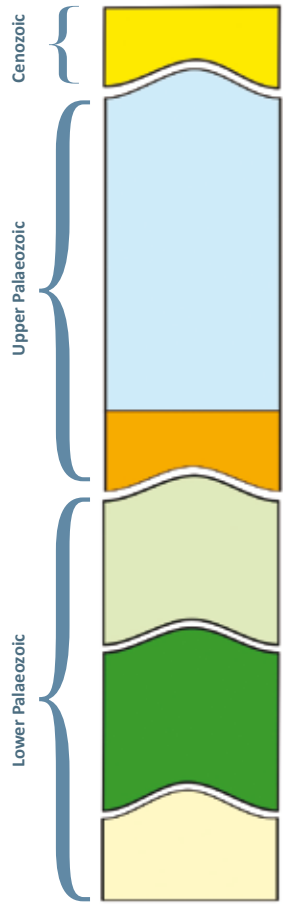
These formations are mapped as a sequence or succession of units in a stratigraphical order, with younger rocks generally overlying older rocks (unless they have been strongly faulted or folded). By compiling the formations into a column, with the oldest at the bottom and the youngest at the top, we can represent the geological history of an area. Internationally recognised names are used for the time periods. The following description of the main events and the rocks they formed in Fingal should be read with reference to the stratigraphical column (page 55), geological timescale (page 57) and map (page 59). The simplified map of Fingal's geology outlines the main units by age. For more detail on the individual formations, consult the GSI's 1:100,000 maps of the area (sheets 13 and 16, available from GSI).



This woodblock print of a fault in Cambrian rocks, east of 'The Needles', Howth, is from the 1861 Geological Survey of Ireland Memoir (note the hat and breeches of the geologist at work!). It reminds us that there is no definitive answer to all geological questions. Our knowledge increases and our interpretations change through time, but fundamentally we always need exposures of rocks, such as on the coast and in quarries, to piece together the jigsaw of Earth's history

Rock Sequence in Fingal

Schematic Stratigraphic Column



Quaternary

(Deposits of clay, sand and gravel commonly known as 'Boulder Clay' or 'Till')

Carboniferous

Formations

Walshestown Formation
Balrickard Formation
Mullaghfin Formation
Holmpatrick Formation
Smugglers Cave Formation
Lane Formation
Loughshinny Formation
Naul Formation
Lucan Formation
Rush Conglomerate Formation
Calp Limestone
Tober Colleen Formation
Malahide Formation
Donabate Formation
Waulsortian Limestone
Boston Hill Formation
Ballysteen Formation

Old Red Sandstone

Silurian Sequence

Formations

Denhamstown Formation
St. Ita's Formation
Skerries Formation
Balbriggan Formation

Ordovician Volcanic Sequences

Formations

Portrane Limestone Formation
Portrane Volcanic Formation
Lambay Volcanic Formation
Shenick's Island Formation
Belcamp Formation
Clashford House Formation

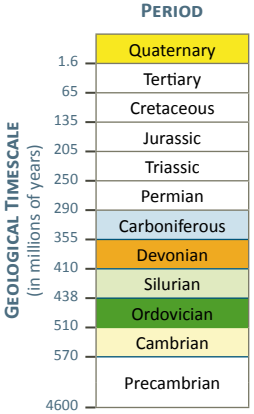
Bray Group

Formations

Pipers Gut Formation
Elsinore Formation
Gaskins Leap Formation
Hippy Hole Formation
Drumleck Formation

Geological Legend

- Carboniferous
- Upper Devonian to Lower Carboniferous
- Silurian
- Ordovician
- Cambrian
- Unconformity (period of non-depostion/erosion)



Cambrian to Devonian (Lower Palaeozoic Era)

Ireland is made up of two 'halves', which were originally separated by an ocean that geologists call Iapetus. The northwestern half was on the margins of a North American continent; the southeastern half was on the margins of the European continent. Plate tectonic movement throughout the Ordovician period saw the Iapetus Ocean close, and the two halves converged and eventually combined in Silurian times. Fingal's rocks tell part of this story.

Cambrian

In the Cambrian, oceanic crust was generated. This crust would later underlie the Iapetus Ocean. Although the basalts and other igneous rocks associated with oceanic crust formation are not seen in Fingal, there are a number of sedimentary formations visible along the coast and inland areas of Howth Head. These are the oldest rocks found in Fingal and indicate deposition in a marine environment. They are composed of sedimentary deposits of greywacke, quartzite and a chaotic mixture of several different sedimentary rocks formed by occasional slumping of the sea floor deposits down slopes. These rocks have faults all around them and are found alongside much younger Carboniferous limestones. Evidence of this faulting can be seen at Balscadden Bay, where a wide zone of fault breccia can be observed.

Ordovician

Iapetus gradually closed during the Ordovician, by the process called subduction, where one tectonic plate of the ocean floor is forced beneath another. Volcanic rocks were erupted into the marine sedimentary sequences, building volcanic arcs along the margins and in the ocean. Andesite lavas and intrusions are well exposed along the shore at Portrane and Balbriggan. Lambay Island and Balbriggan both had volcanic islands centred on them. The Ardgillan House Boulder is an example of pillow lavas produced by underwater eruption of lavas. The Portrane–Balbriggan volcanic rocks formed on the southern margin of the Iapetus Ocean (around 50° south). As northward subduction of the oceanic plate continued, the late Ordovician and early Silurian sediments deposited on the ocean floor were scraped off and piled up as a series of wedges (now in Longford and Down). Volcanoes appear to have ceased by the end of the Ordovician, suggesting that subduction had stopped. The latest Ordovician Portrane Limestone Formation was deposited possibly as an atoll in shallow water around the extinct Lambay volcano.

Silurian

By mid-Silurian times, the ocean had narrowed enough that it was no longer a wide barrier to migration of animal larvae. Silurian rocks are widespread in the north of Fingal, though generally not well exposed. Following deposition of the Lower Palaeozoic rocks, the continents on opposite sides of the Iapetus Ocean were brought together, squeezing the oceanic sediments and volcanic arcs in between. The collision crumpled the rocks and uplifted them to produce a range of mountains, in an event known as the Caledonian Orogeny. The folds, and the associated slaty cleavage, are aligned generally northeast–southwest throughout Ireland and actually link through to the United States and to Scotland and Norway along the collision zone. The base of the crust was pushed down under the weight of the mountains and the heat at depth caused it to partially melt, producing a large volume of magma. This rose up and cooled slowly to form coarse-grained masses of granite in the early Devonian (about 400 million years ago). There are no visible occurrences of this granite in mainland Fingal, but it occurs in Rockabill and has been found in a deep excavation in Drogheda.

Devonian

The Caledonian mountain belt was an area of erosion rather than deposition during most of the Devonian period. Conditions at this time were semi-arid: Ireland lay near the Equator and had a semi-desert environment. Few sedimentary rocks of this age are present in Fingal. The prolonged erosion wore the mountains right down to the granite, so that the next stage of deposition produced a major unconformity, or time gap, in the rock succession.

Geological Timescale for Fingal

AGE (Million Years)	ERA	PERIOD		Events Relating to Ireland and Fingal *(in italics)*
1.6	Cenozoic	Quaternary		*A series of ice ages leaving plains of sand and gravel followed by spread of vegetation, growth of bogs and the arrival of man.*
65		Tertiary		Erosion. Opening of the North Atlantic ocean. Volcanoes in NE Ireland.
135	Mesozoic	Cretaceous		Erosion. Probable incursion of the sea. Chalk deposition preserved today in Northern Ireland.
205		Jurassic		Uplift and erosion. Sediments deposited offshore.
250		Triassic		Erosion and deposition under desert conditions.
290	Palaeozoic	Upper	Permian	Erosion and deposition under desert conditions.
355			Carboniferous	*Land progressively submerged. Coastal plain and nearshore deposits followed by limestone deposition in shallow tropical seas. Subsequent building out of the land, deltaic sands and muds deposited, often under swampy conditions.* Variscan mountain building event (affecting southwest Ireland) towards the end of the Carboniferous.
410			Devonian	*Continued mountain building, rapid erosion and deposition under semi-desert conditions. Intrusions of granites and metamorphism during early Devonian.*
438		Lower	Silurian	*Closure of Iapetus Ocean, continental collision and initiation of Caledonian mountain building.*
510			Ordovician	*Deep-sea mudstone deposition on the floor of the Iapetus Ocean. Volcanism along the southeast margin of Iapetus as the ocean contracts.*
570			Cambrian	*Opening of the Iapetus Ocean between northwest and southeast Ireland.*
2500	Pre-Cambrian	Proterozoic		Oldest Rocks in Ireland
4000		Archaean		Oldest known rocks on Earth
Formation of the Solar System approximately 4600 million years ago				

Carboniferous Period

The eroded Caledonian mountains were partly buried by the river sand and gravel deposits of the earliest Carboniferous arid climate. In the Navan area there may have been remnant hills, formed of resistant Lower Palaeozoic rocks, which were eroded to produce coarse alluvial fans. These 'red beds' were in turn buried as the sea spread northwards over the whole of Ireland during the earliest Carboniferous. It deposited a thick succession of progressively deeper-water limestone sediments which accumulated in slowly subsiding marine basins. Richly fossiliferous mounds of carbonate mud (Waulsortian limestones) are a particular feature of this period. Structurally, some parts of the Earth's crust were uplifted and others moved downwards resulting in the formation of a 'block and basin' topography. Many of the spectacular folds at Loughshinny and in Nags Head Quarry are related to the movements of blocks.

A general subsidence then followed and the shallow platforms were buried by calcareous muds and sands. In the mid-Carboniferous, a southerly advancing delta complex deposited sands and muds in progressively shallower environments overlying the limestone-dominant sequence, seen at Walshestown Stream and Balrickard Quarry.

Permian, Triassic, Jurassic, Cretaceous and Tertiary

These subsequent periods have largely left no trace as rocks on the land. It is inferred that Ireland was mostly land, subject to weathering and erosion, which supplied the offshore basins with sediment. During the Tertiary period Ireland probably suffered karstic weathering with limestone being dissolved into distinctive features like today's Burren. It was possibly a landscape similar to the famous tower karst of Guilin in China.

Quaternary Period

The Quaternary Period covers the last 1.6 million years and includes the Pleistocene and Holocene. During the Pleistocene, which lasted from 1.6 million years to 10,000 years ago, alternating cold and warm stages (glacial and interglacial periods) led to the growth and decay of ice sheets, which covered the country on a number of occasions. The Holocene, which is the current (interglacial or postglacial) period, dates from 10,000 years ago to the present day.

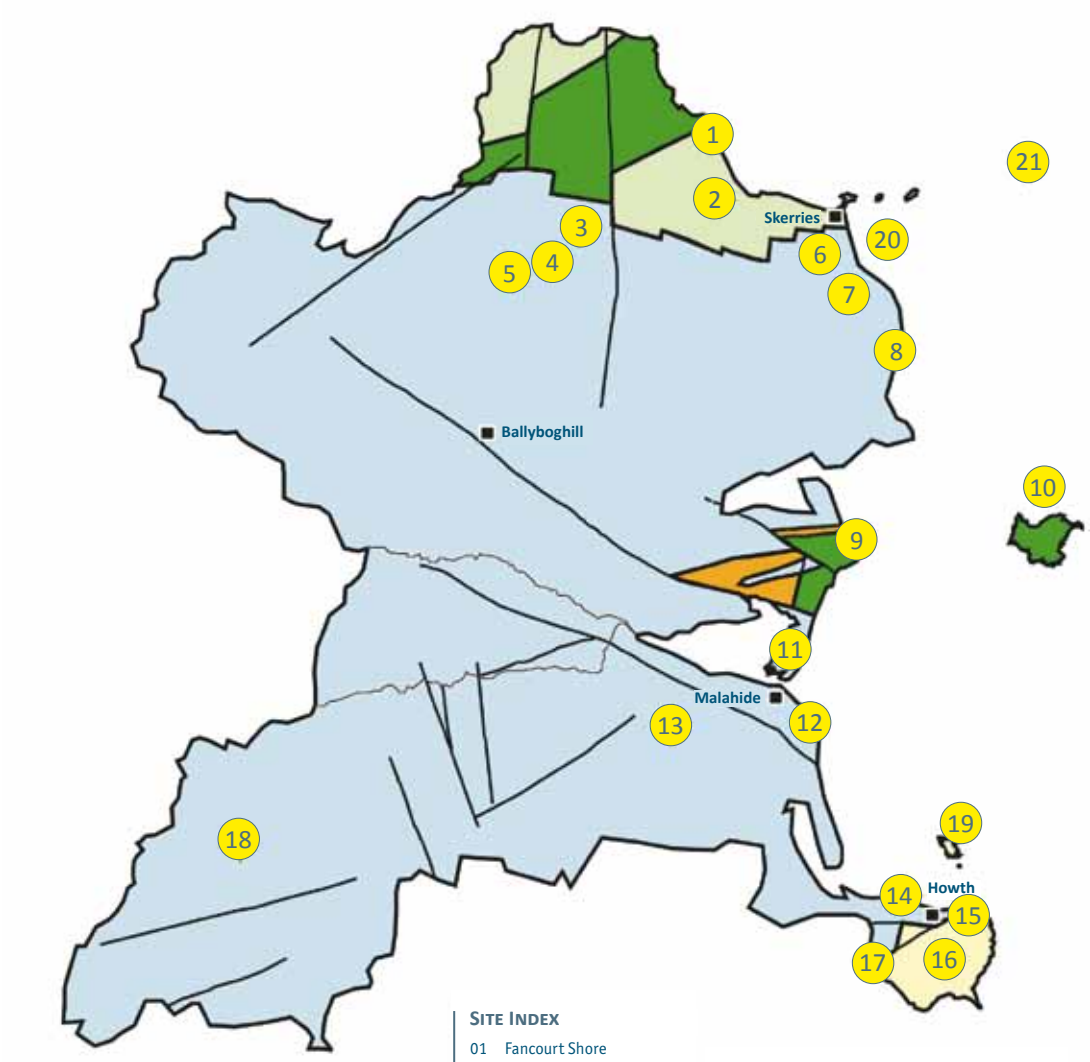
As ice moves over the land, pieces of rock are picked up and moved along with the glacier. The ice is very abrasive, which allows it to scour and erode the bedrock over which it flows. The ice also carried boulders (erratics) far from their source. The rock material eroded by and incorporated into the ice was eventually deposited, either directly by the ice as till (or boulder clay) or by meltwater as gravel, sand, silt or clay. The glacial deposits are thin or absent on the upland areas, but till thicknesses of over 30m are common on the lowlands and can be seen in a number of working quarries in the country as a layer on top of the underlying bedrock.

Towards the end of the last glacial period, the great ice sheets melted and returned the vast amounts of water they contained to the oceans. The sea level, which was 100m below today's sea level, began to rise. As it did, the sea flowed into areas that had been pushed down by the weight of ice.

The modern coastline began to develop after the postglacial sea level stabilised more than 5,000 years ago. Fingal's beaches and spits at Portmarnock, Malahide and Donabate were formed, and blown sand collected to form sand dunes. The peninsula at Skerries is really a tombolo —an island connected to the mainland by a sand spit which is covered by blown sand. The accumulation of these sediments is balanced by the erosion of other parts of the coastline, most spectacularly along the cliffs at Skerries. The Hill of Howth is also joined by a tombolo at Sutton, but rising sea levels could easily make it an island once again in the future!

Geological Map of Fingal

Including site locations



Geological Legend

- Carboniferous
- Upper Devonian to Lower Carboniferous
- Silurian
- Ordovician
- Cambrian

Symbol Key

- Town
- River
- Site Location
- Fault Line

Site Index

01 Fancourt Shore
02 Ardgillan House Boulder
03 Balrickard Quarry
04 Walshestown Stream
05 Nags Head Quarry
06 Milverton Quarry
07 Curkeen Hill Quarry
08 Skerries to Rush
09 Portrane Shore
10 Lambay Island
11 Malahide Point
12 Malahide Coast
13 Feltrim Quarry
14 Claremont Strand
15 Balscadden Bay
16 Hill of Howth
17 Bottle Quay
18 Mulhuddart Holy Well
19 Ireland's Eye
20 Shenick's Island
21 Rockabill

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Finding out more

In a book of this nature, it is impossible to include all the information that a reader might want. So here are a few pointers to where you can find out more.

Key Geological References

This reference list includes selected papers, books and articles that are recommended as access points to Fingal's geological heritage. A full reference list of papers relating to the geology of Fingal is contained in the audit report (available on www.gsi.ie).

Introduction to the geology of Ireland

Aalen, F.H.A., Whelan, K. and Stout, M. (eds) (1997) *Atlas of the Irish Rural Landscape.* Cork University Press, Cork. 2nd edition.

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Earth Science Ireland

This group aims to raise general awareness about the importance of Earth Science in our daily lives, and to support Earth Science education throughout Ireland. Its flagship is the magazine *Earth Science Ireland,* which has very readable, interesting articles on a full range of Irish and related geological topics, written in plain language for a general audience. This is produced twice a year and can be obtained free thanks to generous sponsorship from many organisations and groups. See website www.habitas.org.uk/es2k/index.html to download digital copies of previous issues.

Introduction to the geology of Fingal (and adjoining areas)

Baker, C. (ed.) 2009. *Axes, warriors and windmills: Recent archaeological discoveries in North Fingal.* Fingal County Council, Swords, Dublin.

McConnell, B., Philcox, M.E. and Geraghty, M. (2001) *Geology of Meath: A Geological Description to Accompany the Bedrock Geology 1:100,000 Scale Map Sheet 13, Meath.* Geological Survey of Ireland.

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Wyse Jackson, P., Stone, J., Parkes, M. and Sanders, I. (1993) *Field Guide to the Geology of Some Localities in County Dublin.* Department of Geology, Trinity College Dublin and ENFO, Dublin. (Out of print, but it can be downloaded from the Geoschol website; see below.)

Useful websites

www.gsi.ie – general geological resources.

www.geology.ie – information on the fieldtrips and lectures offered by the Irish Geological Association, appropriate for amateur interest especially.

www.habitas.org.uk/es2k/index.html – downloadable copies of *Earth Science Ireland* magazine.

www.iqua.ie – information, fieldtrips, lectures, etc. in relation to Ireland's Ice Age history.

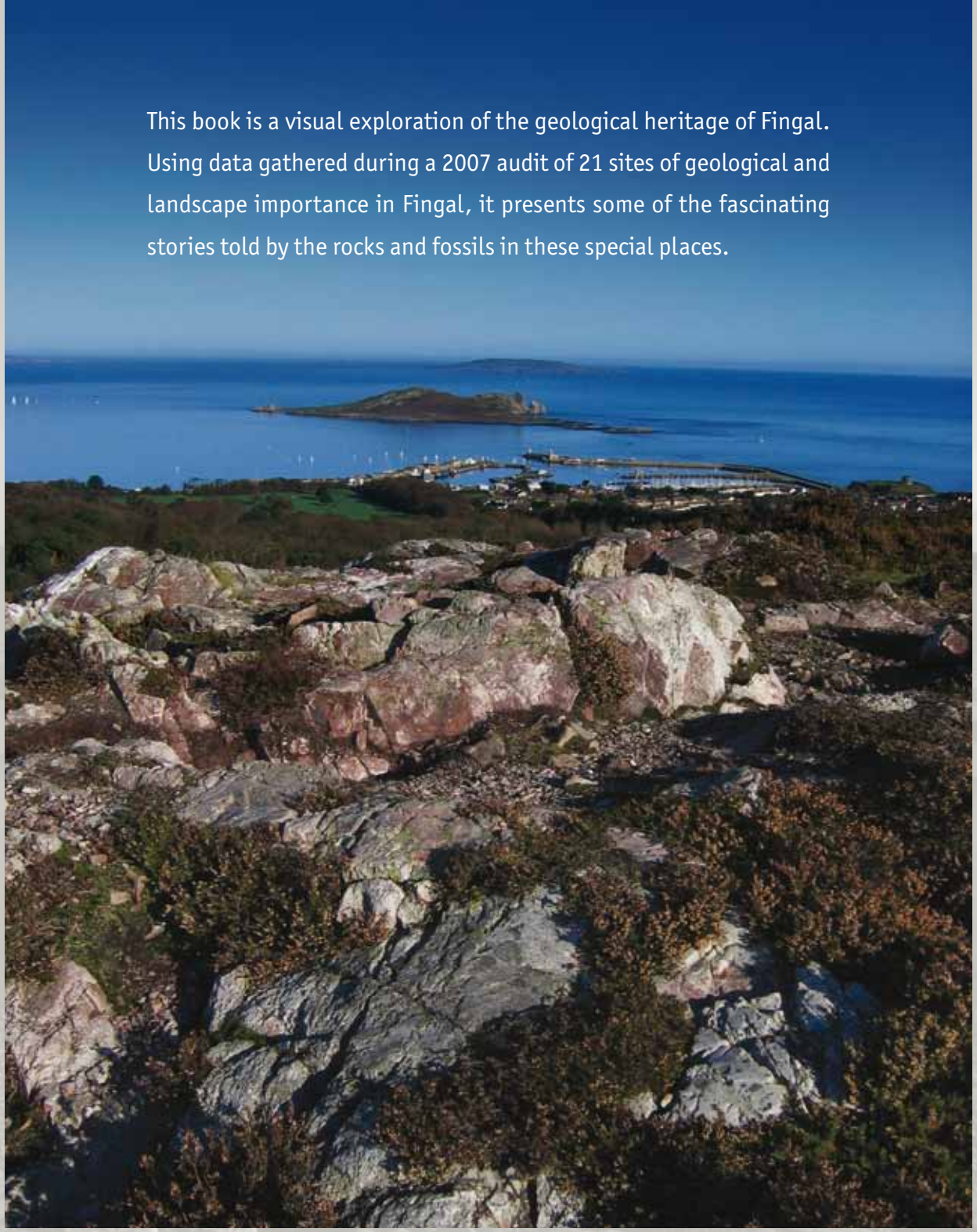
www.progeo.se – information about ProGEO, the European Association for the Conservation of Geological Heritage.

www.geoschol.com – elementary geology material mainly aimed at primary schools or early secondary. You can download posters, activity booklets, fieldguides (including to Portrane and Malahide and other Dublin sites) and single county geology leaflets.

About the author

Matthew Parkes is Assistant Keeper for Natural History in the National Museum of Ireland, working as the geological curator for the national geological collections. Prior experience included many years working in the Geological Survey of Ireland on the Irish Geological Heritage Programme. His geological career in Ireland commenced with a PhD research project in NUI Galway and postdoctoral research in Trinity College Dublin. In all his work in the Museum, and as a Professional Geologist (PGeo and EurGeol, accredited by the Institute of Geologists of Ireland), his passion is to communicate the fascination and relevance of geology to people who have had no previous opportunity to learn about it.

This book is a visual exploration of the geological heritage of Fingal. Using data gathered during a 2007 audit of 21 sites of geological and landscape importance in Fingal, it presents some of the fascinating stories told by the rocks and fossils in these special places.



An Chomhairle Oidhreachta
The Heritage Council

Comhairle Contae Fhine Gall
Fingal County Council

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