A guide to **Cork City's Geological Heritage**

Eolaí ar Oidhreacht Gheolaíoch i gCathair Chorcaí

An introduction to how the area of Cork City has come to be

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Introduction

This booklet will function as an easy guide and introduction to Cork's geology and the heritage tied to it. Part of this is asking and answering how the City's geology is relevant for us today.

It is aimed at the general public and the visitor alike and hopes to highlight the wonderful geoheritage of Cork City, explain how the entire landscape and layout of the city are direct consequences of the sediments and rocks beneath our feet and demonstrate its relevance in our everyday life.

The following pages are designed for those of you who are not comfortable with terms such as "Carboniferous", "orogeny" and "faulting" but would like to understand Cork's deep history and landscape better. You will discover that you cannot escape geoheritage if you live in Cork City - the entire landscape and layout of the area are direct consequences of the sediments and rocks beneath our feet. In Cork City, everything is defined by our rocks.

This booklet and its contents also seek to promote Cork City's geological heritage and to communicate why it is important. Using it, you will have the opportunity to read about the City's geology and have a new appreciation for how the area has come to be. But first, let us familiarise ourselves with what geology and geoheritage really is.

What is Geoheritage/Geology?

"It is part of the natural heritage of a certain area constituted by geodiversity elements with particular geological value and hence worthy of safeguard for the benefit of present and future generations." **- ProGeo (the European association for the conservation of the geological heritage).**

Geoheritage is about appreciating our surroundings through the rocks, sediments and landscape forms we see around us. As you enjoy the view from Bell's Field at the top of Patrick's Hill or the dynamic waters of the Lee, you are, at the same time, appreciating geoheritage. As with everything that exists in abundance, it is easy to take the rocks in our City for granted. Every day we see the different kinds of rocks of Cork protruding from the ground, and our buildings are both made from and supported by these. These rocks have been here for millions of years, and they will be here for many millions of years into the future.

The rocks and sediments of Cork have been studied over centuries and are still being researched by creative, productive and curious scientists referred to as geologists or geoscientists. However, studying the past is difficult.

Truth be told, the past is gone and much of the evidence has been altered significantly over long stretches of time. Sadly, we will likely never find out how things exactly were in Earth's deep history. But we know a lot, and that is amazing in itself, especially given how long ago these processes took place. Any geoscientist has likely had a sense of frustration with not being able to directly observe such things. Yet these scientists have still learned so much about our planet and its past.

But first, here is another attempt at converting you to 'geoheritage' if you aren't already. Ask yourself or the nearest person (or pet):

Why are we here?

Immediately, it becomes clear that this question lacks a lot of specifics. One important factor we need clarified in order to answer it is the relevant timescale. You might ask why you chose your current location a few seconds ago to read this booklet. Or question why you're living in the area you're living in right now. Or perhaps even consider why early settlers of the area of Cork City chose this wet, unpredictable river valley as their hub a few thousands of years ago. Perhaps they found themselves drawn to the River Lee and its resources or to the easy access to the sea. Maybe they simply liked the overall look of the area.

It is hard to consider what decisions our predecessors would have made without looking at our surroundings. Our surroundings not only include Cork City but also the entire planet. Everything is part of a huge global system that is constantly changing. And in order to understand our surroundings here in Cork City, we cannot ignore its geology.

What is geology?

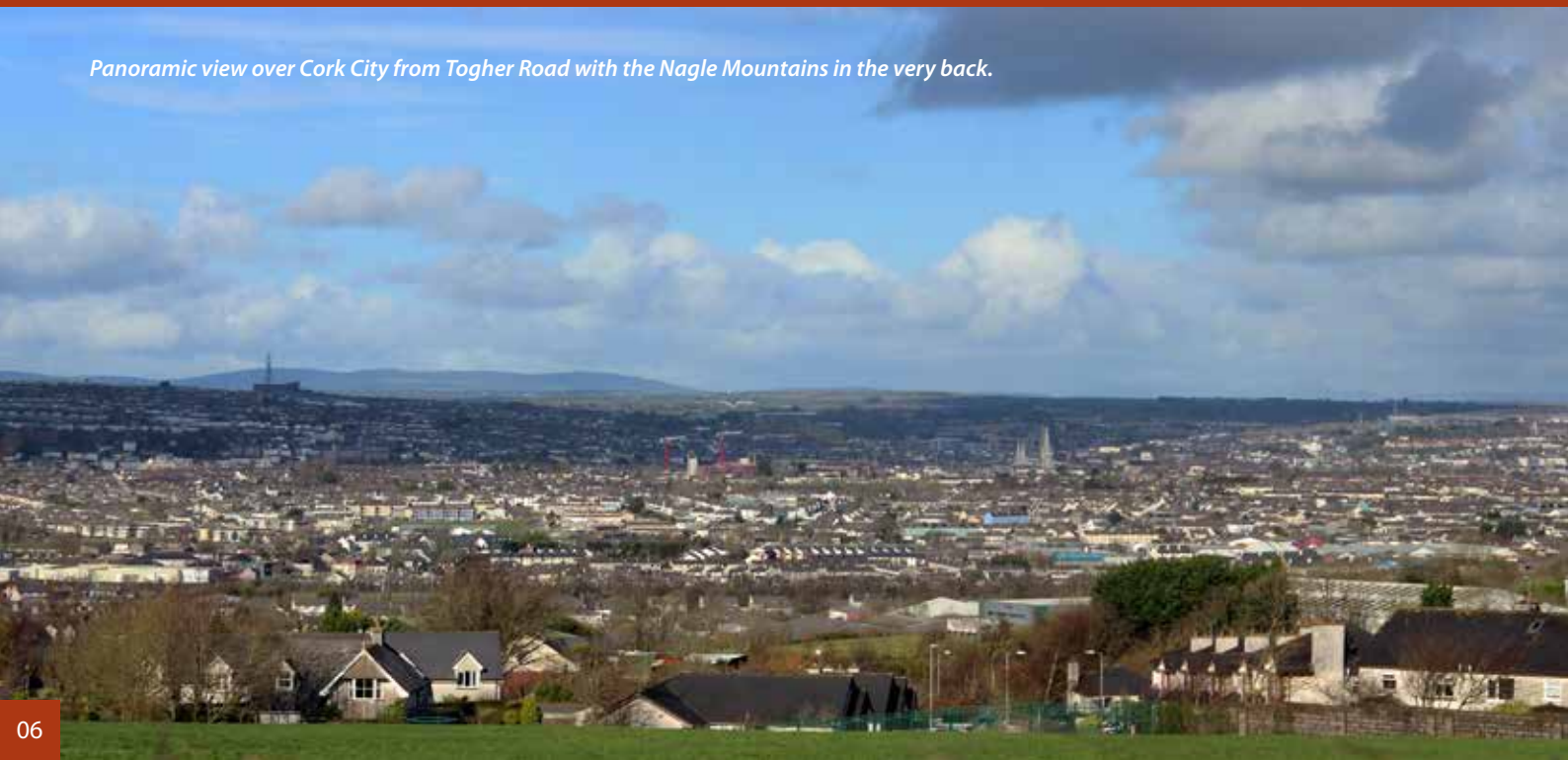
Geology deals with the study of the Earth. Geologists and geoscientists try to understand how the planet has developed, how life came to exist and why everything is the way it is today. To do this, scientists have to study rocks and materials that have existed for a very long time.

In terms of infrastructure and the economy, geology is incredibly important. We would not have materials for computers, smartphones and every plastic product you can think of without geological research and surveys. But also, by studying our planet we learn more about how life came to be and also about the challenges we currently face. In relation to climate change, geological studies have shown us how dramatically we have brought change to our atmosphere, unlike any other processes in Earth's natural history. And while geology can teach us about the severity of climate change and its repercussions, it is also part of finding and creating the many sustainable solutions to climate change currently being engineered around the world.

Thus, geology studies the past, which helps us understand and potentially save the future through studying the vast history of our planet and, more locally, our surroundings.

Further, by understanding the City's geology and appreciating its geoheritage we further realise that our environment is incredibly dynamic despite us often not considering it to be as such. Rivers change their courses; sea levels rise and fall and every day new rocks are created and eroded away. The world around us is constantly changing, even if everything may seem static and solid.

Geology is everywhere in Cork! It is part of our buildings and more obviously the ground. It is in our bodies in the form of dust, minerals and ions and we use it daily. We walk, rest and socialise on it.

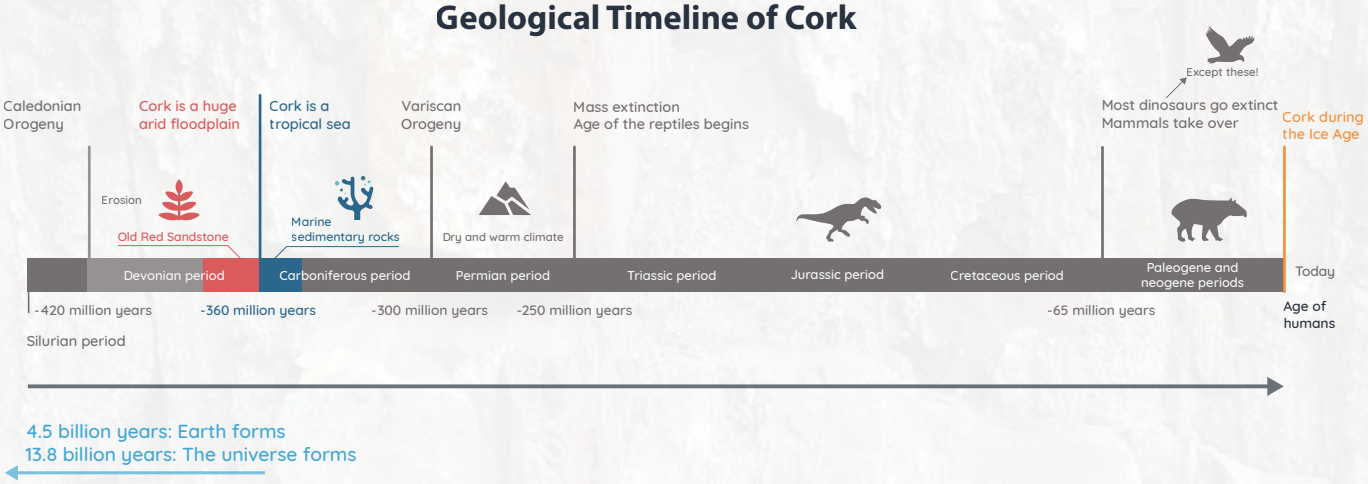


Panoramic view over Cork City from Togher Road with the Nagle Mountains in the very back.

Cork City's Geological History

Before we shift the focus to Cork City's geological sites and heritage, it is fitting that we get an overview of its geological history. Here, 'geological history' means whatever we know about the prehistoric location, atmosphere, life forms, landscape and other properties of an area as it has changed over millions of years. You may have heard about the Devonian, Carboniferous and Quaternary periods. If you haven't, let's do a crash course.

Geological Timeline of Cork



Our planet is staggeringly old having formed around 4.54 billion years ago. So, as a way of categorising and dividing this ridiculously long stretch of time, geoscientists set up what is today the International Geological Time Scale. Just as historians have set up periods in Irish (human) history such as Gaelic, Viking and Medieval Ireland, geoscientists have terms such as Devonian, Carboniferous, Jurassic and Quaternary to describe incredibly long periods of time in Earth's history. The first evidence we have of Cork's past appears 380 million years ago during the late part of the Devonian Period. This is the Old Red Sandstone that you will read and see more about in the coming chapters.

The rocks of Cork are from the geological time periods Devonian, Carboniferous and Quaternary.
Overall, it looks something like this - listed from oldest to youngest:

- **Devonian Old Red Sandstone.**
- **Carboniferous sandstones, siltstones and mudstones.**
- **Carboniferous limestone.**
- **Quaternary glacial sediments**

Croagh Patrick in Co Mayo owes its existence to the Caledonian Orogeny

Remembering these, we will over the next few pages go over how the rocks and sediments of Cork City formed. This overview will not only give you an idea of how the area of Cork came to be, but will hopefully also make it easier to understand the geology of the sites described in this booklet. It starts rather dramatically with…

The Caledonian Orogeny

Somewhere between 500 and 450 million years ago, dramatic events started to unfold in the area north of what is now Cork. At the time, this area was part of the Iapetus Ocean. This ocean does not exist anymore, as it was literally pulled and pushed into the Earth through the dynamics of our moving continents. Since our landmasses and continents formed, they have always been on the move; their main movements being driven by their creation (through regions spreading) and destruction (through regions colliding); large-scale processes that we call 'plate tectonics'.

So, between 500 and 400 million years ago, two of these moving land masses collided. Slowly (on a human timescale), but still powerfully, these collisions pushed up a mountain chain. Geoscientists refer to this huge event as the Caledonian orogeny and the resulting chain of mountain as the Caledonides or Caledonian mountains. This mountain chain has largely been eroded today, but the leftovers of it appear as the hills of Donegal, Galway, Mayo (a stark example is Croagh Patrick visible in the picture above) and Sligo, the Scottish Highlands and the mountains of Norway.

While "Cork City" was not a part of this huge mountain chain, it owes its existence to it, and that is why we cannot ignore these dramatic events. As mountains are created, they erode as well. Together, weather, gravity and water break down mountains. Large mountains shed a lot of sediments, and that is what happened back then.

A rough map of the area during the Late Devonian Period that is today County Cork.

The eroding rock material from the Caledonian mountains was transported to the area of "Cork City" through rivers in the form of sand, silt and mud. This loose rock material is what we call 'sediments' and it is the origin of the sandstone, siltstone and mudstone layers we find in the City today.

The mountain-building processes came to an end, however the crust was still moving. During the Devonian Period other areas of the planet's surface, or more correctly, its crust, were pushed downwards and sideways due to the immense pressures from the colliding landmasses. In Cork, a large area of the crust subsided and became more low-lying relative to the surrounding land. A low-lying area such as this is called a sedimentary basin. We call this subsided region the Munster Basin.

The Devonian floodplains of "Cork City"

The mountain-derived sediments started filling the Munster Basin and by 380 million years ago the entire region was made of widespread, flat, dry floodplains. Due to the movements of landmasses and continents, Cork was closer to the equator back then and thus had a much warmer climate than today. Despite the higher temperatures, it would not have been an ideal holiday destination, as the illustration above shows.

Seasons would have been more dramatic than in today's Cork, with long dry and wet periods. During wet periods, rainfall would turn calm rivers into large floods, while during dry periods the ground would form cracks like we see in deserts today. We refer to this environment as 'semi-arid' as it would mostly have been dry but still with some occasional rainfall.

All the sediments making up this semi-arid area would have come from the huge Caledonian mountains to the north of the area. We talked about these mountains earlier when discussing the geological history of Cork. As the mountains eroded, all the material cascading down from them would have been carried by rivers to the lower areas of the Munster Basin, which is today Cork. When all these sediments were buried and subjected to heat and pressure over millions of years, they were compacted into the Old Red Sandstone that we find today all across the county.

But like any other point in Earth's history, landscapes are never static.

The Old Red Sandstone is a term describing an extensive group of sandstones, mudstones and siltstones that were deposited during the Late Devonian. Not only found in Cork City, but the Old Red Sandstone also appears in large parts of the southern part of Ireland, the UK, Scandinavia, Greenland and part of eastern North America. Going back to the jigsaw puzzle analogy described in the introduction, these areas were once part of one big continent back in the Late Devonian.

1. *Cork during the Devonian: This picture shows one of the first species of trees to exist on Earth: Archaeopteris.*

2. *A bird's-eye view of a semi-arid river plain during the drier season.* ***3.*** *A flash flood during the wetter season.*

The Carboniferous coral reefs of "Cork City"

Eventually, sea levels rose, and the area of "Cork City" transitioned from these river plains to coasts and eventually, by 350 million years ago, to shallow seas. By now we are in the next geological period: the Carboniferous.

The Carboniferous shallow seas were populated by corals, fish, crinoids, molluscs and sea sponges under a tropical climate. It was a much livelier place than the former Devonian floodplains. If you were snorkelling around these parts, you would spot sharks swimming amongst extensive coral reefs with nautiloids suspended in the water sporting beautiful shells. These beautiful sea kingdoms eventually became the limestone that we find all over the City.

The area of Cork City during the Carboniferous.

A lot of the limestone is created from leftovers of corals, seashells, sponges and crinoids, and in the limestone layers of Cork City we find fossils of these in abundance! It is especially the crinoids that are amazing and numerous to observe, and as such some of the limestone is referred to as crinoidal limestone.

There would have been volcanic eruptions on distant surrounding islands, for example, at what is now Buttevant. All in all, an exciting time to have been around: a warm climate, volcanoes, high marine biodiversity and beautiful diving experiences.

But as with anything else, this was not meant to last. These seas disappeared, and land overtook the area again. One more series of events left its impressive mark on the rocks of Cork...

Carboniferous limestone is the most widespread type of rock on the island of Ireland. They form some of the more dramatic landscapes in our country. The Burren of County Clare was once also such an extensive coral reef and equally consists of numerous fossils. It is the chemistry and properties of the limestone rocks that give the Burren such impressive and eerie landscape features. This is also responsible for enormous cave systems such as Mitchelstown Caves

1. The area of Cork City would perhaps have been a lovely holiday destination. 2. Shows nautiloids, a kind of mollusc, floating around in the tropical waters. 3. Crinoids, whose fossils exist in abundance in Ireland's Carboniferous limestones.

The Variscan Orogeny

From about 320 to 290 million years ago, more continents were bashing into each other. Geologists refer to this event as the Variscan Orogeny. As a result of the Variscan Orogeny, another mountain chain sprang up to the south which altered the rocks of Cork. When continents collide, a lot of dramatic things happen: ocean floors and deep rocks are pushed up onto land, rocks layers are compressed and heated and, more relevant to Cork, solid rock starts moving, bending, folding and breaking dramatically.

The folding of the rock layers of Cork City due to the Variscan Orogeny took millions of years, but was an immensely powerful event nonetheless.

This folding took place over many millions of years and would have caused many earthquakes. We see this today as the huge folds and faults in the rocks of Cork, and it gives the rocks in Cork City their characteristic appearance. These appear on different scales: across the entire county, the folds on the scale of kilometres make rock layers dip up and down across the landscape like waves. On a smaller scale in Cork City, we see geological folds on the scale of several metres.

Finally on a human-sized scale, we see smaller folds and also linear/planar textures in the rock known as cleavage. These textures can be compared to the look of elongated grains in wood. The directions that the cleavage textures tell geologists in from which direction the rocks were deformed.

Eventually, the continents stopped colliding and Cork was now part of an even bigger continent. Actually, this was a supercontinent called Pangea and it was made up of nearly every other current continent.

What happened next?

And this is where Cork's geological history comes to a very long halt. Unfortunately, we don't know what Cork looked like during the hundreds of millions of years that followed. It is not that nothing happened after the limestones and the Variscan Orogeny, it is just that any post-limestone rocks and sediments were not deposited in this area or have since been eroded away.

There is evidence from Cloyne that the area around the City sported a warm, tropical land area during the geological period called the Jurassic, the same period that covered a part of the reign of dinosaurs. But within the City we do not have any evidence of what the area looked like back then.

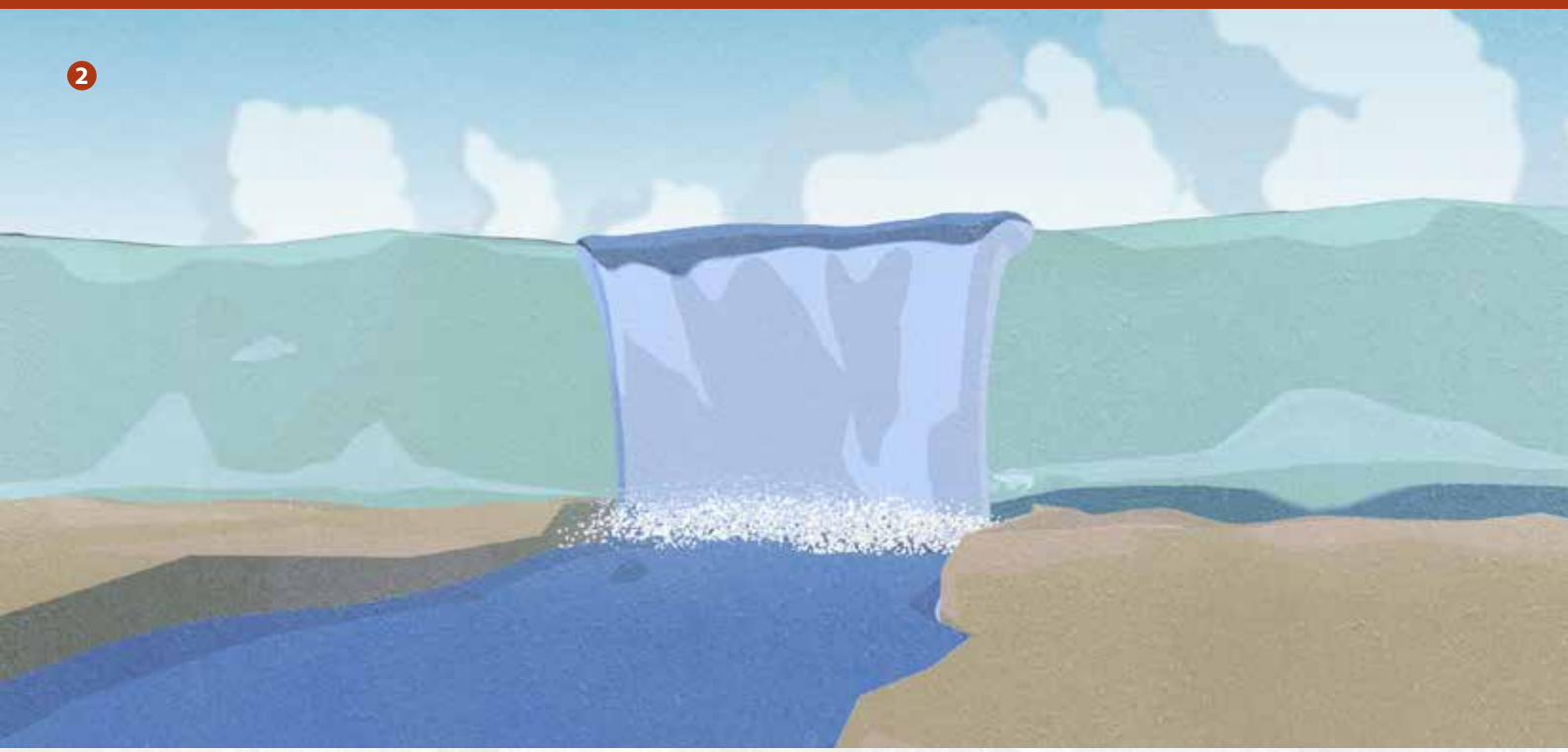
The Ice Age/Quaternary landscape of "Cork City"

From 350 million years to about 13,000 years ago the continents had separated and pretty much moved into the positions that we are familiar with today. A handful of millions of years ago, the Earth's global temperature started changing between warm and cold periods of time. During the colder periods, widespread regions of ice built up around the poles, creating huge ice sheets that eventually reached down to Ireland.

During the Quaternary Period, expansive and thick ice sheets appeared over the area.

All of Ireland, including the area of Cork City, became covered by kilometres of thick ice layers. The ice sheets would have crept very slowly but destructively over large stretches of land, grinding mountains and forever changing the landscape they travelled over. As these massive ice sheets melted (until about 10,000 yrs ago), large rivers carried sediments away from them and laid these in the river valleys of the City. These strong rivers also carved river valleys into the Devonian and Carboniferous rock layers, such as the ones that are now the Glen River and River Bride. Huge volumes of these sediments finally ended up in the Lee Valley, creating deep layers of what we call Quaternary or glacial sediments.

The Ice Age or the Quaternary (starting about 1.2 milion years ago) is not a long time ago compared to the staggering 350 to 380 million years going back to the Devonian and the Carboniferous periods. But the Quaternary landscape of Cork City was still different despite being a few tens of thousands of years ago. We would have had hyenas, reindeer, wolves and bears roaming around in this area as well, while the local sea levels were much lower than they are today. As humans came to the area a few thousands of years ago, we have since further changed the landscape. But that is a historical account for another time!



1. *The illustration shows these enormous ice sheets that shaped the landscape of the area.* ***2.*** *13,700 years ago, the ice began to melt and the waters carved river valleys in the rocks.*

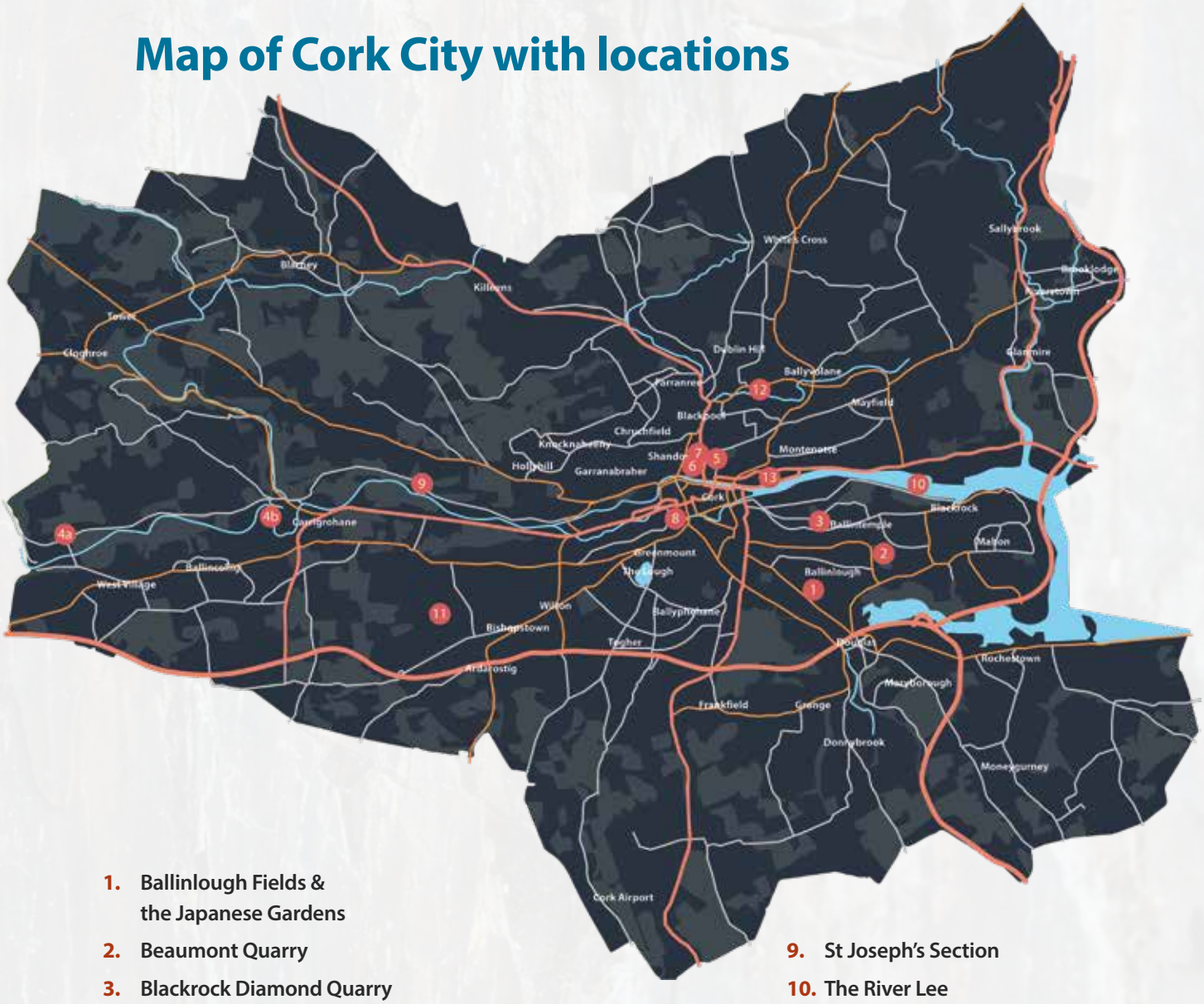
Geoheritage Sites in Cork

In the following chapter we will explore a few of Cork's key geological locations. The geological sites of Cork City have many elements that help us understand and appreciate how dynamic the processes of planet are. It is easy to assume that things remain as they are, even over long periods of time. But the reality is that over millions of years the area of Cork City has had different climates, terrains, landscapes, sea levels and forms of life.

We can see evidence of this very easily in the City, and this booklet has highlighted and described many of these locations for you to learn more about them. Many of these areas are accessible by foot, but caution must be exercised when exploring particularly hilly, tall, steep or exposed sites.

These sites have been curated from Geological Survey Ireland's County Geological Heritage Audit of Cork City. A full list of these sites can be found below the following map.

Map of Cork City with locations



1. Ballinlough Fields & the Japanese Gardens
2. Beaumont Quarry
3. Blackrock Diamond Quarry
4. Ice Age sediments
5. Patrick's Hill
6. Shandon Bells & Tower, St Anne's Church
7. Leitrim Street & Upper John Street outcrops
8. St Fin Barre's Cathedral
9. St Joseph's Section
10. The River Lee
11. Lime kiln ruins along the Curraheen Public Walk
12. The Glen
13. Lower Glanmire Road

Ballinlough Fields and the Japanese Gardens

During spring, Instagram photographers and any admirer of beautiful things visit the Japanese Gardens in Ballinlough to appreciate the vibrant pink cherry blossom as it flowers. While this beautiful phenomenon can only be observed once a year, an extensive and interesting limestone cliff in this area can be observed year-round.

The main limestone cliff face at the Japanese Gardens in Ballinlough.

The cliff can be found behind the cherry blossom at the north-western corner of the park, below a row of houses sitting on the top of the cliff. This outcrop shows many of the characteristics of the limestone layers in Cork. As such, if you want to explore all the beautiful features and structures that the limestone layers of Cork have to offer, then this location is ideal.

The limestone here is also crinoidal meaning it is made of fossils of crinoids (see 'Cork during the Carboniferous Period'). That being said, you can also spot beautiful shells and coral fossils, and the preservation of tiny details in these can be remarkable.

To most people, crinoids may look like plants and are, funnily enough, referred to as sea lilies. But they are very much animals, something that becomes more apparent if you search for videos of 'swimming crinoids'. As you might have guessed by the use of present tense here, crinoids very much exist today. However, they were much more numerous and diverse during the Carboniferous Period.

Looking in the Carboniferous limestones, you see them everywhere, little circles and square disks in all sorts of sizes spread across the rock, sometimes still attached to each other. These pieces are part of the stalks that the crinoids used to cling to the seafloor and possibly other surfaces in the coral reefs at the time.

Locations of diamicts - the graffiti comes in handy here when spotting them.

Karst features are also very visible here. As the limestone has been dissolved by weakly acidic waters running through it, large crevasses and even caves formed here. Small-scale examples of these can be seen along the cliff, in particular along the eastern section.

Related to these karsts, remember how we talked about Quaternary ice sheets? We can see some leftovers from these here. At the eastern sections of the cliff, within the karsted crevasses, you will find a sludge of pebbles and sediments. These infills are called 'diamicts', and they occurred as the ice sheets deposited sediments into the dissolved crevasses of the limestone.

These sediment fillings in the limestone cause plenty of problems for residents in Ballinlough and Ballintemple. Houses have been sinking slowly into the ground, and some properties are tilting severely and have required extensive renovation and reinforcement work.

Geotechnical reports have shown that a lot of this instability is caused by infrastructure resting on unstable limestone rock layers or resting on glacial sediments which are caving and compressing into the limestone layers. The diamicts to the left show small-scale examples of this phenomenon. These geotechnical reports can luckily help us better understand where these phenomenon takes place for future planning

A closer look at a limestone-hosted diamict.

Beaumont Quarry

One rarely gets to explore an unused quarry site. However, Beaumont Quarry is one of these rare privileges and one of the most impressive natural amenities in Cork City. The area was historically an active quarry from the middle of the 19th Century, sitting on the property of the Beamish estate. While the adjacent areas in Ballinlough and Ballintemple had many quarries, this was likely one of the more prominent sites due to its size and provided the City with a lot of limestone.

Looking north from Beaumont Quarry's highest vantage point. On a clear day, this gives a great view to many interesting geoheritage locations visible: the hills of Patrick's Hill, Montenotte, Tivoli and Glanmire, the River Lee itself and Brickfield Quarry along Lower Glanmire Road.

Today, this industry is gone, but the canyon-like appearance of the area is a testament to the productivity of this quarry. Wild plants and animals have now made the inactive quarry their home and will hopefully continue to do so. An excellent way to appreciate this little wildlife enclave is to have a look - or several - at the rocks! The limestone outcrops are often covered by thick vegetation and much of the rock surface has been weathered. But occasionally a fresh glimpse of the limestone can be discovered, and that is when the rock obsession starts. Here at Beaumont Quarry, it is possible to view both the more featureless limestone without fossils and the fossil-abundant crinoidal limestone.

As with the Japanese Gardens, you can see impressive local examples of karstification in this location as well. Here, deep cracks have formed from karstification of the limestones and allowed other more recent sediments to fill in. In fact, cave systems like the ones near Mitchelstown exist here as well, though these are not as accessible.

Crinoid stem fossils bundled together in the limestone. Each individual stem is about half a centimeter across.

Blackrock Diamond Quarry

Located between Monahan Road and Blackrock Road is a location with a name that could make any assuming rock enthusiast fly out with a digger and a hammer! However, the same rock capitalist will be sorely disappointed after spending hours of quarrying for rare precious gemstones as there are no diamonds in Blackrock Diamond Quarry. But there is a reason why it is referred to as such.

Amethysts are very different from diamonds. Though they are both considered gemstones, amethysts are a purple variant of the mineral quartz. Quartz is one of the most common minerals on the surface of our planet, while diamonds are an extremely rare, crystallised form of carbon. Except for the occasional crystal healer and rock admirer, amethysts don't pose much economic value. That doesn't mean that it isn't worth looking at.

Beautiful limestone outcrop at The Black Market Cork along Monahan Road.

Back when it was part of Cork City's productive rock extraction industries, limestone blocks were extracted from this area, likely to be used for construction and agriculture. Some of these limestones had cracks and pockets where mineral-rich waters could flow through. These minerals accumulated in these pockets as the fluids themselves disappeared. Over time, large crystals grew into these pockets and in particular the mineral amethyst, which prompted the name 'Blackrock Diamond Quarry'.

Stunning, but not a diamond!

The quarry is today inactive and the location of an industrial park along Monahan Road and therefore not accessible to the public. That being said, it is of an impressive size and observing it from the road is in itself interesting. Above the tall walls of the quarry, it is possible to see the obelisk McCarthy's Monument with its limestone bricks towering at Blackrock Road. The quarry walls can be accessed through the Black Market Cork, where the white crinoidal limestone outcrop can be studied in close-up.

Ice Age sediments in Inniscarra and Ballincollig

As described earlier, it is difficult to spot proper sedimentary deposits from the Ice Age/Quaternary Period in Cork City. That being said, there are loads of it underneath the Lee Valley. Unfortunately, it is buried under soils, vegetation and human infrastructure. In other locations these deposits are visible as unsorted sediments of various sizes filled in crevasses and cracks of the Carboniferous limestone. However, there are some locations where Quaternary sediments can be seen and studied to a greater extent.

Ballincollig Regional Park looking west: The rise in the landscape at the sides is due to the Old Red Sandstone making up the foundation there, while the lower landscape of the middle marks the Carboniferous sedimentary rocks. The picture below is of an outcrop in Ballincollig Regional Park.

Travelling along the Lee Road from Cork there is a fuel station sitting right at the foot of a towering Old Red Sandstone hill. Behind the fuel station building itself there is an exposed outcrop of messy sediments of pebbles, cobbles, sand and mud. These sediments are from the Quaternary Period or, more informally, from the Ice Age.

As mentioned earlier, Cork was covered by these ice sheets but, as the climate warmed, they started to melt about 13,700 years ago. Meltwater from these huge volumes of ice turned into rivers that washed sediments down into what was the Lee Valley at that time. These flows of meltwater were strong and carried rocks and sediments of all sizes along, eventually leaving them as thick sedimentary layers throughout the area.

A section behind the Inniscarra fuel station shows the variation of materials that these rivers left. The sediments can and should be admired from a distance, this location is not accessible and on private ground. But there is another location with similar Quaternary sediments situated idyllically along a riverbank.

Along the easternmost boundaries of Ballincollig Regional Park is a beautiful river walk. The Lee meanders delightfully through the landscape here, with trees and convenient riverbanks along its sides. One of these riverbanks can be visited from the main path and provides an excellent vantage point to a beautiful outcrop of Quaternary sediments. While the outcrop is on the other side of the river, it can easily be admired from the accessible riverbank.

The sediments were well-layered at the lower section of the outcrop where the rock materials seem to be smaller in size. This is likely due to lower energy levels in the flow of these meltwater rivers. When rivers flow powerfully, light sediments don't deposit as easily and as such a lot what is eventually deposited are large pebbles, cobbles or boulders. However, in rivers with slower or less energetic flows finer sediments such as mud, silt and clays can settle more easily. As the river changes from calm to turbulent or vice versa, the grain sizes of the sediments reflect these changes.

Cork City has few exposed outcrops of Quaternary sediments. Glacial sediments are better exposed around coastal areas (most Irish geology is). This picture is from near Timoleague.

Ice sheets and glaciers are, like rivers, also forms of flow. During the last Ice Age, these ice sheets carried and transported boulders as large as houses several hundreds of kilometres away from their original position. As such, granite rocks from Galway appear down here in Cork. We call these boulders glacial erratics.

By studying the sizes, shapes and sorting of different grains, pebbles and boulders in rocks and sediments, it allows us to get an idea of what took place back when these formations were created.

Patrick's Hill

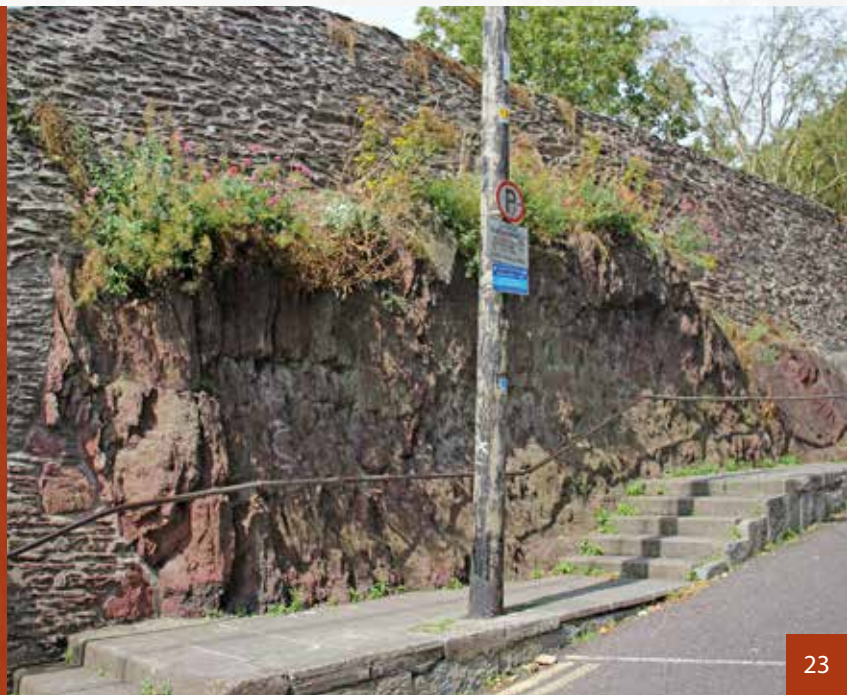
We all know that exercise is important. Yet people who live on the top of Patrick's Hill may tell you that you can also exercise too much, especially when it becomes part of every trip to the corner shop. Alongside its impressive views, Patrick's Hill has a reputation for its steepness. Runners and bikers take great pride in scaling it without stopping, while novice drivers may find themselves uneasily ascending or descending it.

Patrick's Hill: An iconic view!

Patrick's Hill also shows off beautiful aspects of the City's geological heritage. Walking up St Patrick's Hill you will come across an obvious Old Red Sandstone outcrop near Bruce College. This outcrop has had a wall built around it, a common style of architecture in the City. The Old Red Sandstone here shows rock textures caused by the enormous forces of the Variscan Orogeny. This makes the rocks look broken and squeezed. The vertical planar features in the rocks are here known as cleavage and they formed as the rock layers were compressed. In fact, the rocks were originally wider before the Variscan Orogeny.

Getting to the top of Patrick's Hill presents some stunning vistas over the City. Looking south towards Douglas and Grange reveals the sharp drop in elevation as the landscape moves from the more erosion-resistant Old Red Sandstone into the softer Carboniferous rocks. This landscape pattern repeats when looking to the south as one travels from Ballyphehane to Ballycurreen up the Airport Hill, where the terrain rises dramatically due to the Old Red Sandstone appearing as the foundation.

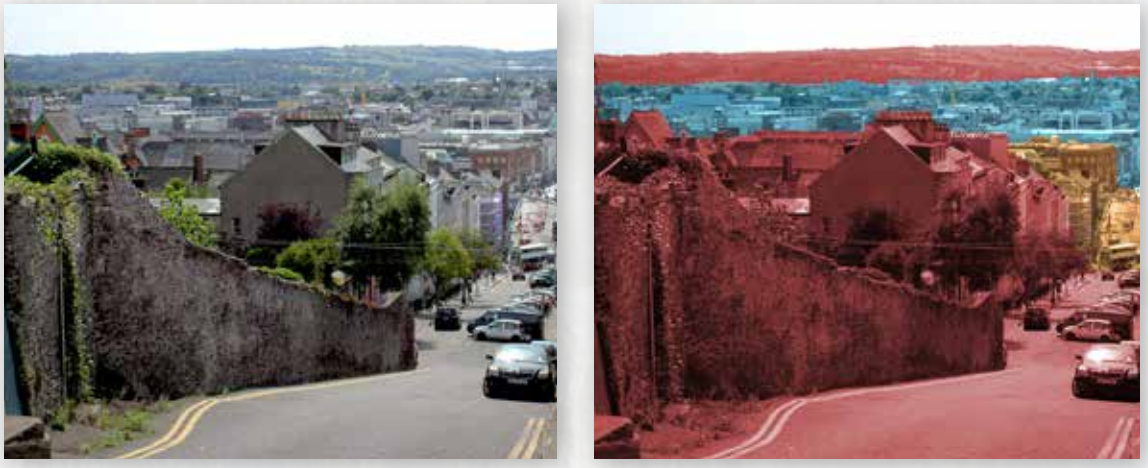
Walking over to Bell's Field and its iconic vantage point to the northside of the City shows more of this landscape form. The whole valley system aligns east-west and can be traced from Youghal in the east all the way to Crookstown in the west. Because of its chemistry, the limestone also marks the valley of Cork City.



The Old Red Sandstone outcrop of Patrick's Hill.

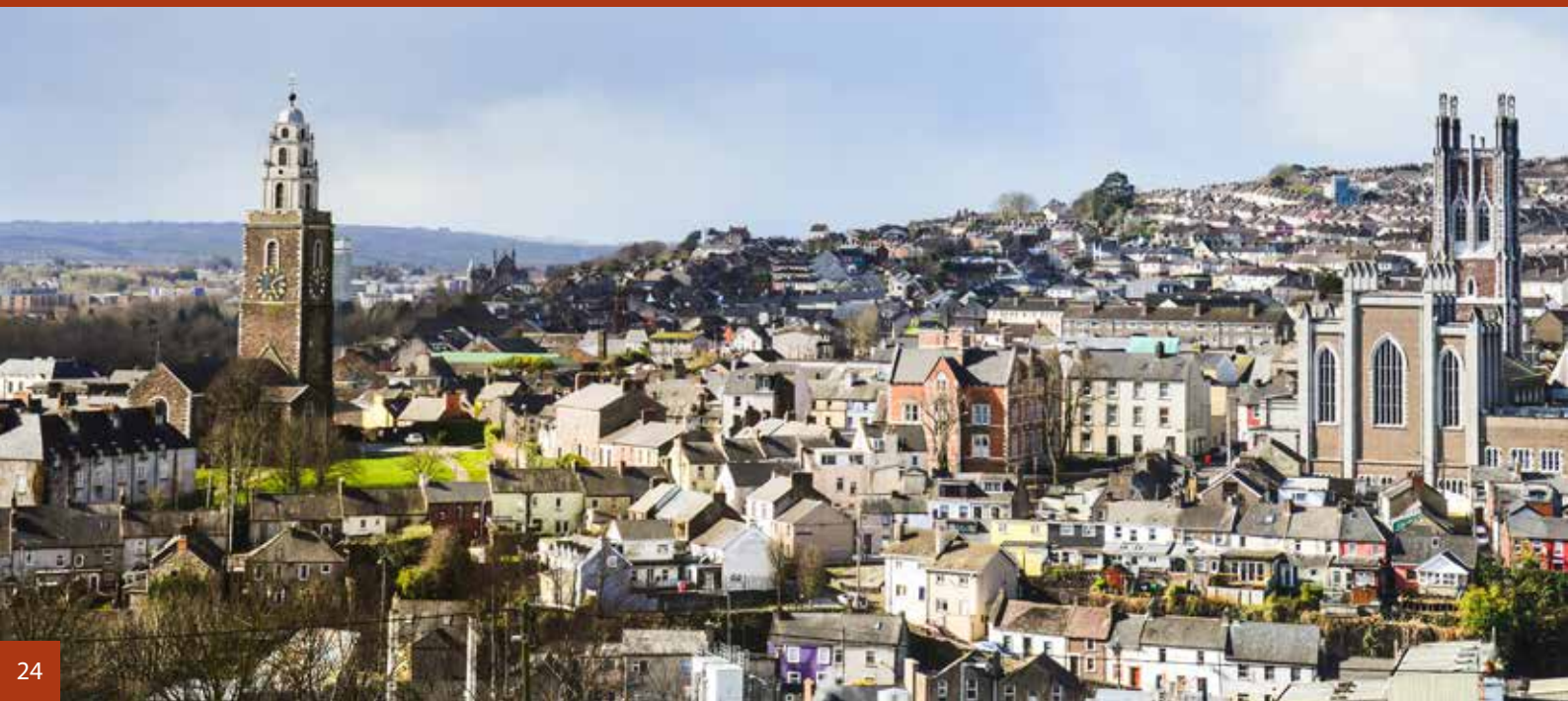
This shape of this landscape is further due to the way the rocks were compressed and deformed during the Variscan Orogeny. That is why we see strong wavy features and folds in cliffs both here in the City and along the coasts of County Cork. Many of these wavy features are small - a few metres wide, for instance, at Upper John Street - but at other times they can reach several kilometres in width. The Lee Valley is shaped from such a huge geological fold structure.

This fold is responsible for the continuous hills running north of the Lee Road and N22. The Old Red Sandstone layers appear topographically taller due to their resistance to erosion compared to the limestone layers. Again, the landscape of the City is a direct consequence of the geology and the structure of the rocks underneath it. The view from Bell's Field confirms this and displays many of the processes and concepts we have discussed here.



View from Patrick's Hill looking down towards the City Centre. The image at the right is a colourised version of the left image. Red marks areas were the Old Red Sandstone makes up the foundation. Orange marks where Carboniferous sandstones, siltstones and mudstones lie beneath. Finally, blue marks the areas were the Carboniferous limestones make up the foundation.

Finally, we can easily traverse over to the building that summarises Cork City's geological heritage: the Shandon Bells & Tower, St Anne's Church.



Shandon Bells & Tower, St Anne's Church

The top of Shandon Bells, also called Shandon Bells & Tower, St Anne's Church, provides not only a view but also an overview of the City. From here it is possible to see past the City boundaries, the rolling hills north and south of the Lee Valley and, as mentioned for Patrick's Hill, the overall structure of the landscape of the area. It is especially from here that we can see how the landscape of Cork City reflects the underlying geology vividly.

View from the top of Shandon Bells (on a wonderful day!).

Visitors to the building have loads to explore inside about its history. For its geological influence one can look from the outside. The tower has two sides made of pale limestone bricks and two sides made of Old Red Sandstone bricks. This is not an unusual colour scheme here in the City, as many buildings and walls are built from the same mix of stones. But the Shandon Tower hammers home the myth about the red and white colours of Cork's identity arising from the red Old Red Sandstone and pale limestone.

Even more striking, its southern tower wall consists of limestone blocks and faces towards the limestone outcrops of the area, while the northern tower wall is made of Old Red Sandstone blocks and faces the southern outcrop of Old Red Sandstone in the City.

Whether you want to believe that the red and white colours of the City are derived from our use of the Old Red Sandstone and the pale Carboniferous limestone, it is still a great story.

The limestone and Old Red Sandstone walls of the Shandon Bells tower.

The geological folding of the Variscan Orogeny is starkly visible here at Leitrim Street.

Leitrim Street and Upper John Street outcrops

The geological folding of the Variscan Orogeny is starkly visible here at Leitrim Street. At the fuel station and the private parking lot next to it we can vividly see impressive geological folds. Notice the smaller vertical planes (looking at the rocks, these planes look like lines or cracks, but are actually planar features) in the layers of the rocks. These planes are known as cleavage, and they formed due to the huge pressures the Variscan Orogeny (the continental collisions south of Ireland) put on the rocks in this area.

Before the rocks were compressed, the layers were straight and flat. To give an idea of what happened, here is a household comparison: imagine compressing half-baked lasagne pasta. At first, small "cracks" form in the pasta dough before the lasagne starts folding and perhaps even breaks. A similar thing happened in the rocks during the Variscan Orogeny.

As the flat rock layers were compressed, the rock responded by becoming shorter, initially by developing this cleavage. This shortened the rock layers by 40-50%. After the compression continued, there was no other way for the rocks to form than to bend and fold. This also caused the huge faults that many rivers in Cork City follow.

St Fin Barre's Cathedral

You can't summarise or illustrate Cork City's skyline without including St Fin Barre's Cathedral. It has interesting designs and decorative rocks on the outside and inside sourced both locally and from afar. The limestones decorating the outer walls of this impressive building sport numerous fossils of seashells, crinoids, sponges and corals. Glimpsing limestone fossils requires a close look, but when finding a sufficient tile on the cathedral, it becomes apparent how populated the tropical sea of Carboniferous Cork was.

We have now mentioned many locations with limestone in the City, and again, it is the most widespread bedrock on our island. But it is still amazing to glance over, imagining the rich tropical coral reefs of the Carboniferous, and the bricks of the Cathedral allow for some detailed looks at these fossilised organisms. Gargoyles and statues also decorate the outer walls of the building, and these are also, of course, made of limestone. Do note that some of the pale limestone is not locally sourced but is from Galway.

There are many decorative rocks marketed as 'marbles' when they are in fact limestones. Marble and limestones may share the same origins, but are created under different conditions. If limestone is subjected to a lot of heat and pressure, it turns into marble. Marble has none of the original features and structures of the limestone it evolved from and consists almost entirely of calcium carbonate in other crystallised forms.

St Fin Barre's Cathedral is an impressive host of many limestones.

Venturing inside the Cathedral allows us to shake things up a bit. Around the interior are pillars and ornamental structures made of colourful and patterned rocks which have taken on all sorts of colours. One of these rocks is red and orange with crinoid fossils in it. This is the Cork Red Marble, and it also exists as an ornamental rock in other areas of the City. Here it is part of a series of other "marbles". Note that these rocks are actually not marbles but are still limestone. In fact, the Cork Red Marble was created in the shallow tropical seas when underwater landslides cascaded down to the seafloor and created jumbled, unsorted deposits of limestone and seafloor

.

The inside of the cathedral reveals many different kinds of building stones from around Ireland and beyond. Decorative 'marbles' and a real marble inside St Fin Barre's Cathedral.

Inside the Cathedral there are other forms of limestone that are referred to as 'marbles'. The black 'marble' has been extracted from Kilkenny, the blue 'marble' is from Northern Ireland, and finally the white 'marble' is from the Pyrenees. That being said, there is actually a real marble here, and that is the green marble from Connemara. Due to the continental collisions during the Caledonian orogeny (if you don't know what this is, you can read the section on Cork City's geological history), limestones in the Connemara area were subjected to enough heat and pressure to turn them into marbles.

St Joseph's Section

On the Lee Road between Inniscarra and Sunday's Well it is easy to let one's glance flicker between the dense forests and views over the Lee Valley. But along the way there is a car park directly opposite an impressive Catholic Marian grotto. The grotto offers some decent sedimentary rock exposures; however, it is the entrance to the Bon Secours Care Village that we will take a look at.

Approximately 30 metres from one end to another, the outcrop at St Joseph's Section offers plenty to look at.

The cliff here is highlighted for both its extensive dimensions and fresh surfaces, but also because it shows the boundary between the Devonian and Carboniferous periods. These rocks belong to the Old Head Sandstone Formation, a suite of sandstones, siltstones and mudstones. The boundary itself is unfortunately not visible to the naked eye.

Instead, scientists have studied tiny fossil spores preserved in this outcrop. Some spores were from the Devonian, while others belonged to the Carboniferous. These have then been used to pinpoint exactly when this transition between the two periods occurred here at the rock layers, and this transition can be traced globally.

A few important things should be stated at this location. Getting close to the cliff can be dangerous due to falling rocks, so exercise care here. Further, this is the road to the healthcare clinic. Do not obstruct the entrance nor the road and be aware of any traffic coming in and out through the entrance.

Facing the cliff, the rocks show a 'marine transgression' - a change from a land environment to a sea environment. Back at the end of the Devonian the seas started rising in the area and eventually what was once part of the floodplains became coast and eventually sea. This change is visible here. To the left, chunky red sandstone layers are visible (hinting at a land environment) and halfway and throughout we see alternating layers of thinner, dark, fine-grained sedimentary rock layers (hinting at marine environments).

The end of the Devonian Period marked some incredible changes to our planet's surface, and it was an interesting time in Earth's history. To understand this, we need to first look at the progress of life during the Devonian. Back then, plants were small and primitive compared to today's plants, but later became the dominant form of complex life on land over the course of the Devonian Period. At the end of the Devonian Period, huge forests were likely a common sight.

Sandstone with ripples created by a river current that flowed back during the Late Devonian.

Dark and thinner siltstone and mudstone layers hint at a marine environment during the Carboniferous.

However, around the transition from the Devonian to the Carboniferous, many species went extinct. We are not entirely sure how or when it happened, but there are many theories.

One of these involves climate change, potentially and ironically caused by the success of plants on land. What we do know is that a great deal of species and groups of species small and large simply ceased to exist.

This is one of the five large mass extinctions that we know of in geological history, the last of these being that which killed the dinosaurs.

In fact, it was likely that several mass extinctions occurred within a few million years around this boundary. What we do know is that many species or groups of organisms existing throughout the Devonian simply disappeared never to appear again.

Whatever happened, some species managed to thrive. The crinoids or sea lilies that we explored in our limestones had a fantastic time and diversified a further into the Carboniferous.

It is rare that we get to see a well-exposed boundary between two geological time periods, especially one that takes place through such incredible global events.

The River Lee

The River Lee is also part of Cork's geological heritage. Rivers create rocks, but they are also created from rocks. This is especially true here in Cork. Rivers transport sediments which accumulate, solidify and eventually turn into layers of rocks. On the other hand, underlying geological structures and features will influence the path of a river.

The water of the Lee flows 100 kilometres from the lake at Gougane Barra to Roches Point in a near east-west alignment. Its east-west alignment is not arbitrary but follows the folds and faults that were formed during the continental collisions of the Variscan orogeny. The same with the Lee's tributaries (small rivers leading to one bigger river), though these smaller rivers follow a north-south trend instead. And as you might suspect, this trend is also caused by the underlying geology.

The north-south alignment of the tributaries follows smaller faults that were formed at a 90-degree angle to the main folding and faulting that happened when the rocks of Cork were squeezed and deformed. The faults act as weaknesses in the rocks that water then flows through.

Over long periods of time these streams cut into the rock, eroding more rock material away and eventually forming river valleys.

This pattern is visible over the course of the Glashaboy River running through Glanmire, and the River Shournagh entering the Lee near Kerry Pike. Both of these rivers flow into the Lee where large faults exist in the rocks underneath them.

A CROPPED GEOLOGICAL MAP OF CORK

- Dark blue: Main rivers
- Black lines: Large faults
- Red/orange: Old Red Sandstone
- Yellow: Carboniferous sandstones, siltstones and mudstone
- Light blues: Carboniferous limestones
- Pink: Cork Red Marble

Lime kiln ruins along the Curraheen Public Walk

The Curraheen Public Walk offers excellent opportunities to walk along the banks of Curraheen River, one of Cork's well-known tributaries. Again, this river courses in a zig-zag path across the county following the north- south and east-west alignment of the Variscan folds and faults of the area. However, there is also a geo-historical site here that is related to the limestone.

The ruins that were once an active lime kiln along the Curraheen River.

Limestone is historically a resourceful rock, even in Cork City. Today we see how many significant buildings in the City, such as cathedrals and churches, were built from limestone blocks and bricks. However, it has also been used to produce lime and cement. Lime has been essential in agriculture for regulating soils and as fertiliser for crops, and large ovens called lime kilns would have been scattered around the City for the production of lime.

Along the Curraheen, we see one of the best-preserved lime kiln ruins in the City. These impressive structures were built to burn limestone to produce lime. Limestone consists of the chemical compound calcium carbonate, with calcium itself being chemically basic, meaning the opposite of chemically acidic. Thus, acidic soils can be neutralised by adding lime to them. Today, the production of lime is performed in larger plants and thus there is no need for standalone lime kilns.

Lime kilns are part of the geological heritage of the City, as they remind us of the economic value the rocks have had. The limestone still has a wide variety of uses due to its chemistry, ubiquity and ornamental value. From once being expansive tropical reefs to now being a rock used by us humans in every setting possible, the limestone is both impressive and resourceful.

The Glen has a lot to offer.

The Glen

As the ice sheets melted, the meltwaters cut deep river valleys into the Devonian and Carboniferous rocks. The Glen River and River Bride on the northside are likely examples of such rivers that are now much less energetic and more idyllic than they would have been a few thousand years ago. But the effect of these strong forces is as visible as the Glen itself. A small canyon valley to the east of Blackpool, the Glen is a beautiful park with grass fields, benches and adventurous trails.

Around the valley there are remains of former sandstone quarries, now covered in thick vegetation and more recent sediments and soils. Gravel pits from where Quaternary sediments were extracted also existed in his area. Today, the area is recreational and a fantastic natural amenity for the City.

Layers of sandstones, siltstones and mudstones in the park.

At the western side of the Glen the valley opens up and offers an environment that will make you consider whether you are in the City or on a hill walk in West Cork. It is also here where tilted layers of sandstones, siltstones and mudstones can be closely examined.

The side of an enormous geological fold in the Old Red Sandstone layers.

Lower Glanmire Road

Let us revisit the Old Red Sandstone one last time. Along Lower Glanmire Road the rock reveals some of the previously described structures on a larger scale. Instead of folds on the scale of a few metres, we see them on tens of metres along the road. Most of these sites are behind the train tracks or on private ground, but are conveniently large enough to be viewed from the pavement.

Along Lower Glanmire Road we can also spot the former site of the largest Old Red Sandstone quarry in the City, just next to Lover's Walk. This quarry was known was Brickfield Quarry, and prior to that, Flaherty's Quarry. At the top, we see green rock layers and and directly below it red-coloured rocks.

Despite the name, the Old Red Sandstone take on a broad range of colours, going from vibrant dark red to purple, green or grey. The colours reflect different chemical elements, minerals and iron rusting processes in the rocks. For instance, the red-coloured rock layers indicate that the rocks were exposed to open air when they formed, and thus the iron in the rocks was allowed to rust. On the other hand, the green or grey rocks hint at having originated under water.

The Former Brickfield/Flaherty's Quarry is perhaps the most vibrant rock outcrop in the area.

A leaf fossil from the Archaeopteris-tree found in the Old Red Sandstone near Glanmire Road.

There were other quarries in this area; however most of them are now covered up. One important site described as Tivoli Quarry has yielded some impressive local fossils!

Casually looking for fossils in Cork City's Late Devonian Old Red Sandstone is a futile effort. The rock does contain fossils, but they are rare: complex life on land was not as plentiful in the Devonian Period as it is today, and the sediments of the semi-arid land areas were not ideal for preserving plant or animal material.

However, thanks to the patience of both rock experts and amateurs there have been fascinating discoveries made. In fact, amazing evidence of prehistoric forests and complex life has been found in the Glanmire/Tivoli areas. Fossils of prehistoric trees such as Archaeopteris have been found and, as seen in the illustration above, these were quite different from trees that we know today. The fossilised bark from another prehistoric tree has also been found in this area.

Also due to the discoveries of important fossils of plant and pollen spores in the rocks, geologists have been able to say a lot about how the area of Cork City was like back in the Late Devonian. These fossilised plant particles are so small that they are not visible to the naked eye and must be studied under a microscope. But they are incredibly important in interpreting the conditions back in the geological past and they help scientists determine how old specific rocks are. Without these tiny discoveries, we would know significantly less about this lost world.

There are likely many more amazing discoveries to be made, but currently most of these former fossil sites are covered by human infrastructure.

In other areas of the country, other amazing fossils have been found. For instance, the Iveragh Peninsula in Kerry has many locations with amazing fossil sites from the Old Red Sandstone. Perhaps most spectacularly, in Kerry, on Valentia Island, footprints of Late Devonian four-legged vertebrate animals can be seen. These were likely amongst our first land-dwelling ancestors. In the same Old Red Sandstone layers, there are also traces of early centipede-like animals and fish and plant fossils.

Overall, the rocks from the Old Red Sandstone of Ireland are part of a larger setting and time that saw many interesting changes on Earth: vertebrate organisms were starting to live on land and plants were rapidly taking over the surface of the Earth, changing the atmosphere, waters and surface of the entire planet.

For further information and more details look at

Cork City Council Heritage Officer:
https://www.corkcity.ie/en/council-services/services/arts-culture-heritage/heritage/contact-the-heritage-officer.html

Geological Survey Ireland: https://www.gsi.ie

Hardcore Cork: https://www.hardcorecork.ie

School of Biological, Earth and Environmental Sciences: https://www.ucc.ie/en/bees/

The Cork Geological Association: https://www.ucc.ie/en/cga/

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