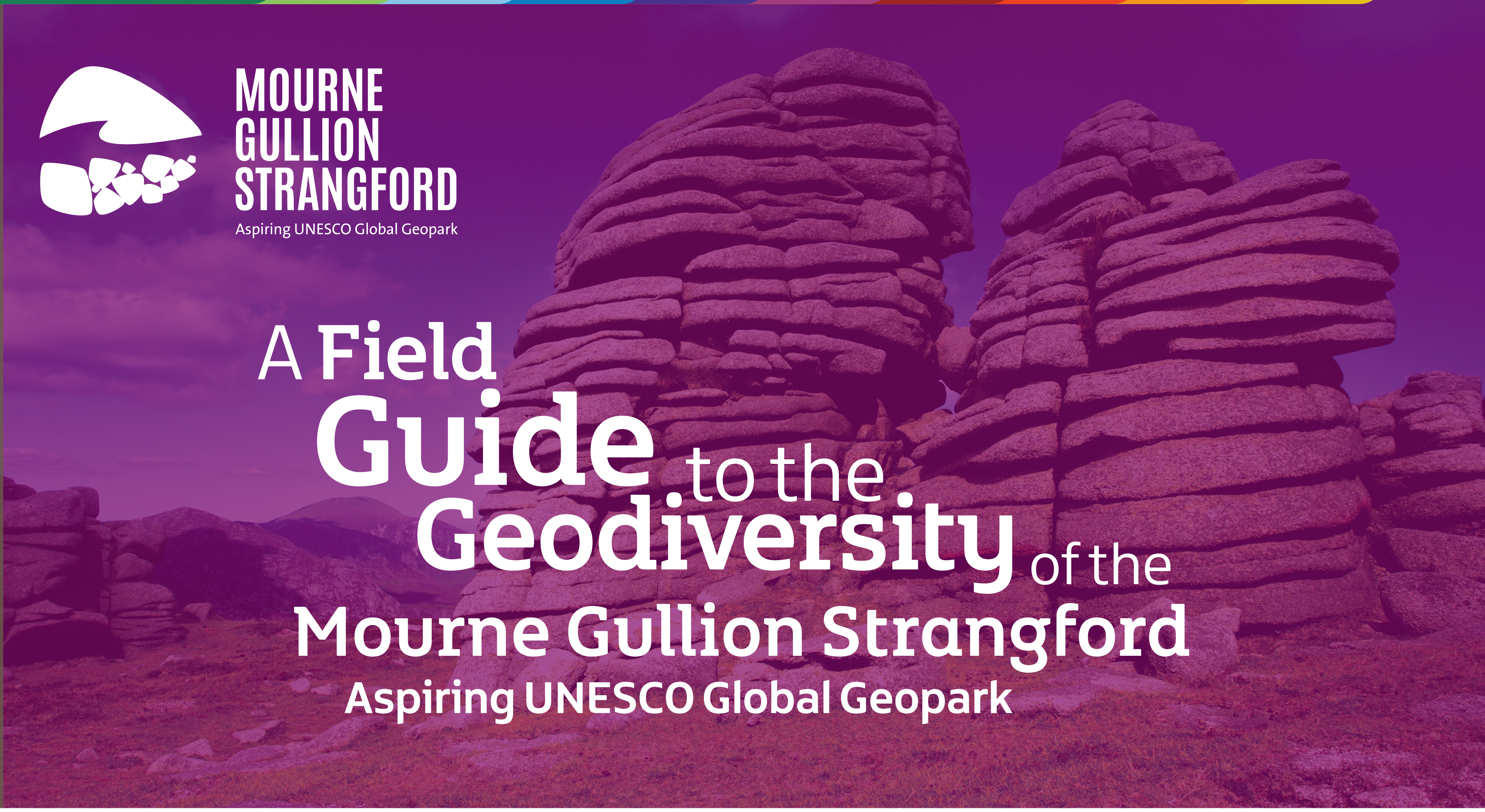
MOURNE
GULLION
STRANGFORD
Aspiring UNESCO Global Geopark



A Field Guide to the Geodiversity of the Mourne Gullion Strangford Aspiring UNESCO Global Geopark

A Field Guide to the Geodiversity of the Mourne Gullion Strangford

Aspiring UNESCO Global Geopark

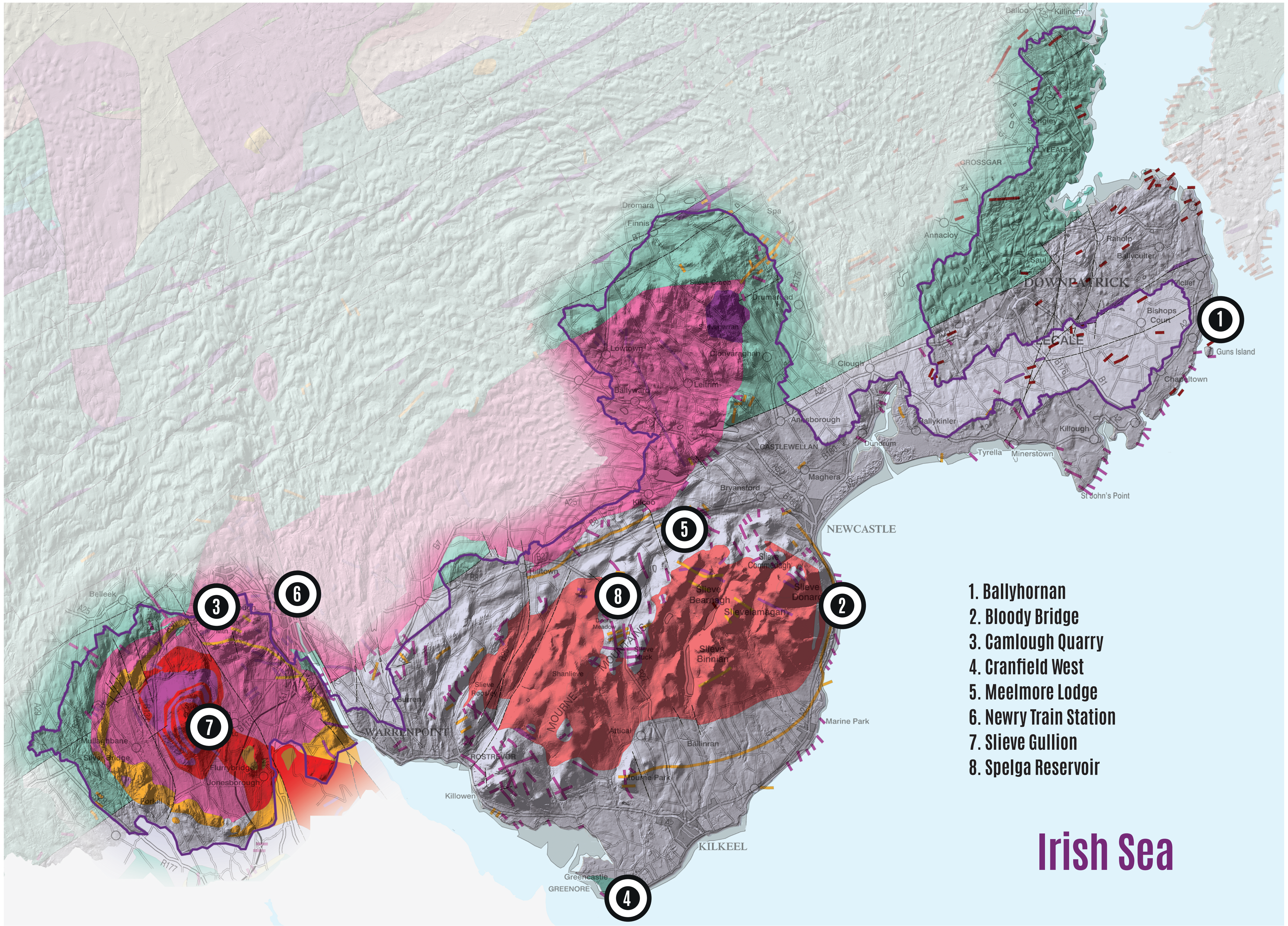
MOURNE
GULLION
STRANGFORD
Aspiring UNESCO Global Geopark

Comhairle Ceantair
an Iúir, Mhúrn agus an Dúin
Newry, Mourne and Down
District Council

Department of
Enterprise, Trade and Investment
www.detini.gov.uk
Geological Survey of Northern Ireland

www.mournegullionstrangford.com

Geological Map of the Mourne Gullion Strangford Aspiring UNESCO Global Geopark



1. Ballyhornan
2. Bloody Bridge
3. Camlough Quarry
4. Cranfield West
5. Meelmore Lodge
6. Newry Train Station
7. Slieve Gullion
8. Spelga Reservoir

MOURNE GULLION STRANGFORD ASPIRING UNESCO GLOBAL GEOPARK

Guide to rock units shown on the map

Palaeogene		🟥	Granite
		🟨	Felsite
		🟫	Gabbro
		🟥	Granophyric granite
		🟪	Microgabbro
	66		
	300		
Carboniferous		🟦	Limestone
	355		
Devonian		🟪	Diorite
		🟥	Granodiorite
	418	🟥	Lamprophyre
Silurian		🟩	Sandstone, siltstone and mudstone
	444		
Ordovician		⬜	Sandstone and silty mudstone
		🟪	Mudstone

Scale

0 5km 10km

Department for the Economy
www.economy-ni.gov.uk

GSNI Geological Survey of Northern Ireland
www.bgs.ac.uk/gsni

A Field Guide to the Geodiversity of the Mourne Gullion Strangford

Aspiring UNESCO Global Geopark

How to use this guide

The pack contains a suite of resources for seven field sites within the Mourne Gullion Strangford Aspiring UNESCO Global Geopark. It has been designed to equip post-primary school teachers with the information and knowledge to lead field visits to each of these sites as well as providing materials for students to enable them to carry out activities in the field.

This pack has been designed to fit in with specifications offered by examining bodies in both Northern Ireland and the Republic of Ireland. These are as follows:

Northern Ireland
CCEA GCSE Geography
WJEC GCSE Geology
CCEA GCE AS/A2 Geography
OCR GCE AS/A2 Geology

Republic of Ireland
Junior Certificate Geography
Leaving Certificate Geography

Each field site has information that can be used independently but for a broader understanding of the geological history of the area, it is recommended that a number of sites should be visited. A summary of both the bedrock geology and the superficial geology has been provided as well as a simplified geological map to provide an overview.

All of the field sites mentioned are suitable for students of GCSE / Junior Certificate age or older. However, this will depend on a number of factors including but not limited to age, ability and maturity so suitability is at the teachers' discretion. Information has been provided on site specific hazards as well as teaching and learning issues that should be considered prior to visiting. An appropriate risk assessment should always be carried out before any field visit, and it is recommended that each site is visited by the person with responsibility prior to bringing students.

Mourne Gullion Strangford Aspiring UNESCO Global Geopark accepts no responsibility for any injuries, losses or damages that result from using this field guide.

For more information on the Mourne Gullion Strangford Aspiring UNESCO Global Geopark please visit
www.mournegullionstrangford.com

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Mourne Gullion Strangford Aspiring UNESCO Global Geopark

The Mourne Gullion Strangford Aspiring UNESCO Global Geopark takes in the scenic areas of the Mourne Mountains, the Ring of Gullion and Strangford and Lecale. The spectacular beauty of the Geopark has been forged by nature, torn apart by volcanic activity and sculpted by ice, providing a stunning backdrop to remarkable people and places.

UNESCO Global Geoparks are areas with internationally important rocks and landscapes, all of which are managed responsibly for tourism, conservation and education. Whilst geology may be their foundation, UNESCO Global Geoparks build upon that by bringing it together with other aspects of heritage such as archaeology, history, culture and biodiversity, which are intricately linked. All of this is in collaboration with local communities who help drive forward sustainable economic development and conservation to make it a better place to work, live and visit.

The Mourne Gullion Strangford Aspiring UNESCO Global Geopark has over 400 million years of geological history. It charts the closure of the Iapetus Ocean and the bringing together of the two parts of what we now know as the island of Ireland, its passage through tropical latitudes, the birth of the North Atlantic Ocean, and finally the shaping of landscape by ice during the last glaciation. All of this remarkable diversity within a relatively small area makes it an ideal outdoor classroom for all ages.

For more information on UNESCO Global Geoparks please visit
http://www.unesco.org/new/en/natural-sciences/environment/earth-sciences/unesco-global-geoparks/

Geological history of the Mourne Gullion Strangford Aspiring UNESCO Global Geopark

Bedrock Geology

The oldest rocks in the Mourne Gullion Strangford Aspiring UNESCO Global Geopark were formed during the Ordovician and Silurian time periods 450 to 435 million years ago (mya). These greywacke sandstones and mudstones were laid down on the floor of an ancient ocean known as Iapetus as layers of sand and mud. Iapetus was a vast ocean that separated the northern continent of Laurentia (made up from much of what is now North America, together with the north of Ireland and Scotland), from the southern continent of Avalonia (made up of what is now the south of Ireland, England and Wales). When first deposited, these layers of sand and mud rested on top of an area of the Earth's crust, known as a tectonic plate, which was being subducted, or pushed down under another tectonic plate. As the plate was subducted, the soft horizontal layers of mud and sand were scraped off the top and contorted. These are now seen as steeply dipping layers or beds of solid sedimentary rocks within which folds can sometimes be seen.

The next oldest rocks are granodiorites of the Newry Igneous Complex that formed between 414 and 407 mya as a result of the closure of the Iapetus Ocean during the Devonian time period. The Newry Igneous Complex comprises a series of three bodies of igneous rocks known as plutons that extend over an area of 45 km2 from Slieve Croob in Co. Down to Forkhill in south Co. Armagh. The plutons are believed to have formed as Iapetus oceanic plate was subducted under Laurentia. Melting of the plate generated huge amounts of magma that was then intruded into the pre-existing rocks.

Carboniferous rocks are found as limestone and mudstone (shale) in the Cranfield area of Co. Down. These were deposited 340 to 345 mya as horizontal layers of lime-rich mud on the bottom of a tropical sea. The sea swarmed with life and as a consequence the rocks contain abundant fossils including corals, crinoids (sea lilies) and shells known as brachiopods.

The majority of the rocks in the Mourne Gullion Strangford Aspiring UNESCO Global Geopark formed during the Palaeogene period between 65 to 55 mya. Crustal stretching and thinning associated with the opening of the North Atlantic Ocean was responsible for the generation of huge amounts of magma in chambers beneath the surface. Pre-existing crustal weaknesses, which developed during the closure of the Iapetus Ocean some 350 million years earlier, meant that this was an ideal location for the intrusion of magma, resulting in a series of large igneous intrusions that now characterize this area.

The Slieve Gullion Complex is the oldest igneous complex in the Mourne Gullion Strangford Aspiring UNESCO Global Geopark. It began with the formation of ring dyke that began as a ring of fractures that developed around the edge of a diminishing magma chamber deep within the Earth. The magma was squeezed (or intruded) upwards into the fractures where it cooled and crystallised to form a large cylinder-shaped body of rock some 11km in diameter. The surrounding rock has now been weathered and eroded leaving the ring dyke exposed as a ring of hills, some 11km in diameter. These display evidence of localized explosive activity that is recorded by the presence of chaotic volcanic sediments known as vent agglomerates. In the centre of the Ring of Gullion lies Slieve Gullion, a layered igneous intrusion of granite and dolerite that is thought to be part of a magma chamber.

The youngest igneous complex from the Palaeogene period is the Mourne Mountains Complex which is 56 to 55 mya. The Mournes are composed of granite, of which there are five different types recognized. The Mourne Mountains Complex was intruded into pre-existing Silurian rocks and in a number of places, such as at Bloody Bridge, the contact between the two can be clearly seen. Surrounding the Mourne granites is a cone sheet, 15 to 20km diameter that was intruded as a result of a cone-shaped fracture that developed outwards from the base of the magma chamber and which fed both granite and dolerite magma upwards

Glacial Geology

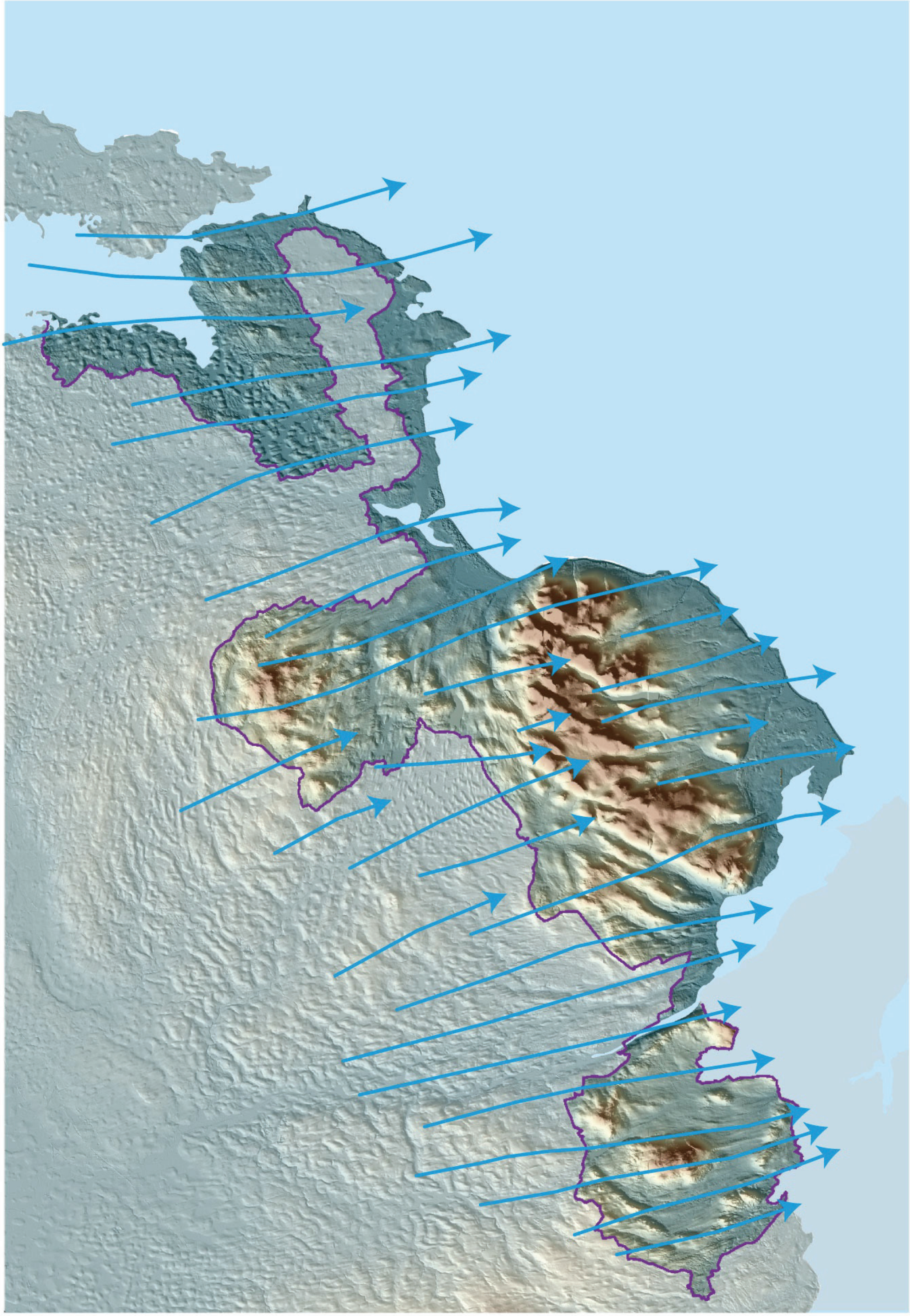
The last 2.6 million years of Earth's history (the Quaternary period) have been characterised by Ice Age conditions. These are cycles of colder Glacial periods and warmer Interglacial periods; each lasting between 40,000 and 100,000 years. Today we are in an Interglacial phase known as the Holocene. The last glacial phase in the UK and Ireland is known as the Devensian. This started around 110,000 years ago and finished around 10,000 years ago, when the last remains of glacier ice in Ireland melted. At the height of the Devensian, c. 27,000 years ago, so much water was locked up in huge ice sheets that sea level was ~120 m lower than it is today. At the same time, an ice sheet up to 1.5 km thick covered all of the UK and Ireland, filling the Irish Sea and reaching as far south as the Isles of Scilly off the coast of Cornwall. The last glacial phase in Ireland was known for most of the 20th Century as the 'Midlandian', because the ice sheet was thought to reach only as far as the Irish Midlands. Offshore surveys conducted by the Geological Survey, Ireland and the British Geological Survey have shown that not only were the British and Irish Ice sheets part of a single larger ice sheet, but that they extended for hundreds of kilometres beyond the present day shoreline.

The history of the ice sheet can be unravelled by looking at the shape of the landscape. Different types of landscape features (e.g. drumlins, glacial valleys and glacial lineations) help us understand how ice behaved in different areas. The huge ice sheet in the north of Ireland was nourished by an ice dome centred over Lough Neagh. From there, ice flowed southeast through and around the relatively high mountains of Mourne and Gullion. Drumlins to the north of the Mournes tell us that ice was flowing over soft deformable sediment (see ice flow illustration). Glacial lineations within the Slieve Gullion ring dyke demonstrate that these areas formed part of the Irish Sea ice stream; a corridor of fast moving ice draining the ice sheet southwards along the Irish Sea. Most of this ice was sourced from an ice dome centred over Scotland. As it flowed south it helped to carve out Strangford Lough, moving rocks from distant areas into Northern Ireland (e.g. Ailsa Craig microgranite). These rocks, known as 'erratics', help us to unravel the pathways of past ice sheets. In contrast, the high mountains of the Mournes acted as a barrier to the passage of ice southwards. Deep glacial valleys attest to ice overtopping the mountains and gradually excavating drainage networks over thousands of years.

In response to both climatic warming and growth of the ice sheet at low elevations the British and Irish ice sheet started to thin and retreat rapidly c. 25,000 years ago. A short period of cooling around 16,000 years ago halted this retreat and resulted in a brief re-advance of the ice sheet. Ice flowing south and southeast from Lough Neagh was funnelled by the uplands of the Cooley and Mourne mountains into large valley glaciers. These glaciers terminated in the low lying areas around Carlingford Lough and Dundrum Bay, forming broad ice lobes and a series of push moraines. These moraines were formed as the glaciers bulldozed the land in front of them as they advanced across the landscape; they can still be seen today. Along the coast, sediments exposed in cliff sections at Killard Point, and Kilkeel reveal a complex interaction between advancing valley glaciers and rising sea levels caused by melting of ice sheets globally.

The last gasp of the Devensian happened 11,500 years ago and lasted for only 1000 years. This phase, known as the Nahanagan in Ireland, resulted in a limited number of small corrie glaciers forming high up in the mountains. Possible sites of corrie glaciers are the north faces of Slieve Donard and Slieve Meelbeg in the Mourne Mountains.

Ice Flow



Bloody Bridge

Student Sheet

Visit Time: 2 – 3 hours

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks/fossils or sand from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Do not attempt to climb the fence at the car park or on the coastal path, as there is a steep drop on the other side. Always be aware of traffic, especially when crossing the main road to access the Bloody Bridge site. If you are walking up the river then make sure that you listen to the teacher in charge. If visiting the quarry ensure that you wear a hard hat at all times and stay well away from the quarry face and piles of loose boulders.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	**Coastal path:** Draw a labelled sketch of the Silurian rocks at the coastline.	☐
3	**Bloody Bridge:** (a) Explain what a misfit stream is. (b) Identify 3 products brought here as a result of glacial melting.	☐
4	At the **granite and Silurian rocks contact**: (a) Explain what thermal metamorphism is. (b) What is the main cause of landslips? (c) Give two pieces of evidence that indicate that this is the edge of a major igneous intrusion.	☐
5	**Granite quarry** (a) Why do you think that granite is a valuable building stone? (b) Why do you think the granite industry went into decline? (c) Draw a labelled sketch of the quarry face. (d) What is aplite and how does it form?	☐

Name

Location Bloody Bridge

1a. List of risks/hazards:	1b. How to reduce risks/hazards:

2. Draw a labelled sketch of the Silurian rocks at the coastline:

3a. Explain what a misfit stream is:

3b. Identify 3 products brought here as a result of glacial melting:

4a. Draw a labelled sketch of the contact between the granite and the Silurian rocks (label the contact, the fine-grained granite, granite veins, and bedding)

4b. Explain what thermal metamorphism is:

4c. Give two piece of evidence that indicate that this is the edge of a major igneous intrusion:

Evidence 1:

Evidence 2:

5a. Why do you think that granite is a valuable building stone:

5b. Why do you think the granite industry went into decline:

5c: Draw a labelled sketch of the quarry face:

5d: What is aplite and how does it form?

Bloody Bridge

Information Sheet

Location: Bloody Bridge and Bloody Bridge Quarry

GR: Bloody Bridge J 38824 27133 , Bloody Bridge Quarry J 36087 26731

Lat/long: Bloody Bridge 54.174300, -5.873748, Bloody Bridge Quarry 54.171424, -5.915816

Education for employability:
- Tourism
- Quarrying

Relevance to spec:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv, Human Interaction)
AS/A2: Geology/Geography Rocks, Global Tectonics, Climate Change

Rock types observed: granite, mudstone, sandstone, hornfels, aplite

Geological structures: granite / Silurian rocks contact, granite veins

Geomorphological features: misfit stream, glacial deposits

Site specific hazards:
- Traffic
- River levels
- Slippery rocks
- Loose rocks
- Steep drop at cliff

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear

Sketches to be drawn:
- Silurian rocks from the coastal path
- Quarry face

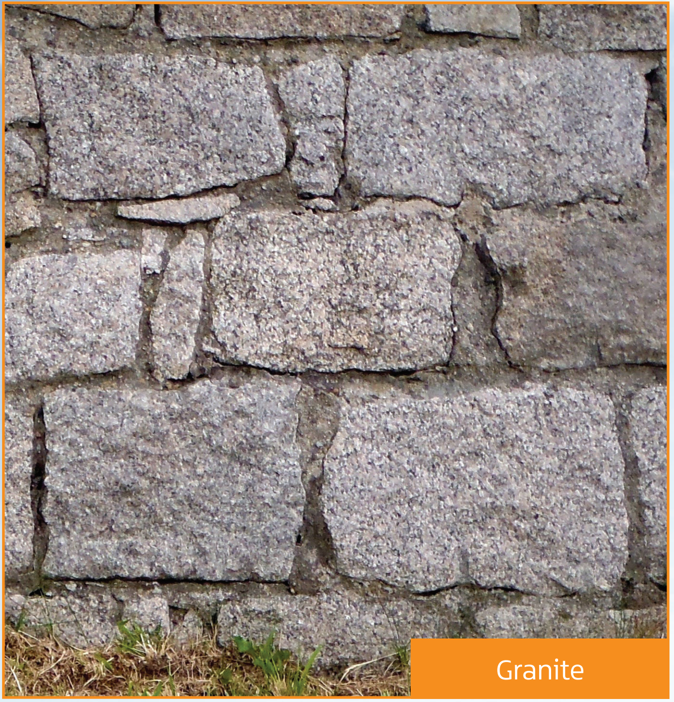
Equipment:
- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
N/A

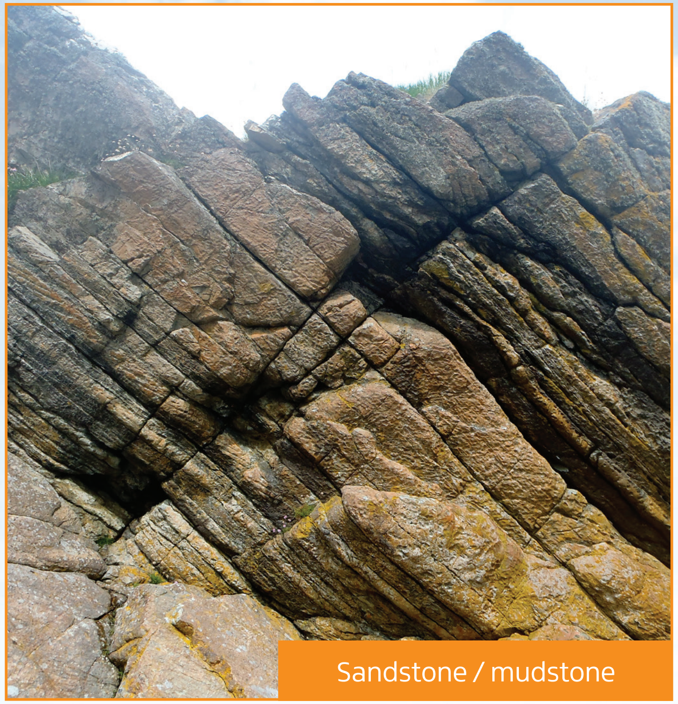
Prior knowledge: igneous rocks and processes, plate tectonics, glacial processes and products, sedimentary rocks and processes.

Keywords: granite, mudstone, sandstone, Silurian, Palaeogene, glaciation, misfit stream, hornfels, meltwater, aplite, veins.

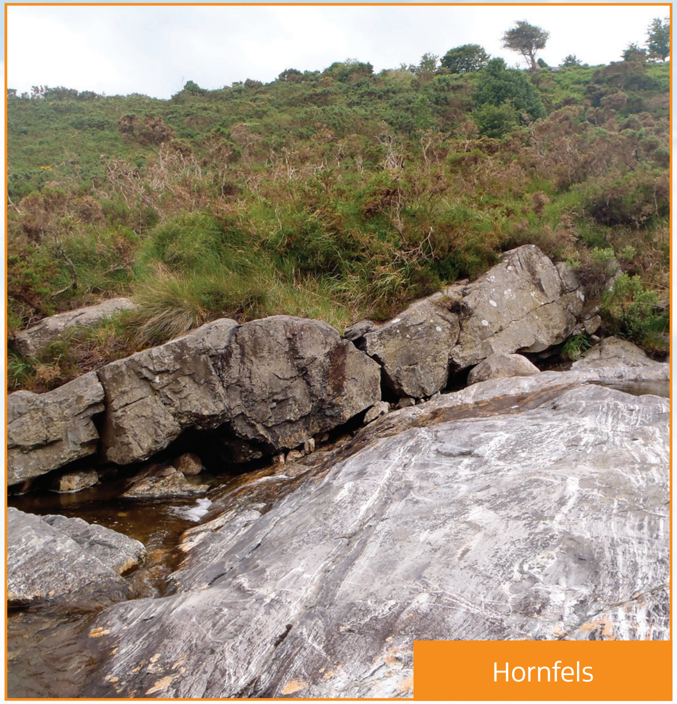
Format developed by the Western Education and Library Board's Magilligan Field Centre



Granite



Sandstone / mudstone



Hornfels

Description of granite:

- Medium to coarse grained
- Interlocking crystals
- Pale grey
- No fossils
- No reaction with HCl
- Dominated by quartz, plagioclase and orthoclase

Description of sandstone / mudstone:

- Clastic rock
- Medium grained / fine grained
- Dark grey / pale grey or green
- No fossils
- No reaction with HCl
- Thin layers (laminations) (mudstone only)

Description of hornfels:

- Clastic rock
- Very fine grained
- Dark grey / purple in places
- No fossils
- No reaction with HCl
- Very hard
- Thin layers (laminations)

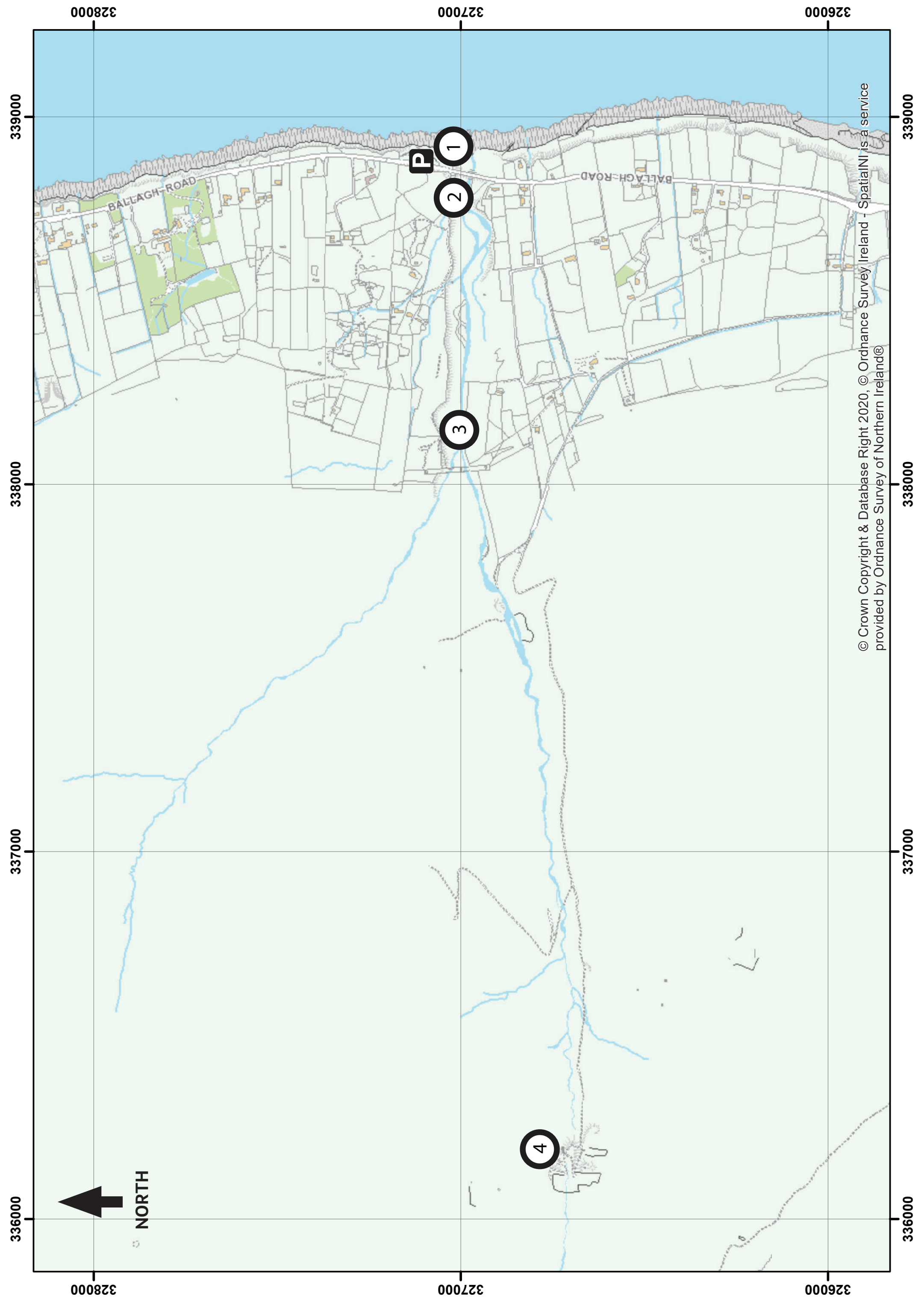
Geological history:

The oldest rocks at Bloody Bridge were deposited as sands and muds during Silurian times (430 Ma). During the Palaeogene period (around 60 Ma), crustal stretching and thinning associated with the opening of the North Atlantic Ocean generated huge amounts of magma and led to the intrusion of igneous rocks beneath the surface. Where the magma came into contact with the pre-existing Silurian rocks, they were fused and hardened to form hornfels. During Quaternary times, ice sheets moved across the entire area shaping and sculpting the land beneath. As the ice melted, the water released carved out large river valleys and brought with them huge amounts of glacial material, the remnants of which is seen at the Bloody Bridge.

Bloody Bridge

Teacher's Sheet

Visit Time: 2 – 3 hours



Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available in the Bloody Bridge amenity area. There are toilets and a small number of picnic tables.
1	**Coastal Path** The first locality can be found by following the small path that leads down from the southern end of the car park to the coast. The rocks exposed here Silurian mudstones and sandstones that formed between 445 and 440 million years ago. They were originally deposited as sand and mud on the bottom of an ancient ocean and over million of years they have hardened to form sandstone and mudstone. When the sands and muds were deposited they lay on top of an area of tectonic plate that was being subducted, or pushed under another tectonic plate. As the tectonic plate moved downwards, the soft horizontal layers of sand and mud were scraped off the top and folded into the near vertical layers that you see here.
2	**The Bloody Bridge** Return to the car park before crossing the main road and entering the National Trust managed Bloody Bridge site. Please take extreme care when crossing this busy road. Not long after you enter the site you will come to the old bridge from where Bloody Bridge gets its name. It is at this site that a particularly bloody battle took place during the 1641 rebellion. Take the time to stand on the bridge and look upstream. It is clear at this point that the small Bloody Bridge River is what is known as a misfit stream. The valley is clearly too large to have been excavated by the present river and was produced by meltwater that resulted from the disappearance of the last glaciers about 15,000 years ago. On the other side of the bridge some of the sand, gravel and boulders carried here by the glacial meltwater can also be seen.
3	**Granite Contact** The best way to observe the geology of the Bloody Bridge River is to walk along the rocks that make up the river bed and surrounding banks. However, this should only be attempted if river levels and weather are favourable and appropriate equipment is used. If you chose not to walk along the river bed and banks, there is a path that follows the course of the river that provides adequate rock exposures. Make your way upstream, observing the rocks in the river bed as you go. For the first 600m, this is all Silurian mudstones and sandstones. As you progress upstream the rocks become progressively more altered and take on a dark grey or purple hue. The contact between the granite and the Silurian rocks is clearly seen, and as this contact is approached you will notice that the sandstone and mudstone has been altered to alternate layers of pale green and purple rock. This is due to the heating caused when the granite was emplaced and is known as thermal or contact metamorphism. You may also notice some thin granite veins appear in the Silurian rocks. The granite is one of the 5 granites that make up the Mourne Mountains. Each of these formed as a result of crustal stretching and thinning associated with the opening of the North Atlantic Ocean. This led to the generation of huge amounts of magma that was then intruded into pre-existing rocks, which in this case was the Silurian mudstones and sandstones. For the first few 100m upstream from the contact, the granite is quite fine-grained as a result of cooling more quickly at the contact with the colder country rocks.

4	**Granite Quarry** Continue for 1km upstream until you reach a disused quarry. Do not enter without appropriate protective equipment including hard hats and high vis jackets, and always keep away from quarry faces. This is one of many quarries that were once active in the Mourne Mountains. Quarrying granite started in the early part of the 19th century where it would have been taken off the mountain via a mineral railway using carts called bogies. These would have travelled to King Street in Newcastle and on to the harbor where the granite was exported. A huge amount of the rock was taken to England where it was used to build cities such as Liverpool and Manchester. In the late 19th century, tens of thousands of tonnes of granite were produced every year, but by the end of World War 2 the industry had fallen into decline. The quarry offers a good section through one of the Mourne granites and has small veins of aplite which is a sugary, fine-grained type of granite that was squeezed out of the main granite mass in the final stages of solidification.

Spelga Reservoir and Meelmore Lodge

Student Sheet

Visit Time: 2-3 hours

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially in the car parks of both Spelga Reservoir and Meelmore Lodge and if you are crossing the main road to use the toilet facilities at Spelga Reservoir.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	Have a look at the solid geology ay **Meelmore Lodge**; first of all in the gate posts and then out in front of you. (a) Describe and identify 3 rock types in the pillars. (b) Draw a labelled sketch of the contact between the granite and the Silurian rocks.	☐
3	Now think about the glacial landscapes seen from **Meelmore Lodge**: (a) Draw a labelled sketch of the glacial landscapes seen from Meelmore Lodge and add the labels required. (b) Describe how the listed glacial landscape features are created.	☐
4	From the car park looking our over **Spelga Reservoir**: (a) Explain why the Mourne Mountains make a good location for sourcing a water supply. (b) Draw a labelled sketch of Spelga Reservoir, marking on any inflows and outflows of water and any potential directions of ice flow. (c) Name four towns along the course of the River Bann.	☐

Name		**Location**	Spelga Reservoir and Meelmore Lodge

1a. List of risks/hazards:	1b. How to reduce risks/hazards:

2a. Describe and identify 3 rock types in the pillars:

Rock 1	Rock 2	Rock 3

2b. Draw a labelled sketch of the contact between the granite and the Silurian rocks:

3a. Draw a labelled sketch of the glacial landscapes seen from Meelmore Lodge (label u-shaped valley, hanging valley, col, corrie, lateral moraine, direction of ice flow).

3b. Describe how the following glacial landscape features are created:

Corrie:

U-shaped valley:

Hanging valley:

Lateral moraine:

4a. Explain why the Mourne Mountains make a good location for sourcing a water supply:

4b: Draw a labelled sketch of Spelga Reservoir marking on any inflows and outflows of water and any potential directions of ice flow:

4c. Name four towns along the course of the River Bann

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Spelga Reservoir and Meelmore Lodge

Information Sheet

Location: Spelga Reservoir and Meelmore Lodge

GR: Spelga Reservoir J 26730 27341, Meelmore Lodge J 30564 30782

Lat/long: Spelga Reservoir 54.179297, -6.058775, Meelmore Lodge 54.209233, -5.998590

Education for employability:
- Tourism
- Resource management

Relevance to spec:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv, Human Interaction)
AS/A2: Geology/Geography Rocks, Global Tectonics, Climate Change

Rock types observed: granite, mudstone, sandstone, basalt

Geological structures: granite / Silurian rocks contact

Geomorphological features: corrie, col, hanging valley, u-shaped valley, lateral moraines

Site specific hazards:
- Traffic

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear

Sketches to be drawn:
- Contact between granite and Silurian rocks (Meelmore Lodge)
- Glacial landscape (Meelmore Lodge)
- Spelga reservoir

Equipment:
- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
N/A

Prior knowledge: igneous rocks and processes, plate tectonics, glacial processes and products, sedimentary rocks and processes.

Keywords: granite, mudstone, sandstone, Silurian, basalt, Palaeogene, glaciation, u-shaped valley, moraine, hanging valley, corrie, col, pluck, abrade.

Format developed by the Western Education and Library Board's Magilligan Field Centre


Corrie


Col


Hanging valley


U-shaped valley


Lateral moraine


Glacial depression

Geological history:
The oldest rocks at Spelga Reservoir and Meelmore Lodge are Silurian in age (approx. 430 Ma) and were deposited in a now disappeared deep ocean. The granites formed much later, during the Palaeogene period (around 60 Ma) as the result of the opening of another ocean, this time the North Atlantic Ocean. This caused the stretching and thinning of the crust and the generation of huge volumes of magma. This magma was intruded into the Silurian rocks where it cooled and solidified. During the Quaternary period, successive glaciations removed the Silurian rocks, leaving behind the harder granites and shaping the rocks into the landforms that are seen at Spelga Reservoir and Meelmore Lodge.

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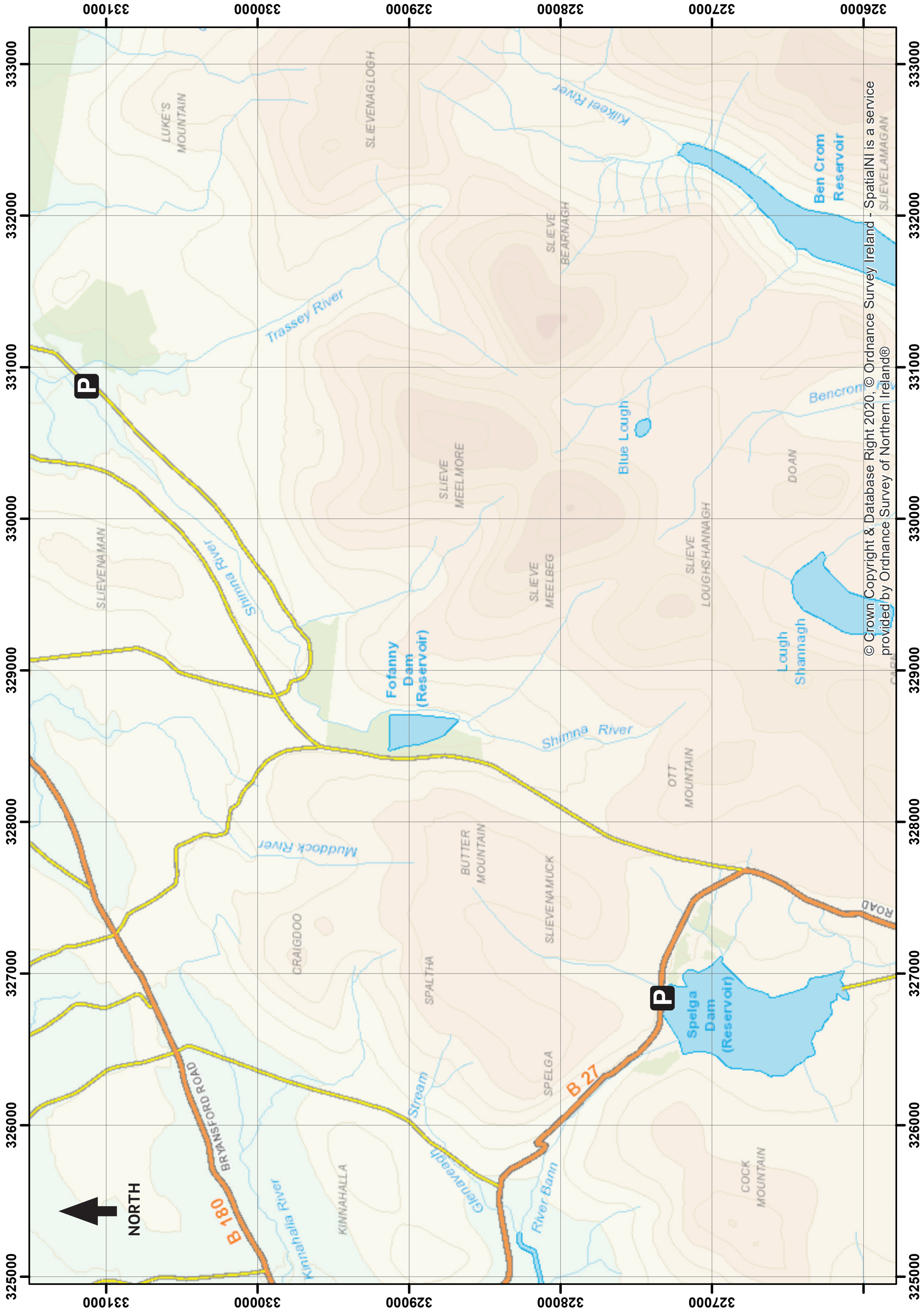
Aspiring UNESCO Global Geopark

Spelga Reservoir and Meelmore Lodge

Teacher's Sheet

Visit Time: 2-3 hours



Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access:	**Parking is available in the amenity areas of both Meelmore Lodge and Spelga Reservoir. Both locations have picnic tables and toilets, and Meelmore Lodge has a small cafe.**
1	**Meelmore Lodge** Park in the car park and walk alongside the main building until you reach the stone gate pillars at the entrance to the camping ground. Before doing anything else, have a look at the pillars and examine the different rock types. There are examples of a number of different types of granites, basalt, mudstone and sandstone, all of which are locally sourced. Look south from the gateway along the valley of the Trassey River. The landscape features are very obvious but first of all talk about the underlying geology. Directly in front of you is Slievenaglogh and Hare's Gap, both of which are made of granite. There are 5 different types of granites that make up the Mourne Mountains but they are all very similar and are quite often difficult to tell apart. However, they all formed during the Palaeogene period when crustal stretching and thinning occurred as a result of the opening of the North Atlantic Ocean. This led to the generation of huge amounts of magma beneath the surface. The magma was intruded into the pre-existing rock (known as country rock) about 57 million years ago, which in this case was sandstone and mudstone of Silurian age (430 million years old). The contact between the granite and the much older Silurian rocks can be clearly seen in Slieve Meelmore to the north. The contact is expressed as the lighter rocks to the left (granite) and the much darker layered rocks (Silurian) to the right. The entire view from this location is a result of ice movement during the last glaciation. The broad valley running E-W directly below you is a u-shaped valley, formed by a glacier as it moved eastwards down the Shimna Valley. On the sides of the u-shaped valley are hummocks of glacial material known as moraines, that formed along the edge of a glacier as the ice melted. The broad cross-section of a u-shaped valley directly in front of you is a hanging valley, so called as it was a much smaller glacial valley that fed into the larger and deeper glacier below, and was left 'hanging' when the ice melted. Behind the hanging valley is a corrie, a bowl-shaped depression with steep walls that formed due to the accumulation of snow and ice over many years. As the ice built up, it began to pluck and abrade the rock below, causing it to deepen and form a hollow. The ice eventually began to flow due to gravity, and would have moved down the now hanging valley to join the main u-shaped valley. The final glacial feature is known as Hare's Gap and is seen as a notch in the hillside directly in front of you. This is known as a col and formed as the low spot (or saddle) in between two corries, indicating that there is another corrie on the other side.

2	**Spelga Reservoir** From the car park look out across Spelga reservoir which sits in a glacial depression where snow and ice would have accumulated during the last glaciation before radiating outwards in numerous directions as a result of its own weight and gravity. The Reservoir is just one of several located in the Mourne Mountains that have been exploited for their ability to store water. The Reservoir itself was constructed in the 1950s but is part of the much older 'water story'. In 1891, the city of Belfast was expanding rapidly and the Belfast City and District Water Commissioners were getting increasingly worried about the level of resources available. They began investigations to find a suitable area for a plentiful supply of good water and due to the high levels of rainfall, inexpensive transport (due to gravity), and the impermeable bedrock (granite), with ample potential reservoirs (u-shaped valleys), the Mournes were identified as the prime area. Work began immediately and involved several phases of work including the construction of Silent Valley Reservoir, the largest of the reservoirs. The massive engineering works involved provided valuable employment to an area that depended solely on quarrying and fishing. Spelga Reservoir is located on the course of the River Bann that has its source as a small stream to the SE of the reservoir. From Spelga Reservoir it flows on towards Katesbridge, Banbridge and Portadown before entering Lough Neagh at Bannfoot. It reemerges from Lough Neagh at Toome Bridge and flows on to Coleraine before entering the Atlantic Ocean at the Barmouth. It is the longest river in Northern Ireland and has its humble origins here. Spelga Reservoir and Reservoir has not altered the course of the River Bann but it has altered the road network as the old Annalong Road used to travel straight across where the reservoir is now. After a long, dry spell it is possible to see the remains of the old road and the bridge where it crossed the stream that goes on to become the River Bann.

Cranfield West

Student Sheet

Visit Time: 1½ – 2 hours

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks/fossils or sand from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially when crossing the road to access the beach. Stay well away from the wave zone and take extra care when climbing on the rocks at Cranfield Point as they can be very slippery.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	Examine and describe samples of the conglomerate.	☐
3	(a) Make a list of measures taken to reduce coastal erosion on the beach, sand dunes and harbour. (b) Explain how longshore drift causes coastal erosion.	☐
4	Draw a labelled sketch of the raised beach, cliffs and caves from the road behind the apartments.	☐

Name

Location Cranfield West

1a. List of risks/hazards:	1b. How to reduce risks/hazards:

2. Identify the main rock types of the pebbles on the beach and guess their approximate percentage in 1m^2:

3. Describe the methods used to stabilise the coastline:

4a. Describe the main rocks types at Cranfield Point:

4b. Identify as many fossils as you can:

4c. Describe the environment in which these rocks formed:

5. Draw a labelled sketch of the dyke (label the dolerite and the surrounding rocks as well as marking on the width and orientation of the dyke).

5b. Draw a labelled sketch of the tension gashes (label the direction of stress).

5c. Describe how the tension gashes formed:

5d. Put in order the sequence of events at Cranfield Point starting with the oldest:

Cranfield West

Information Sheet

Location: Cranfield West, Cranfield Point

GR: Cranfield West J 26317 10744, Cranfield Point J 25613 10577

Lat/long: Cranfield West 54.030354, -6.072017,Cranfield Point 54.029030, -6.082821

Education for employability:
- Tourism
- Coastal engineering

Relevance to specification:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv), Human Interaction
AS/A2: Geology/Geography Rocks, Global Tectonics, Coastal Processes

Rock types observed: limestone, shales, dolerite

Geological structures: dyke, faults, tension gashes

Geomorphological features: n/a

Coastal protection and engineering strategies: rip-rap, gabions

Site specific hazards:
- Traffic
- Loose rocks
- Tides
- Slippery rocks
- Wave zone

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear
- Tide tables
- Guidance for HCl

Sketches to be drawn:
- Intrusive dyke
- Tension gashes

Equipment:
- Camera
- Metre stick
- Hand lens
- HCl

Personnel to be contacted prior to visit:

N/A

Prior knowledge: igneous rocks and processes, plate tectonics, glacial processes, sedimentary rocks and processes, fossils and fossil preservation, coastal protection strategies.

Keywords: bedding, bedding planes, dykes, gabions, sedimentary, igneous, rip-rap, brachiopods, crinoids, corals, faults, tension gashes.

Format developed by the Western Education and Library Board's Magilligan Field Centre


Limestone


Shale


Dolerite

Description of limestone:

- Non-clastic rock
- Very fine grained
- Medium grey
- Abundant fossils
- Reacts with HCl

Description of shale:

- Clastic rock
- Very fine grained
- Dark grey
- Some fossils
- Reacts with HCl
- Thin layers (laminations)

Description of dolerite:

- Medium grained
- Interlocking crystals
- Dark grey/green
- No fossils
- No reaction with HCl
- Dominated by plagioclase and pyroxene

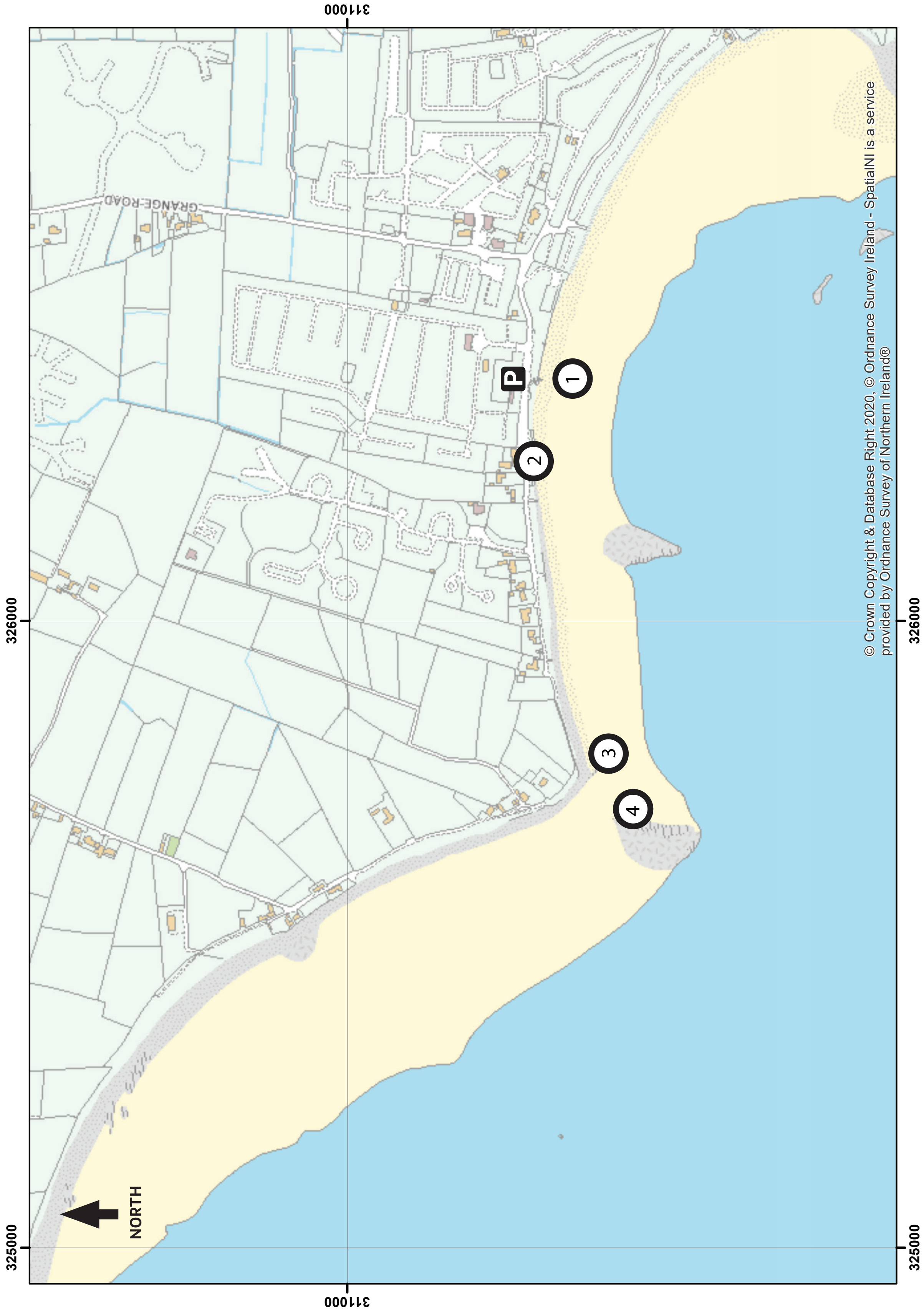
Geological history:

The rocks around Cranfield West are dominated by clean outcrops of limestone and shale that date back to the Carboniferous period (around 340 Ma). The limestone contains abundant fossils indicating a tropical sea environment. The layers of shale indicate periodic deepening of the sea resulting in the deposition of fine layers of mud from suspension. A dolerite dyke cross-cuts the limestone and shale and was intruded during the Palaeogene period as a result of crustal stretching and thinning approximately 60 Ma.

Cranfield West

Teacher's Sheet

Visit Time: 1½ – 2 hours



Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available at the amenity area at Cranfield West where there are also toilets and changing facilities. The car park is not suitable for coaches but it is possible to park outside the entrance to the amenity area.
1	**Ameracam Lane: East** Access the beach at the steps opposite the amenity area and walk west. Take care crossing the road. As you walk you will see numerous different pebbles on the beach. These are a good representation of the geology of the surrounding area in general but there are also some from further afield. Rock types found are limestone (local), granite (local), quartz pebbles (local), mudstone/sandstone (local) and flint (from Co. Antrim).
2	**Cranfield Beach: West** Stop at the gabions (rock cages) that are exposed below the access road approximately 200m west from the access point to the beach. These have been constructed and installed as coastal protection to keep the access road to the houses along Ameracam Lane from being undercut and collapsing. Further along there are large granite boulders (rip-rap) that have also been placed as a method of coastal protection, but this time it is to protect the headland at Cranfield.
3	**Cranfield Point: 1** Keep walking west until you get to the rock outcrop. This rock is limestone and forms in layers (or beds) together with a type of finely layered mudstone known as shale. The beds are dipping at about 15o to the west and are not of uniform thickness. The limestone and shale would have been deposited as horizontal layers of lime-rich mud on the bottom of a tropical sea floor during the Carboniferous period, some 340 million years ago. The limestones, and sometimes the shales contain abundant fossils of various marine creatures that inhabited the shallow tropical sea. These include corals, crinoids (or sea-lilies), sea-shells known as brachiopods, and also some evidence of burrowing.
4	**Cranfield Point: 2** A dyke is exposed at the farthest tip of Cranfield Point, trending NW/SE. Dykes are intrusions of magma that were squeezed into pre-existing faults (or cracks) within the older surrounding rocks. The magma never reached the surface, but instead remained beneath where it cooled and solidified. They are usually very easy to identify within sedimentary rocks such as limestone as they cross-cut any bedding in the surrounding rock. They are often more resistant to coastal erosion and therefore stand well above the surrounding rock and in this case have contributed to the location of the headland. The dyke would have been intruded approximately 60 million years ago, during a period of major earth movement that occurred as the North American Plate pulled away from the Eurasian Plate. The resulting crustal stretching and thinning produced huge volumes of magma below the ground, some of which was intruded as dykes such as this one. There are a number of small white veins within the limestone that are roughly s-shape, all of which are parallel to each other. These are known as tension gashes and form as small fractures open up when rocks was stretched.

Slieve Gullion Forest Park

Student Sheet

2-2½ Hours

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks/fossils or sand from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially in the car park at Slieve Gullion Courtyard, but also along the scenic drive. Stay well away from the edge of the layby on the way up the forest drive as there is a steep drop. Do not attempt to climb the loose boulders at the Slieve Gullion summit car park, as many are unstable and they can be safely observed from a distance.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	**Slieve Gullion Courtyard Car Park**: (a) Draw a labelled sketch of the ring dyke and the surrounding countryside and add the labels required. (b) Describe how ring dykes form and how we know that it is not a super volcano.	☐
3	On the **exterior courtyard walls**: (a) Identify and describe the three rocks, granodiorite, rhyolite and granite. (b) Decide whether the type of rock influences what position in the wall it is and explain your answer. (c) What is the most common rock type in the wall? Why do you think this is the case?	☐
4	**Slieve Gullion car park**: (a) Draw a labelled sketch of the rock face at Slieve Gullion. (b) Look at the loose boulders and find two different rock types and describe them. (c) Describe how the layered igneous intrusion formed.	☐

Name

Location Slieve Gullion Forest Park

1a. List of risks/hazards:	1b. How to reduce risks/hazards:

2a. Draw a labelled sketch of the ring dyke and the surrounding countryside (label the ring dyke, Newry granodiorite, and indicate the position of Slieve Gullion):

2b. Describe how ring dykes form and how we know that it is not a super volcano:

2a. Describe and identify 3 rock types in the pillars:

Rhyolite	Granodiorite	Granite

3b. Does the type of rock influence what position in the wall it is? Explain your answer:

3c. What is the most common rock type in the wall? Why do you think this is the case?:

4a. Draw a labelled sketch of the rock face at Slieve Gullion (label the granite, dolerite, loose boulders, any contacts between the two different rock types):

4b. Look at the loose boulders and find two different rock types. Describe these below:

Granite:

Dolerite:

4c. Describe how the layered igneous intrusion formed:

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STRANGFORD
Aspiring UNESCO Global Geopark

Slieve Gullion Forest Park

Information Sheet

Location: Slieve Gullion Courtyard and Slieve Gullion Drive

GR: Slieve Gullion Courtyard J 04051 19744, Slieve Gullion Drive J 01755 20046

Lat/long: Slieve Gullion Courtyard 54.116157, -6.408625, Slieve Gullion Drive 54.119329, -6.443612

Education for employability:
- Tourism
- Environmental protection

Relevance to spec:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv, Human Interaction)
AS/A2: Geology/Geography Rocks, Global Tectonics

Rock types observed: granodiorite, dolerite, granite, rhyolite

Geological structures: ring dyke, layered igneous intrusion

Geomorphological features: n/a

Site specific hazards and control measures:

- Traffic
- Loose rocks
- Timber felling

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear

Sketches to be drawn:
- Ring dyke and surrounding area
- Rock face at Slieve Gullion upper car park

Equipment:
- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
Park closes every evening at dusk

Prior knowledge: igneous rocks and processes, plate tectonics, engineering issues

Keywords: granodiorite, dolerite, ring dyke, granodiorite, layered intrusion, igneous, volcanic activity, super volcano, rhyolite, granite.

Format developed by the Western Education and Library Board's Magilligan Field Centre


Granodiorite


Rhyolite


Dolerite / gabbro

Description of granodiorite:

- Medium to coarse grained
- Interlocking crystals
- Medium grey
- No fossils
- No reaction with HCl
- Dominated by quartz, plagioclase and orthoclase (more plagioclase)

Description of a rhyolite:

- Very fine grained
- Dull
- Pale grey
- No fossils
- No reaction with HCl
- Small pits in the surface

Description of dolerite / gabbro:

- Medium / coarse grained
- Interlocking crystals
- Dark grey/green
- No fossils
- No reaction with HCl
- Dominated by plagioclase and pyroxene

Geological history:

The oldest rocks at Slieve Gullion Forest Park are the granodiorites intruded as part of the Newry Igneous Complex some 410 Ma. These rocks originated as magma that a formed as a result of heat generated when the Iapetus Ocean closed. During the Palaeogene period, this pre-existing weakness in the crust was exploited once more when crustal stretching and thinning led to the formation of more igneous rocks beneath the surface around 60 Ma. This led to the formation of the Slieve Gullion layered igneous intrusion and the Ring of Gullion ring dyke. The ring dyke formed when magma was squeezed through circular cracks surrounding a disappearing magma chamber. In some instances the magma reached the surface and produced volcanic material, such as rhyolite.

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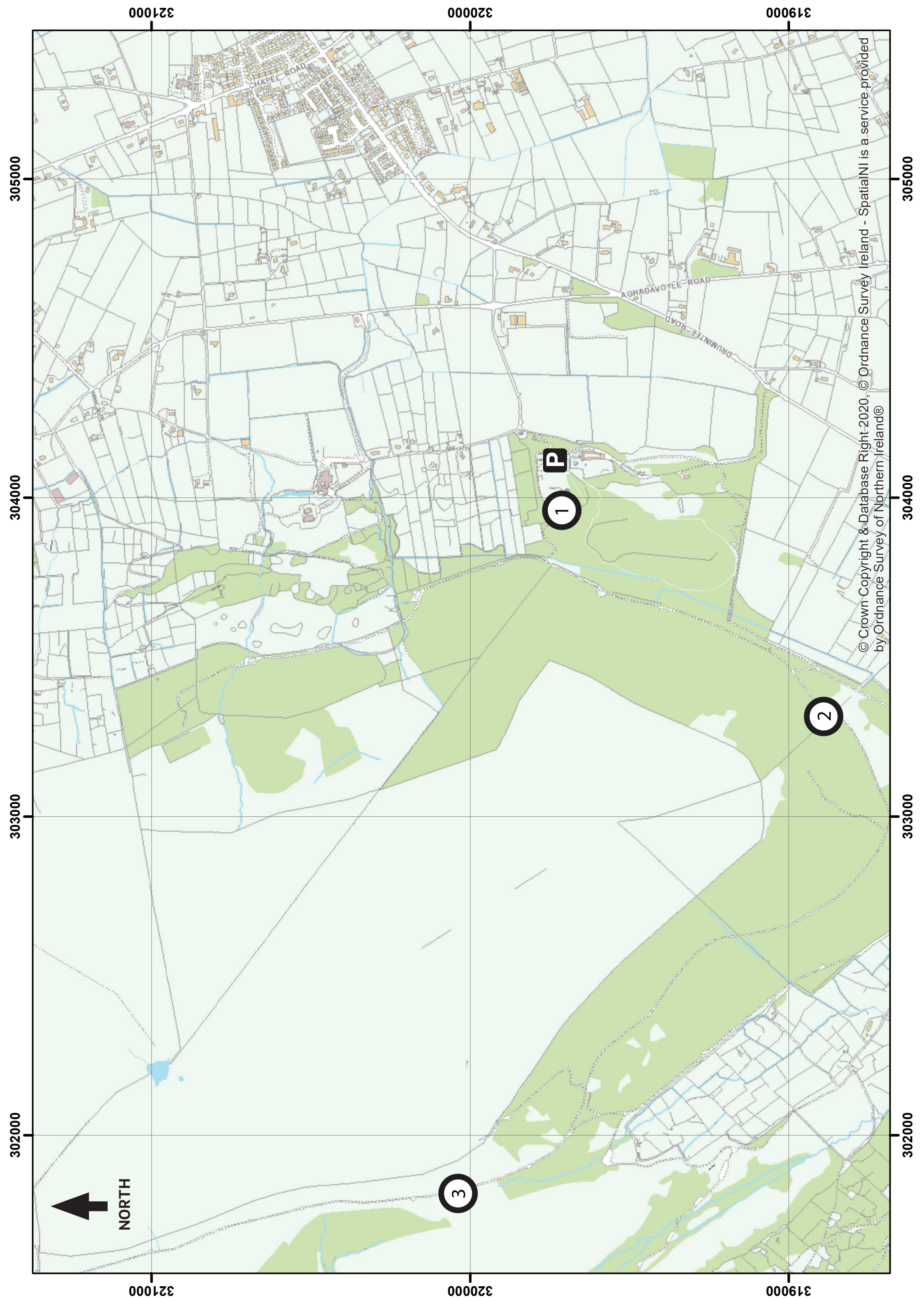
Slieve Gullion Forest Park

Teacher's Sheet

2-2½ Hours



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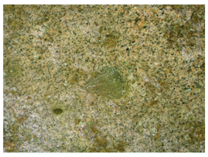
Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available at the Slieve Gullion Courtyard. There are numerous picnic benches, toilets and a coffee shop. The main scenic drive leaves from this location.
1	**Courtyard Car Park** Walk to the fence overlooking the farmland towards the east and observe the line of hills that can be seen in the middle distance. These hills are the Ring of Gullion ring dyke (also referred to as the Slieve Gullion ring dyke) and are expressed on the landscape as a near continuous ring of hills approximately 11km in diameter. The ring dyke formed during the Palaeogene period some 60 million years ago as magma was intruded into a circular fracture that surrounded the edge of a magma chamber deep within the earth. Fracturing occurred as magma from the chamber drained away, no longer able to support the surrounding rocks, and causing a line of cracks or fractures to develop all the way around the periphery of the chamber. As these fractures formed, magma was intruded into them where it remained and then cooled and solidified to form solid rock. The majority of the ring dyke is formed from granite but due to the method if its formation it is often cracked and broken up and looks very different from other granite intrusions in the area. The ring dyke is often explained as being a massive super volcano, but this is not the case. If there was a volcano of this size there would be evidence of huge volumes of volcanic material such as ash and lava but there is nothing of this sort. There are some examples of small volcanic eruptions at a couple of places around the ring itself, but these are very minor and would have formed as part of the ring dyke with as small breaches of magma erupted above the surface. In between the ring dyke and where you are standing is flat-lying farmland. This area is underlain by the much older Newry granodiorite. This granite-like rock was intruded around 410 million years ago and is part of the Newry Igneous Complex that stretches from Forkhill in south County Armagh to Slieve Croob in Co. Down.

2	**Courtyard Building** Walk over to the Slieve Gullion Courtyard building and to the glass walkway that covers the front of the building. This is signposted as a conference and training centre. Walk to the right, to the very far end and look at the various rock types used to build the wall. The corner stones of the building are made out of Newry granodiorite. This is a pale-grey, medium-grained, crystalline rock that is often characterized by containing black 'blobs' or xenoliths. Granodiorite is used as cornerstones as it is an excellent dimension stone and can be cut to the required size adding support and strength to the structure. Newry granodiorite is quarried extensively and there are quarries (active and disused) at Ballymagreehan, Goraghwood and at Aughnagon. It is a very desirable building stone and has ben used for many important buildings and structures in Newry and in the surrounding area including the Craigmore Viaduct, Newry Cathedral and Killevy Castle. If you move towards the entrance to the walkway, you will see a dull, pale grey, fine-grained rock, often containing small pits. This is rhyolite and is the volcanic equivalent of granite. This means that it formed from a volcanic eruption. Rhyolite is very viscous lava, and eruptions of this type are often described as being like squeezing a tube of toothpaste. The third rock type to look at is granite from the ring dyke itself. This is not easy to spot as it looks quite similar to the granodiorite. The main difference is that the ring dyke granite is broken up due to the nature of its intrusion and it therefore looks very patchy. This is one of the few places that you can view the volcanic rocks as well as the granites of the ring dyke safely.
3	**Slieve Gullion Car Park** Join the scenic drive and after about 0.8 miles you will see a small layby that offer wonderful views over the ring dyke, out towards Carlingford Lough and also out over Forkhill Quarry (source of the rhyolite seen at the Courtyard). Continue on the scenic drive for another couple of miles and you will come to the main car park at the base of Slieve Gullion itself. From here you can reach the summit of the mountain easily but it is not necessary. Standing in the car park, look towards Sieve Gullion at the main rock face. Slieve Gullion is located at the centre of the ring dyke and although it formed in association with it, it is not part of the ring dyke structure. If you look at the rock face you will begin to see both light-coloured and dark-coloured rocks. Slieve Gullion is what is known as a layered igneous intrusion; this means that it is made up of layers of igneous rock that were intruded into the surrounding country rock. The layers are composed of lighter-coloured granite-type rock, and darker-coloured dolerite-type rock. However, the layers are not always straightforward and show evidence of mingling and mixing which indicates that two very different types of magma existed at the same time. These rocks are the same approximate age as the ring dyke (60 million years old) and formed in association with the stretching and thinning of the crust as a result of the opening of the North Atlantic Ocean. Continue on the scenic drive before exiting the forest park, but as you make your way down hill, look out for other evidence of the layered igneous intrusion expressed as alternate layers of dolerite (dark) and granite (light).

Newry Railway Station



Student Sheet

Visit Time: 1 Hour

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks/fossils or sand from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially in the car park at the train station. Always stay on the footpath and do not climb on the railings on the bridge over the A1. If you are observing the dykes along the A1 from within the minibus please ensure that you remain in your seat and do not distract the driver.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	At the **railway station access road**: (a) Describe the granodiorite. (b) Draw a labelled sketch of the granodiorite with a xenolith. (c) Describe the formation of the Newry Igneous Complex.	☐
3	From the **bridge looking over the A1**: (a) Draw a labelled sketch of pre-splitting holes in the granodiorite. (b) Explain the process of pre-splitting. (c) What properties make granodiorite suitable for pre-splitting? (d) Name 3 problems the engineers encountered when blasting was being carried out to make the new road.	☐
4	On the **Newry to Dundalk Road (A1)**: (a) Draw a labelled sketch of a dyke within the granodiorite. (b) Why are the dykes problematic for managing the cut rock faces at the roadside?	☐

Name

Location Newry Railway Station

1a. List of risks/hazards:	1b. How to reduce risks/hazards:

2a. Describe the granodiorite:

2b. Draw a labelled sketch of the granodiorite with a xenolith:

2c. Describe the formation of the Newry Igneous Complex:

3a. Draw a labelled sketch of pre-splitting holes in the granodiorite:

3b. Explain the process of pre-splitting:

3c. What properties make granodiorite suitable for pre-splitting:

3d. Name three triggers for landslips and what is the likely one here:

1.

2.

3.

4a. Draw a labelled sketch of a dyke within the granodiorite:

4a. Draw a labelled sketch of a dyke within the granodiorite:

MOURNE
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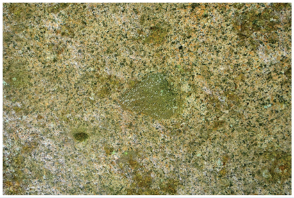
STRANGFORD

Newry Railway Station

Information Sheet



Location: Newry Railway Station

GR: Newry Railway Station J 06892 27929

Lat/long: Newry Railway Station 54.189090, -6.362283

Education for employability:
- Infrastructure
- Engineering

Relevance to specification:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv, Human Interaction)
AS/A2: Geology/Geography Rocks, Global Tectonics

Rock types observed: granodiorite, dolerite

Geological structures: faults, dykes, xenoliths

Geomorphological features: n/a

Site specific hazards:
- Traffic
- Loose rocks

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear

Sketches to be drawn:
- Granodiorite with xenoliths
- Pre-splitting holes within granodiorite
- Dykes within the granodiorite

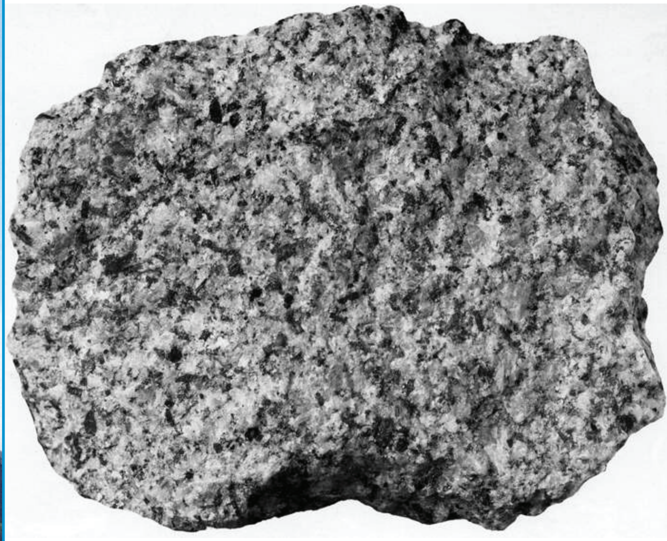
Equipment:
- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
N/A

Prior knowledge: igneous rocks and processes, plate tectonics, engineering issues

Keywords: granodiorite, xenolith, pre-splitting, dolerite, Palaeogene, dykes, faults, igneous complex, pluton

Format developed by the Western Education and Library Board's Magilligan Field Centre



Granodiorite

Xenoliths

Dolerite

Description of granodiorite:

- Medium to coarse grained
- Interlocking crystals
- Medium grey
- No fossils
- No reaction with HCl
- Dominated by quartz, plagioclase and orthoclase (more plagioclase)

Description of a xenolith:

- Not a rock type but a generic term for a piece of rock trapped within another.
  At Newry they are:
- Fine grained
- Dark grey / black
- Crystalline
- Diffuse or straight contact

Description of dolerite:

- Black
- Small sized crystals
- Composed of olivine, augite and plagioclase feldspar
- No fossils
- No reaction with HCl
- Cuts up through the sedimentary rocks (limestone and flint beds)

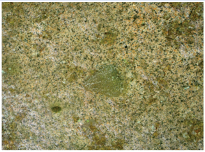
Geological history:

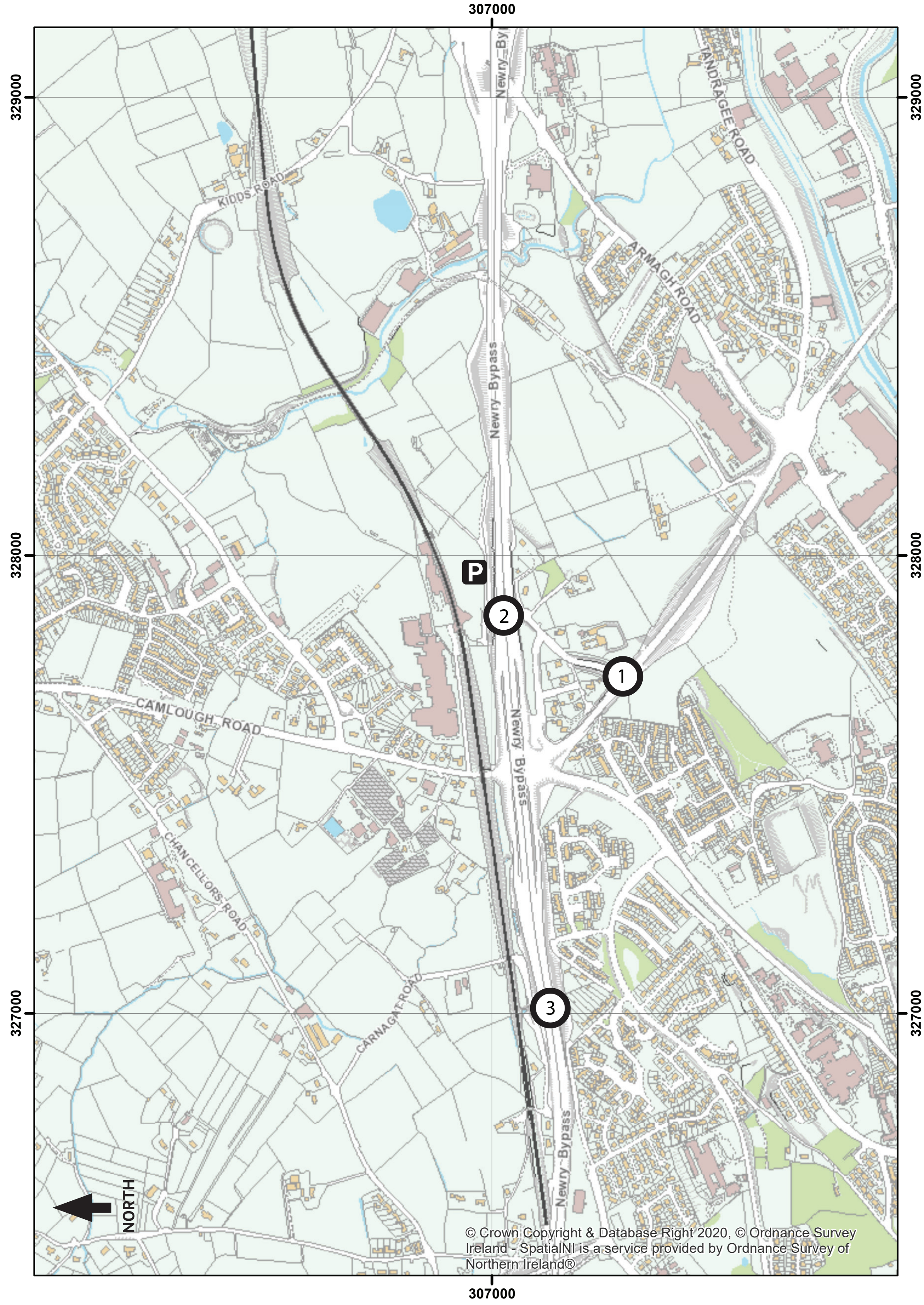
The majority of the rocks seen at Newry Railway Station are granodiorite (a type of igneous rock) that was intruded as part of the Newry Igneous Complex some 410 Ma. This formed when magma was produced as a result of heat generated when the Iapetus Ocean closed. Much later, during the Palaeogene period, crustal stretching and thinning associated with the opening of the North Atlantic Ocean produced yet more magma. In some cases it formed huge igneous complexes (such as the Ring of Gullion) but here at Newry it was squeezed in to pre-existing cracks within the granodiorite. It remained within the rock where it cooled and crystallised as vertical sheets of solid rock known as dykes.

Newry Railway Station

Teacher's Sheet

Visit Time: 1 Hour





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Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available at the Newry Train Station. There are toilets inside the station and a small number of vending machines.
1	**Railway Station access road** From the car park walk down the road on which you came in and stop to have a look at the rock cutting. This is a rock called granodiorite. It is a type of igneous rock that is similar to granite but it has a slightly different chemistry. The rock is pale grey in colour, has a medium- to coarse-grained texture and is made up of quartz, plagioclase feldspar and orthoclase feldspar. To be classed as a granodiorite, it needs to contain more plagioclase than orthoclase but this may be difficult to assess by students in the field. The granodiorite is part of the Newry Igneous Complex and is much older that the igneous rocks that make up the Cooley Peninsula, Ring of Gullion and the Mourne Mountains. The Newry Igneous Complex formed as a result of the closure of the Iapetus Ocean about 410 million years ago. The Iapetus Ocean separated the northern continent of Laurentia (made up from much of what is now North America, together with the north of Ireland and Scotland), from the southern continent of Avalonia (made up of what is now the south of Ireland, England and Wales). As the ocean shrank, the continents on either side came together and eventually collided. The granodiorite of the Newry Igneous Complex formed in association with this major earth movement and the heat generated produced huge volumes of magma, leading to the formation of a number of igneous complexes including the Newry Igneous Complex. The Newry Igneous Complex comprises a series of three overlapping plutons (the name given to a body of igneous rock that is crystallised from magma slowly cooling beneath the surface of the earth), that extend over an area of 45km^2, from Slieve Croob in County Down to Forkhill in south County Armagh. If you look closely you may see some xenoliths (from the Ancient Greek meaning ‘foreign rock’). These are seen as dark grey or black ‘blobs’ within the granodiorite and are a characteristic feature. A xenolith is a piece of rock trapped within another and it is formed as pieces of the original bedrock (usually Silurian age mudstones and sandstones in this case) were torn off as magma was emplaced.
2	**Bridge over the A1** Walk down to the bridge and look northwards on to the main A1 road. This road was completed in 2010 and is the main transport route between Belfast and Dublin. The majority of this section of the road cuts right through the very hard Newry granodiorite and in order to do this, a huge amount of blasting was needed. This process was made even more difficult by the proximity of nearby homes, sometimes as close as 25m to the required blast site. In addition, the proximity of the main Belfast to Dublin railway line, and the extremely busy Newry by-pass meant that this was a difficult task to carry out safely. Blasting took place over a 12 month period and in total 330,000m^3 of rock was blasted and removed at a cost of £1.4 million. Rock blasting is the controlled use of explosives to remove rock. A method known as pre-splitting was used to ensure a flat rock face was produced. This was necessary due to the roadside location as it leads to reduced slope failure and therefore reduced maintenance costs. This method involves blasting pre-split holes at close spacing. These are seen as thin vertical lines in the rock face and are visible at the railway station access road and all the way along the A1 road cutting. This technique performs particularly well in hard, competent rocks such as granodiorite.

3

Main A1 road cutting

The road cutting that can be found adjacent to the main A1 between Newry and Dundalk contains numerous examples of dykes that are much younger than the granodiorite of the Newry Igneous Complex. These dykes would have originated as fractures within the granodiorite. Sometime after, magma would have been intruded into these cracks before solidifying into a vertical layer of solid, igneous rock. These are usually composed of dolerite, or its fine-grained equivalent, basalt. Both of these have a very different chemistry to the granodiorite and are dark grey or black in colour. They also have much smaller crystals indicating that they cooled much quickly allowing less time for crystals to grow. Dykes are clearly visible as vertical or sub-vertical exposures of dark grey to black rock within the pale grey rock of the Newry granodiorite. Most of these formed during the Palaeogene period about 60 million years ago as a result of the stretching and thinning of the crust related to the opening of the North Atlantic Ocean. The associated heat generated huge amounts of magma beneath the surface, leading to the intrusion of the Cooley, Gullion and Mourne igneous centres. However, it also led to the formation of many small igneous intrusions such as the dykes seen along the A1.

The dykes quite often provide problems for the management of the road as they are rich in minerals and attract vegetation growth. This makes the cliff unstable in many locations. The best example of this as at the Cloghoge roundabout.

It is not safe to stop at any location on the A1 between Newry and Dundalk. If you are driving along this section of the road, for safety reasons, you should advise students of the presence of dykes and describe what they look like before setting off and let them observe the numerous easily recognizable dykes for themselves.

Cam Lough and Camlough Quarry

Student Sheet

1-1½ Hours

General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks/fossils or sand from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially when crossing the main road to access the quarry as there is no footpath. When visiting the quarry, make sure that you wear a hard hat at all times and that you do not enter the quarry past the concrete hut. Do not climb on any of the piles of loose boulders and do not go near any rock faces.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	**Camlough Quarry**: (a) Sketch the quarry and add the labels required. (b) Describe the two main rock types from the loose boulders at your feet. (c) Describe how the geology in the quarry has meant that it is particularly dangerous to access.	☐
3	From the amenity area at **Cam Lough:** (a) Sketch Cam Lough and the surrounding landscape and add the labels required. (b) Describe how ribbon lakes form.	☐

Name		**Location**	Cam Lough and Camlough Quarry

1a. List of risks/hazards:	**1b. How to reduce risks/hazards:**

2a. Sketch the quarry and add labels for:

- Granite (ring dyke)
- Silurian sedimentary rocks
- Granite / sedimentary contact

2b. Describe the two main rock types from the loose boulders at your feet:

2c. Describe how the geology in the quarry has meant that it is particularly dangerous to access:

3a. Sketch Cam Lough and the surrounding landscape and add labels for:

- Ribbon lake
- Direction of ice flow
- Ring dyke (two locations)
- Inferred location of fault

3b. Describe how ribbon lakes form:

MOURNE
GULLION
STRANGFORD
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Cam Lough and Camlough Quarry

Information Sheet

Location: Cam Lough, Camlough Quarry

GR: Cam Lough J 03701 24130, Camlough Quarry J 03570 24607

Lat/long: Cam Lough 54.155618, -6.412466, Camlough Quarry 54.159928, -6.414311

Education for employability:
- Tourism
- Quarrying

Relevance to spec:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv)
AS/A2: Geology/Geography Rocks, Global Tectonics, Climate Change

Rock types observed: granite, sandstone, mudstone, granodiorite

Geological structures: ring dyke, faults, fractures

Geomorphological features: ribbon lake

Site specific hazards:
- Traffic
- Loose rocks
- Quarry faces

Teaching & Learning issues:
- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear

Sketches to be drawn:
- Camlough Quarry
- Cam Lough and the surrounding landscape

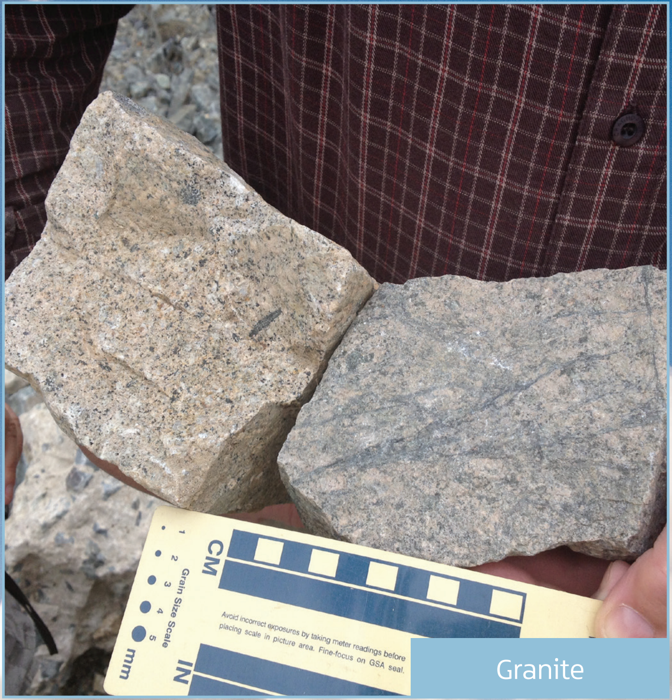
Equipment:
- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
N/A

Prior knowledge: igneous rocks and processes, plate tectonics, sedimentary rocks and processes, glacial processes and products

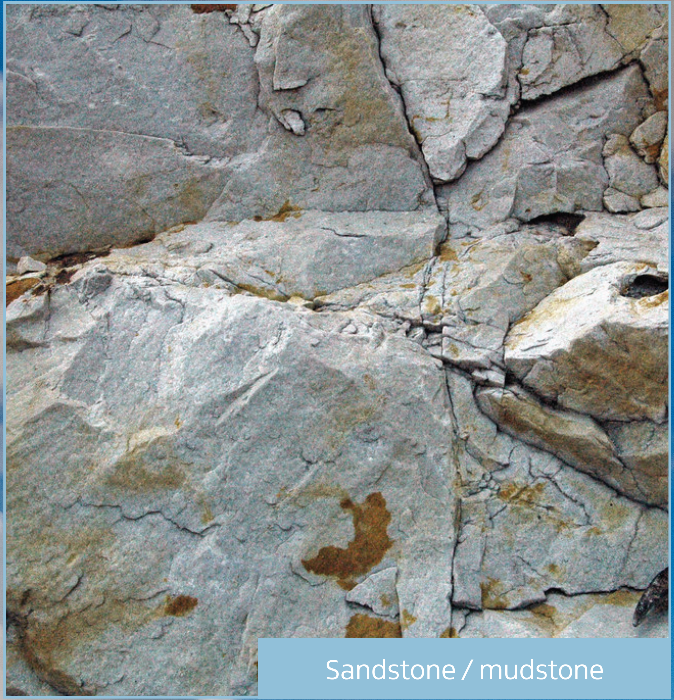
Keywords: bedding, bedding planes, competent rocks, cone sheets, dykes, flow banding, granite, granodiorite, hornfels, sandstone, igneous, faults, Silurian, Palaeogene, ring dyke, ribbon lake.

Format developed by the Western Education and Library Board's Magilligan Field Centre



Granite

Granodiorite



Sandstone / mudstone

Description of granite

- Medium to coarse grained
- Interlocking crystals
- Pinkish brown
- No fossils
- No reaction with HCl
- Dominated by quartz, plagioclase and orthoclase

Description of granodiorite

- Medium to coarse grained
- Interlocking crystals
- Medium grey
- No fossils
- No reaction with HCl
- Dominated by quartz, plagioclase and orthoclase (more plagioclase)

Description of sandstone / mudstone:

- Clastic rock
- Medium grained / fine grained
- Dark grey / pale grey or green
- No fossils
- No reaction with HCl
- Thin layers (laminations) (mudstone only)

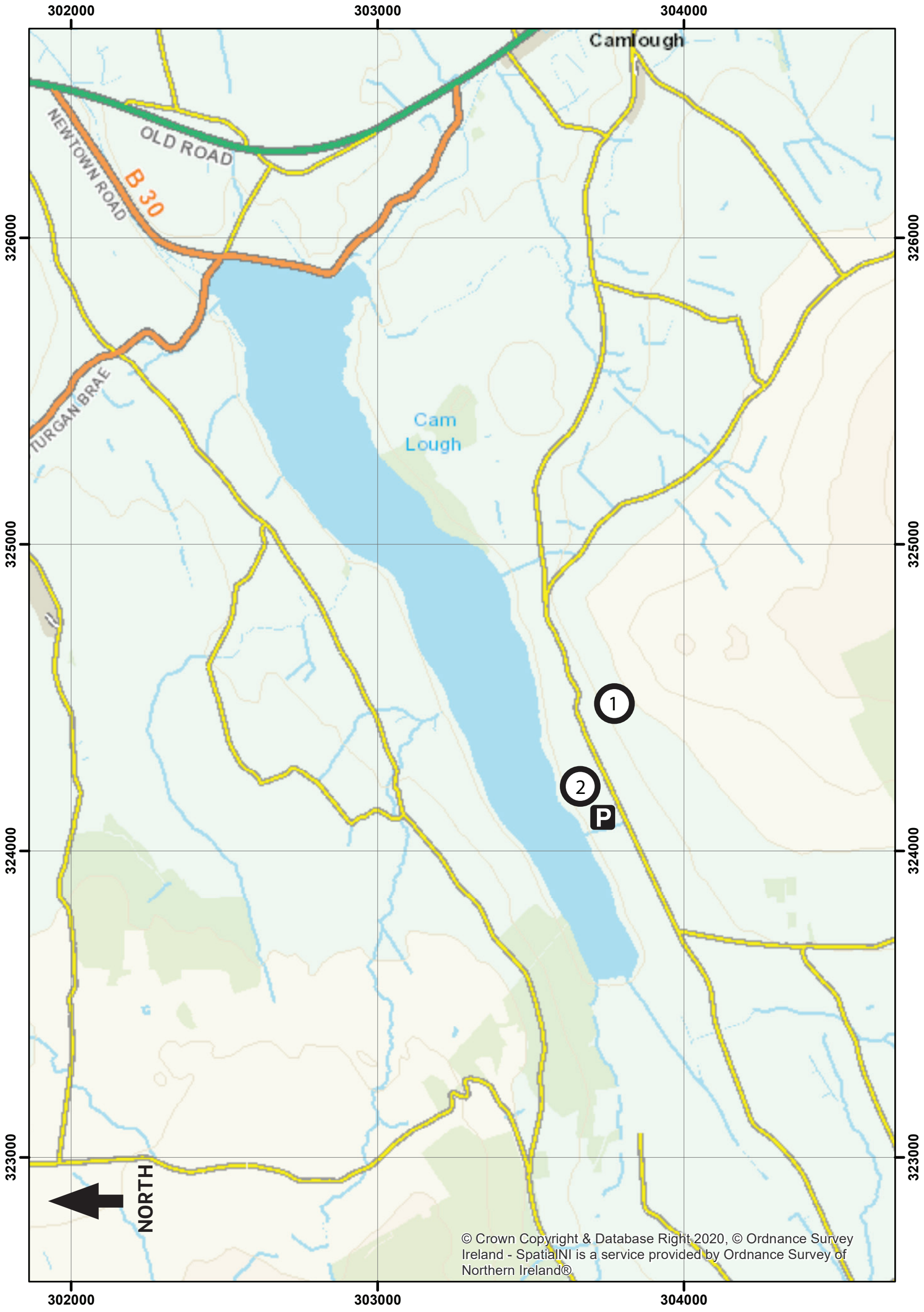
Geological history:

The oldest rocks at Cam Lough and Camlough Quarry were deposited as sands and muds during Silurian times (430 Ma). These were then intruded by granodiorite as part of the Newry Igneous Complex some 410 Ma, when magma formed as a result of heat generated when the Iapetus Ocean closed. During the Palaeogene period, this pre-existing weakness in the crust was exploited once more when crustal stretching and thinning led to the formation of more igneous rocks beneath the surface around 60 Ma. This led to the formation of the Ring of Gullion ring dyke when magma was squeezed through circular cracks surrounding a disappearing magma chamber. During Quaternary times, ice sheets moved across the valley carving out a deep narrow valley.

Cam Lough and Camlough Quarry

Teacher's Sheet

1-1½ Hours



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Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available at Cam Lough where there is a small amenity area with picnic tables. This is not suitable for coaches but it is possible to park at the entrance. From here you must walk the short distance to the quarry as there is no parking available.

Camlough Quarry

From the amenity area walk east for the short distance to the quarry. Extreme caution should be exercised whilst walking to the quarry as there is no footpath. Hard hats and high-vis jackets should be worn at all times and no one should enter the quarry past the concrete building at the entrance.

The back wall of the quarry shows a clear contrast between dark grey rocks at the base and lighter coloured pinkish-brown rocks at the top. The contact between the two can be seen dipping away into the mountain behind.

The paler rocks are part of the Slieve Gullion ring dyke that formed during the Palaeogene some 60 million years ago. This granite-type rock was intruded in to a circular fracture that surrounded the edges of a magma chamber deep within the earth. Fracturing occurred as the magma drained away and was no longer able to support the surrounding rocks, causing a line of cracks or fractures to develop all the way around the periphery of the chamber, some 11km in diameter. Magma was squeezed into these fractures where it remained below the ground for the most part and solidified as a ring-shaped intrusion known as a ring dyke. This feature is clearly expressed in the landscape as the Ring of Gullion, but only rarely do you get to see the granite-type rock that makes up the ring dyke itself.

The darker rocks are Silurian age sandstones and mudstones that formed on the bottom of deep ocean approximately 430 million years ago. The heat produced when the Newry granodiorite was intruded some 410 million years ago has altered the sandstone and mudstones to hornfels, a fine-grained, dark grey rock with exceptional hardness and smooth texture.

1 The Newry granodiorite formed as a result of heat generated by the closure of an ocean called Iapetus. The Iapetus Ocean separated the northern continent of Laurentia, made up from what is now North America together with the north of Ireland and Scotland, from the southern continent of Avalonia, made up of the south of Ireland, England and Wales. As the ocean shrank, the continents on either side came together and eventually collided. The granodiorite of the Newry Igneous Complex formed in association with his major earth movement, and the heat generated produced huge volumes of magma leading to the formation of a number of igneous complexes. In places, thin bands of granodiorite can be seen but should not be searched for if not readily visible. Granodiorite is a type of igneous rock that is similar to granite but it has a slightly different chemistry. The rock is pale grey in colour, has a medium- to coarse-grained texture and is made up of quartz, plagioclase feldspar and orthoclase feldspar. To be classed as a granodiorite, it needs to contain more plagioclase than orthoclase but this may be difficult to assess by students in the field.

The quarry is now inactive but in the past it was used for building stone. Due to the nature of the rocks found, the quarry face is exceptionally dangerous with a number of overhangs. The fractured nature of the granite-type rock means that there are many unstable cliff faces.

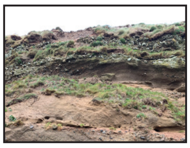
The Slieve Gullion complex was the subject of serious scientific debate over the mechanism for its formation. The many fractures in the granite at this location helped to prove the theory of the ring dyke.

2	**Cam Lough** Return along the road to Cam Lough. Once again, exercise extreme caution. Cam Lough or Camlough Lake is a good example of a ribbon lake. A glacier carved the valley during the last glaciation as it moved its way southwards towards Dundalk Bay. Glaciers work by plucking and abrading the surfaces that they come into contact with, and the gouging out of this valley is no exception. The particular length and narrowness of this valley was facilitated by the fact that a major fault zone can be found along its length, making the surrounding rocks weaker and more susceptible to erosion. Whilst movement along faults is not always visible, in this case it is expressed by the displacement by nearly 2km horizontally of the rocks that make up the ring dyke. At the quarry, the ring dyke makes up the higher ground. On the far side of the lake, the ring dyke makes up the small hills to the NW.

Ballyhornan Bay

Teacher's Sheet

Visit Time: 2-3 hours



General instructions to students:

1. Note the main risks at the site when you arrive.
2. Respect the geological code of conduct at all times, do not disturb wildlife, close gates, do not remove rocks from the site.
3. Before leaving the minibus, check that you have suitable clothing and footwear and the equipment to record your field observations:
   - ✔ Pencils
   - ✔ Clipboard
   - ✔ Task sheet
4. Stay close to the teacher in charge at all times. Always be aware of traffic, especially in the car park. Stay well away from the wave zone and take extra care when climbing on the rocks at the northern end of Ballyhornan Bay as they can be very slippery.
5. Try and complete your observations in as much detail as possible. Listen to the teacher as they explain what you are looking at and ask questions if you are unsure about any aspects of these sites.

Tasks to be completed:

Task	Description	Completed (tick)
1	(a) Examine the risks/hazards at this site and (b) Describe how they might be reduced.	☐
2	Along the beach **just north of Ballyhornan car park**: (a) Sketch a section of the cliff and annotate clearly any visible coastal erosion and associated coastal engineering measures. (b) Name one hard engineering measure and one soft engineering measure for coastal erosion management.	☐
3	On the small headland at the **northern end of Ballyhornan beach**: (a) Sketch tension gashes found within the Silurian bedrock. Clearly indicate the direction of stress. (b) Describe how tension gashes form. (c) Describe how glacial striations form and measure the direction of palaeoflow of the ice.	☐
4	At the cliffs in the **small bay just south of Killard Point**: (a) Draw a detailed field sketch or sedimentary log, clearly identifying the three main units and their main characteristics. (b) Briefly describe how each unit was deposited. (c) Describe the diamict in the cliff. (d) Identify as many clasts (pebbles) within the diamict as you can and identify where they are from. (e) Explain how the diamict formed. (f) What do the clasts tell you about the ice flow to this area. (g) Draw a detailed sketch of a dropstone. (h) Describe how dropstones form. (i) Write a short description of the glacial history of Ballyhornan Bay.	☐

Name		**Location**	Ballyhornan Bay

1a. List of risks/hazards:	**1b. How to reduce risks/hazards:**

2a. Sketch a section of the cliff and annotate clearly any visible coastal erosion and associated coastal engineering measures.

2b. Name one hard engineering measure and one soft engineering measure for coastal erosion management

3a. Sketch tension gashes found within the Silurian bedrock. Clearly indicate the direction of stress

3b. Describe how tension gashes form.

3c. Describe how glacial striations form and measure the direction of palaeoflow of the ice.

Direction of ice palaeoflow =

4a. There are three major units in the cliff face in front of you. Draw a detailed field sketch or sedimentary log, clearly identifying each unit and their main characteristics.

4b. Briefly describe how each unit was deposited.

Unit 1 – Base:

Unit 2 – Middle:

Unit 3 – Top:

4c. Describe the diamict in the cliff.	4d. Identify as many clasts (pebbles) within the diamict as you can and identify where they are from.

4e. Explain how the diamict formed.

4f. What do the clasts tell you about the ice flow to this area.

4g. Draw a detailed sketch of a dropstone. Include the following terms:

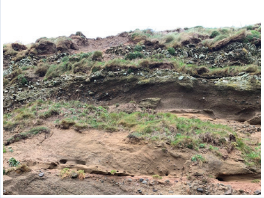
- Dropstone
- Clasts
- Depressed laminations (layers)
- Draped laminations (layers)
- Matric (mud/sand holding everything together)

4h. Describe how dropstones form.

4i. Write a short description of the glacial history of Ballyhornan Bay.

Ballyhornan Bay

Information Sheet



Location: Ballyhornan Car Park, Killard Point

GR: Ballyhornan Car Park J 59226 42012, Killard Point J 60138 43167

Lat/long: Ballyhornan Car Park 54.302166, -5.554403, Killard Point 54.312251, -5.539788

Education for employability:

- Tourism
- Coastal engineering

Relevance to spec:
Junior Cert: Geography The Earth's Surface
GCSE: Geography The Restless Earth
Leaving Cert: Geography Rock Cycle, Tectonic Cycle, Landform Development (i to iv), Human Interaction
AS/A2: Geology/Geography Rocks, Global Tectonics, Coastal Processes, Climate Change

Rock types observed: mudstone, sandstone, diamict

Geological structures: tension gashes, kink bands

Geomorphological features: glacial striations, dropstones

Coastal protection and engineering strategies: rip-rap, slope stabilization (tree-planting)

Site specific hazards:

- Traffic
- Loose rocks
- Tides
- Slippery rocks
- Wave zone
- Cliffs

Teaching & Learning issues:

- Consult weather forecast
- Outdoor learning qualification
- First aid kit
- Appropriate teacher / student ratio
- Clear instructions to be given to students
- Ensure students have appropriate clothing / footwear
- Tide tables
- Students not to stand close to cliff faces without appropriate PPE

Sketches to be drawn:

- Cliffs and coastal management measures
- Tension gashes
- Dropstone

Equipment:

- Camera
- Metre stick
- Hand lens

Personnel to be contacted prior to visit:
N/A

Prior knowledge: plate tectonics, glacial processes, sedimentary rocks and processes, coastal protection strategies

Keywords:
Beach, cliff, coastal erosion, rip-rap, climate change, sandstone, mudstone, plate tectonics, tension gashes, palaeoflow, deformation, kink bands, glacial striations, folding, moraine, diamict, clasts, dropstone, sub-glacial.

Format developed by the Western Education and Library Board's Magilligan Field Centre

Diamict

Description of diamict:

- Poorly-sorted (particles of all different sizes)
- Range of particle (clast) sizes from clay to cobble
- All held together by mud or fine sand

Tension gashes

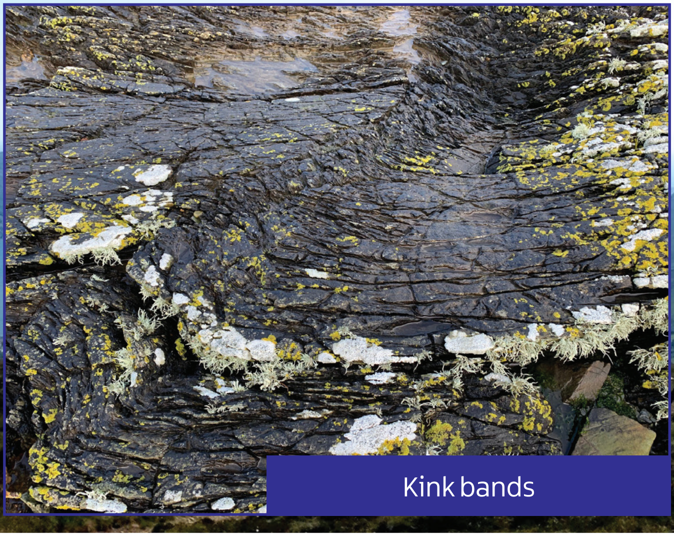
Description of tension gashes:

- S-shaped
- Parallel to each other
- Composed of white minerals (usually calcite or quartz)

Dropstone

Description of a dropstone:

- Large clast within layers of sediment
- Seems to depress underlying layers
- Layers above may appear to be ‘draped’ over the top



Kink bands

Description of kink bands:

- A type of fold
- Indicated by an abrupt change in the orientation of layers within a finely-layered rock

Geological history:

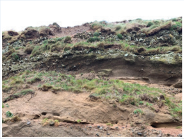
The bedrock at Ballyhornan is dominated by mudstones and sandstones deposited in a relatively deep sea during the Silurian period (445 to 440Ma). The Silurian rocks have been deformed due to the closure of the Iapetus Ocean and are now strongly folded and near vertical. The cliff exposures along this section of the coast record the events and processes between about 17,000 and 15,000 years ago during the closing stages of the last glaciation when a rapidly flowing ice sheet entered a tidal sea.

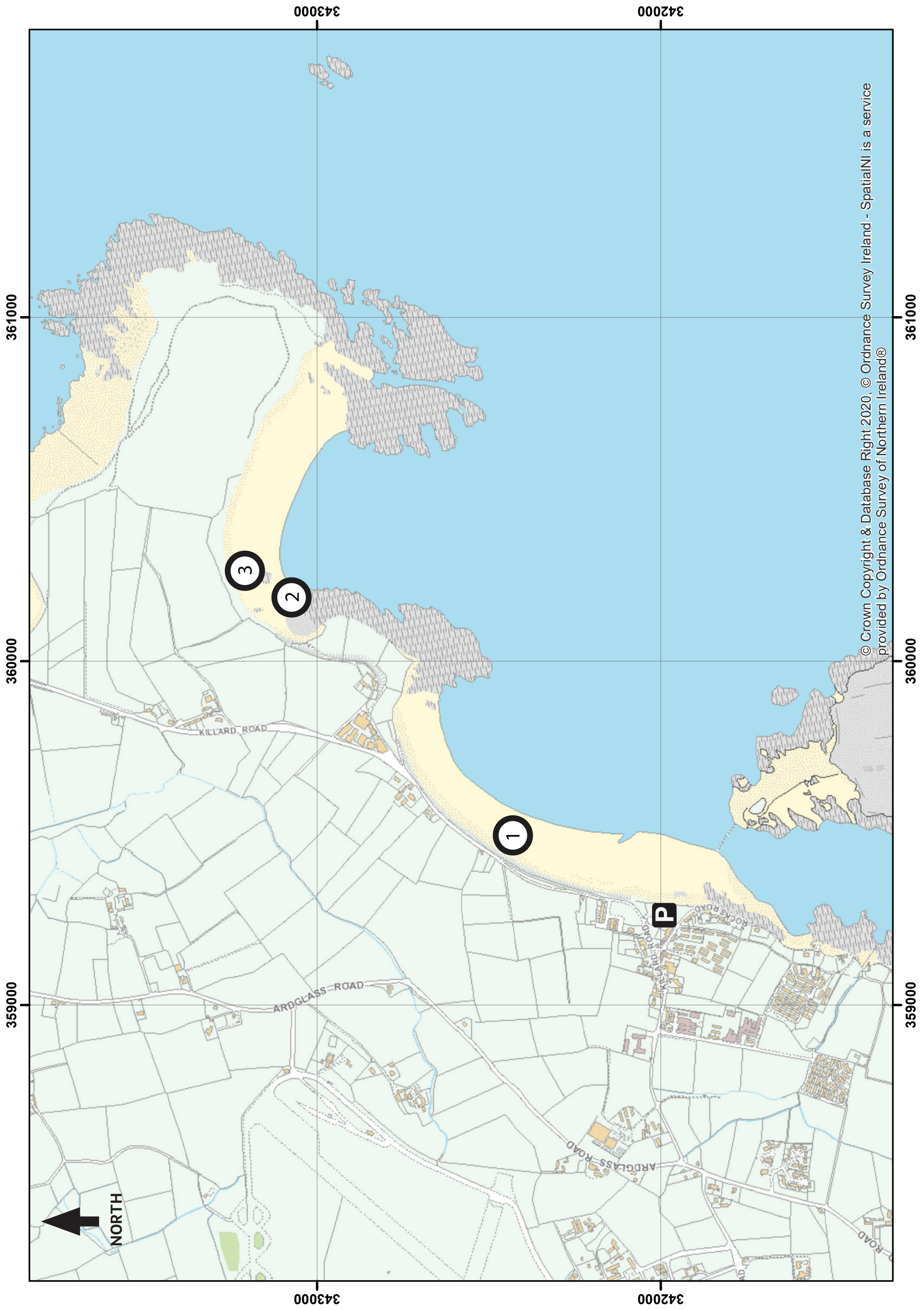
MOURNE GULLION STRANGFORD
Aspiring UNESCO Global Geopark

Ballyhornan Bay

Teacher's Sheet

Visit Time: 2-3 hours





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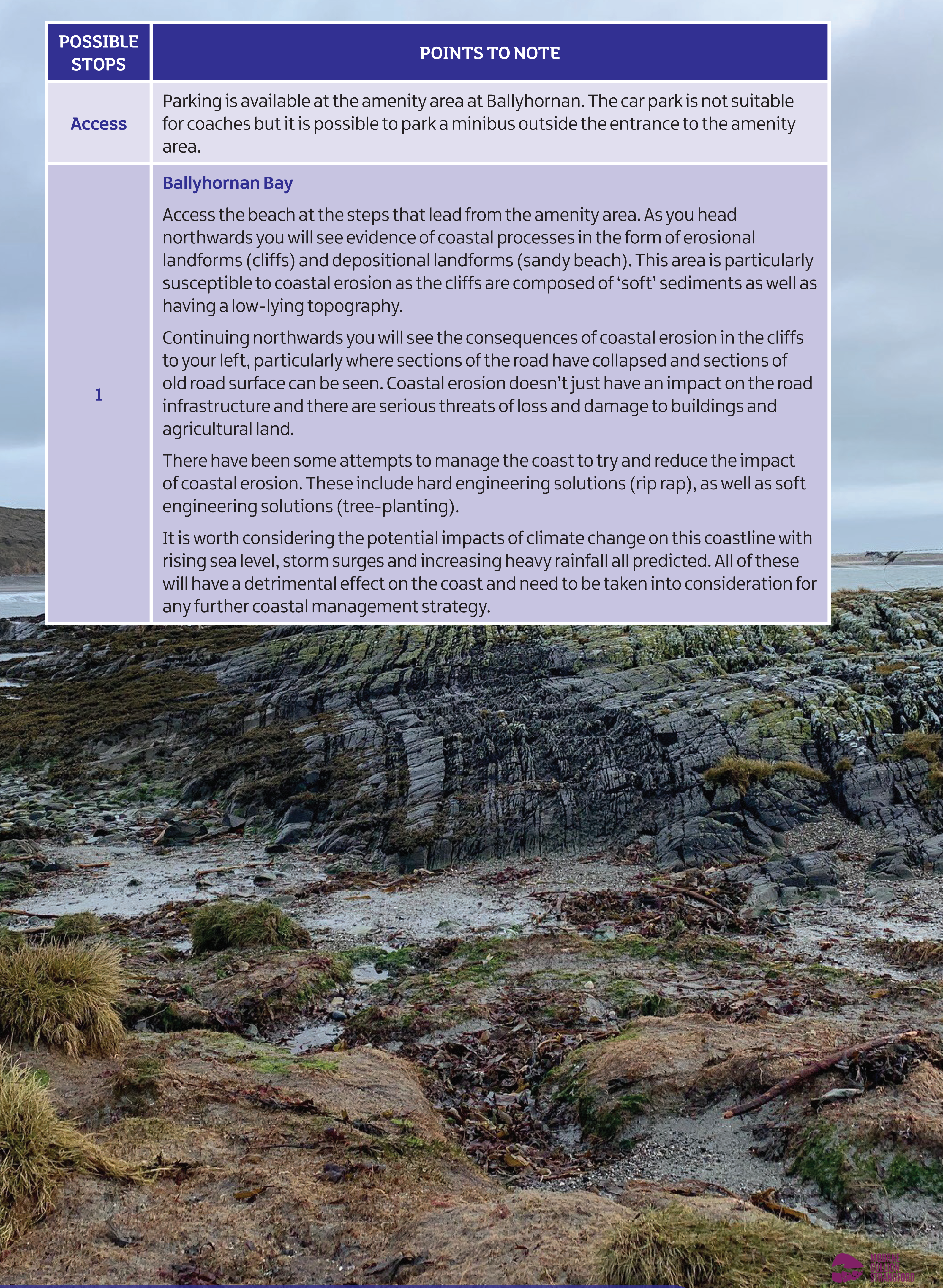
Location Map

POSSIBLE STOPS	POINTS TO NOTE
Access	Parking is available at the amenity area at Ballyhornan. The car park is not suitable for coaches but it is possible to park a minibus outside the entrance to the amenity area.
1	**Ballyhornan Bay** Access the beach at the steps that lead from the amenity area. As you head northwards you will see evidence of coastal processes in the form of erosional landforms (cliffs) and depositional landforms (sandy beach). This area is particularly susceptible to coastal erosion as the cliffs are composed of 'soft' sediments as well as having a low-lying topography. Continuing northwards you will see the consequences of coastal erosion in the cliffs to your left, particularly where sections of the road have collapsed and sections of old road surface can be seen. Coastal erosion doesn't just have an impact on the road infrastructure and there are serious threats of loss and damage to buildings and agricultural land. There have been some attempts to manage the coast to try and reduce the impact of coastal erosion. These include hard engineering solutions (rip rap), as well as soft engineering solutions (tree-planting). It is worth considering the potential impacts of climate change on this coastline with rising sea level, storm surges and increasing heavy rainfall all predicted. All of these will have a detrimental effect on the coast and need to be taken into consideration for any further coastal management strategy.



2

Ballyhornan Bay – North

Continue walking to the far end of the bay where you will see rock outcrops begin to appear. You can either walk over the rock outcrops to reach the northern section of this small headland or you can walk along the edge of the field which can be accessed by a make-shift path.

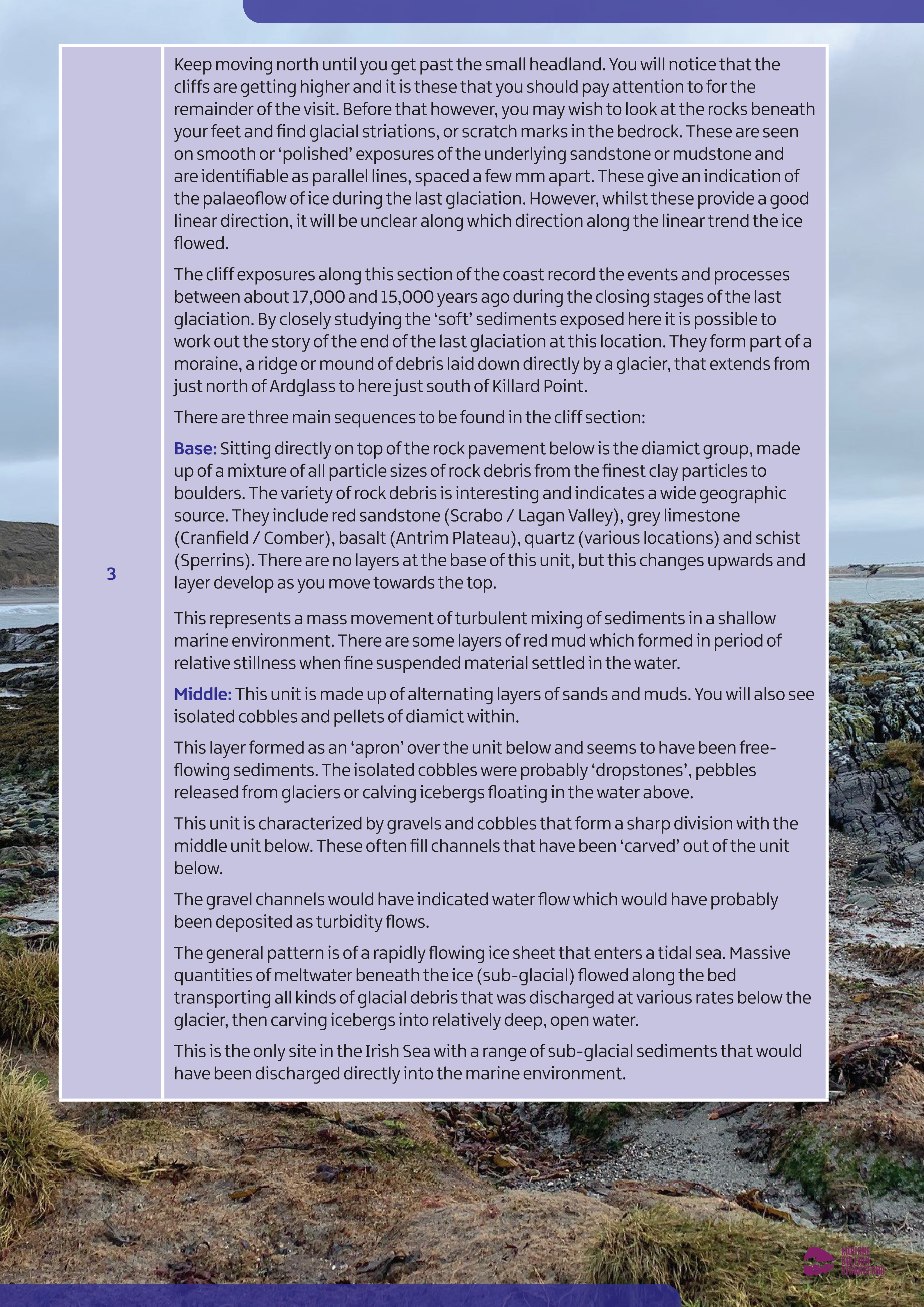
The coastline provides an excellent exposure of Silurian black/grey mudstone and dark grey sandstone. These are approximately 445 to 440 million years old and formed on the floor of an ancient ocean known as Iapetus. The sandstone layers were laid down by energetic, sediment rich flows known as turbidites. During quiet times, particles settled out of suspension forming layers of mud. Over millions of years, these layers of sand and mud were transformed into sandstone and mudstone.

When the sands and muds were deposited, they lay on top of an area of tectonic plate that was being subducted, or pushed down under another tectonic plate. As the plate moved beneath the other, the soft horizontal layers of sand and mud were scraped off the top and folded into the near vertical layers that you see here.

There are a number of other deformation features in the rocks that tell us that they have been affected by the movement of plate tectonic:

Tension gashes: At this location these are seen as parallel, sigmoidal-shaped features. They are easily recognisable as they are made up of white minerals set within the darker mudstone/sandstone. They form within rocks that have been subjected to brittle-ductile deformation which occurs in regions of about 15km depth. As the rock stretches, a 'gash' is formed creating an opening. This is then filled with moving superheated groundwater that contains minerals in solution (usually calcite or quartz). As deformation continues the gashes start to rotate giving them the characteristic sigmoidal or s-shaped appearance.

Kink bands: These structures are common in the deformation of rocks that are made up of many thin layers such as those found here. The kink band is recognized as being an angular fold that appears as a 'kink' in these layers, bound on either side by the parallel surfaces of the layers.



3	Keep moving north until you get past the small headland. You will notice that the cliffs are getting higher and it is these that you should pay attention to for the remainder of the visit. Before that however, you may wish to look at the rocks beneath your feet and find glacial striations, or scratch marks in the bedrock. These are seen on smooth or 'polished' exposures of the underlying sandstone or mudstone and are identifiable as parallel lines, spaced a few mm apart. These give an indication of the palaeoflow of ice during the last glaciation. However, whilst these provide a good linear direction, it will be unclear along which direction along the linear trend the ice flowed. The cliff exposures along this section of the coast record the events and processes between about 17,000 and 15,000 years ago during the closing stages of the last glaciation. By closely studying the 'soft' sediments exposed here it is possible to work out the story of the end of the last glaciation at this location. They form part of a moraine, a ridge or mound of debris laid down directly by a glacier, that extends from just north of Ardglass to here just south of Killard Point. There are three main sequences to be found in the cliff section: **Base:** Sitting directly on top of the rock pavement below is the diamict group, made up of a mixture of all particle sizes of rock debris from the finest clay particles to boulders. The variety of rock debris is interesting and indicates a wide geographic source. They include red sandstone (Scrabo / Lagan Valley), grey limestone (Cranfield / Comber), basalt (Antrim Plateau), quartz (various locations) and schist (Sperrins). There are no layers at the base of this unit, but this changes upwards and layer develop as you move towards the top. This represents a mass movement of turbulent mixing of sediments in a shallow marine environment. There are some layers of red mud which formed in period of relative stillness when fine suspended material settled in the water. **Middle:** This unit is made up of alternating layers of sands and muds. You will also see isolated cobbles and pellets of diamict within. This layer formed as an 'apron' over the unit below and seems to have been free-flowing sediments. The isolated cobbles were probably 'dropstones', pebbles released from glaciers or calving icebergs floating in the water above. This unit is characterized by gravels and cobbles that form a sharp division with the middle unit below. These often fill channels that have been 'carved' out of the unit below. The gravel channels would have indicated water flow which would have probably been deposited as turbidity flows. The general pattern is of a rapidly flowing ice sheet that enters a tidal sea. Massive quantities of meltwater beneath the ice (sub-glacial) flowed along the bed transporting all kinds of glacial debris that was discharged at various rates below the glacier, then carving icebergs into relatively deep, open water. This is the only site in the Irish Sea with a range of sub-glacial sediments that would have been discharged directly into the marine environment.