Beach Pebble Guide

Information and activities to help you explore Scotland's pebble beaches, geology and climate change

- Explore the variety of pebbles on Scotland's beaches
- Find out what these pebbles tell us about Scotland's geological story
- Learn about beach processes and the impact of climate change on the coast
- Try out some hands-on beach pebble activities next time you visit the beach

This guide was prepared for the Scottish Geology Festival 2021, organised by the Scottish Geology Trust

Beach pebbles at Auchmithie, Angus. Photo: Katie Strang

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Welcome

Scotland has amazing pebble beaches and amazing geology. We hope this guide will help you explore them.

We encourage everyone who visits Scotland's beaches – either as a visitor finding a beach for the first time, or as a local returning to your favourite spot – to pick up a pebble or two, enjoy the variety of pebbles on the beach, and explore what the pebbles tell us about Scotland's geological story. It is a remarkable story of change, of mountain ranges and coal swamps, of volcanoes and deserts, of minerals and crystals of incredible age, and of the recent shock of a series of ice sheets scraping across the land and seabed. Everywhere you look in Scotland, this geological history is written in the variety of rocks and the myriad ways in which geology provides the foundations of our landscape, settlements, history and culture.

Beaches are more than about the past, though: they also demonstrate the ongoing geological processes that shape Scotland. James Hutton, pioneer of modern geology, recognised this when he first identified the vast lengths of time and the ongoing cycles of erosion, deposition and uplift that shape landscapes. He proposed a *"succession of worlds is established in the system of nature"* – and that the past geological processes he identified in Scotland's rocks would continue into the future, with *"no vestige of a beginning, no prospect of an end"*.

In the current climate emergency, beaches are also a good place to contemplate the interactions between land and sea, between ocean and atmosphere, and to grasp how human activities are intersecting and interfering with natural processes. It is fairly well known that Scotland is still 'bouncing back' from the weight of the last great ice sheet. What is less well known is that global sea level rise, driven by warming and expanding seawater, now outpaces the rate of land rise and after thousands of years of retreat, the sea is coming in again on Scotland's coast. The climate emergency is not just in faraway places, it is happening now in our landscape and our beaches and will have profound effects on all aspects of life in Scotland in the coming decades.

James Hutton 1726-1797

Painting of James Hutton by Sir Henry Raeburn, Scottish National Portrait Gallery.

James Hutton was an Edinburgh polymath who played a key role in establishing the science of geology. He supported his 'Theory of the Earth' with observations at key coastal locations in Scotland, including north Arran and Siccar Point near Cockburnspath in the Scottish Borders.

"we never see a storm upon the coast, but we are informed of a hostile attack of the sea upon our country; attacks which must, in time, wear away the bulwarks of our soil, and sap the foundations of our dwellings."
Theory of the Earth, vol 1, 1795

How to use this guide

This guide is for parents, youth leaders, teachers and anyone who goes to beaches. It is not specifically written for children but we hope you will use the guide and the activities to help young people explore pebbles, beaches, geology and climate change.

Please share your adventures – follow us and share on social media, send us photos, and join the Scottish Geology Trust to support our work inspiring people everywhere to understand, love and care for Scotland's incredible geological heritage and its role in creating a sustainable future.

The general rule is to take nothing but pictures. However, the joy of a special pebble in your pocket is not to be under-estimated, and many people have pebbles at home that are a very strong connection to a place and a memory. Generally in Scotland it is not too much of a problem to remove a pebble from the beach, but please be respectful of any local rules and minimise your impact on the beach and the environment. Similarly, if you are making beach art or cairns, think about what you leave behind and how it will affect other visitors to the beach.

Finally, leave the beach in a better place than you found it. Take your litter home, and do what you can to clean up plastic and any other litter. Check out the Marine Conservation Society in Scotland for beach cleans and campaigns.

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Stay safe at the beach

Beaches can be dangerous places. Stay alert, keep an eye on everyone in your group and in an emergency at the coast, call 999 and ask for the coastguard. Here are some key hazards to look out for:

- Waves and tides. Watch out for large waves when you are near the water, and be aware of the tide: don't get cut off.
- Slips and trips. Beaches can be very slippery, especially below the high tide mark. Wear the right footwear and watch your step.
- Hammering or breaking rocks can cause flying rock splinters that could blind someone. Don't break rocks unless everyone is wearing eye protection.
- Rock fall and cliffs. Stay away from the top and foot of cliffs and steep slopes. Be careful especially in windy conditions.

What is a pebble?

Most people instinctively know what a pebble is, although it is hard to define exactly. It is a natural piece of rock, not a manufactured artefact such as concrete or a brick. It is often rounded, although it doesn't have to be completely smooth: what most people consider to be a pebble won't have too many sharp edges. And in size, technically a pebble is a clast between 4–64 mm in diameter in the Udden-Wentworth scale! A granule is smaller, and cobbles and boulders are bigger. In this guide, we take a more informal approach – a pebble fits in your hand, feels good to hold and gives you a window to the world.

> ***"A pebble is a smooth rock that fits neatly into the palm of your hand"***
>
> **Clive Mitchell, *The Pebble Spotter's Guide, 2021***

Most pebbles are local They have broken off from a nearby cliff or rock exposure, and then have been transported by rivers, sea currents, ice sheets or sometimes by people. Along the way, often the corners have been knocked off and the rock has become gradually more smooth and rounded. Although a pebble might not have travelled very far, it has probably spent a really long time becoming a pebble, gradually shaped by each movement of the waves over thousands of years. And if you leave it on the beach, it will still be here long after you've gone!

Not all pebbles are equal some rocks are *much* tougher than others, and when they are crashing around together on the beach, the tough ones survive. So the pebbles on the beach do no accurately reflect the variety of local geology. If you are in an area with lots of mudstone for example, you won't find many mudstone pebbles, because they break up easily.

Beach pebbles on the Shiant Isles, where there is one main rock type – dolerite. One exotic pebble of metamorphic rock has been transported from the mainland, probably by ice.

And not all pebbles are local It is one of the delights of Scotland's varied geology that while each area tends to have its characteristic pebble types, there is always geological variety nearby because this small country has an incredible mix of rock types. If the conditions are right, pebbles can be transported. You might find exotic pebbles from faraway have ended up on your beach. There are two big processes that help transport pebbles to new locations:

1. The Ice Age Many times during the last two million years, Scotland has been entirely covered by a thick ice cap. The last big one started to melt about 20,000 years ago. Each time the climate cools, ice builds up on the high ground, mainly in the Highlands, and slowly spreads outwards, heading downhill towards lower ground and the sea. Flowing ice is great at picking up rocks, moving them and shaping them. Scotland is covered in *erratic boulders* – rocks that don't match the local geology. These boulders were a puzzle for early geologists and eventually helped persuade people that Scotland had been covered in ice in the past. Erratics are always tough rocks – often igneous rocks like granite or dolerite.

Since ice flows downhill towards the sea, this is a good way of bringing new rocks to the coast. There is a contrast between Scotland's east and west coasts. Generally the ice has travelled shorter distances on the

west coast, because it builds up along the high ground of the watershed. This is closer to the west coast, and gradients are steeper. On the east coast, you've got more chance of finding pebbles from farther away – the Firth of Forth is a good example, where you often find small pieces of quartz or metamorphic rocks from the southern Highlands. Even more exotically, occasionally the east coast of Scotland has been inundated by ice from Scandinavia! The ice caps there were thicker and bigger, and sometimes extended all the way across the bed of the North Sea to lap onto Scotland's shores.

1000 million year old Torridonian sandstone pebbles, Stac Pollaidh Northwest Highlands Geopark

2. River power River transport of pebbles and sediment is one of the great surface geological processes. since it first rained on land, billions of years ago, water has flowed from land to sea, eroding and transporting fragments and depositing them on low ground and in the sea, to create new sedimentary rock.

To transport pebbles, slow and lazy rivers like today's Clyde and Forth are not quite enough! Even in flood conditions, they only move sand and mud downstream. But Highland rivers in spate are descending steeper gradients with faster flows, and can move pebbles and sometimes boulders. Today's rivers are generally following the same routes as the glaciers did, so it can be hard to tell if an individual pebble has been transported by ice or river water. But the mix of rocks along rivers like the Spey and the Dee is certainly partly to do with the rivers bringing a mix of pebbles downstream.

Not all pebbles are new! Scotland has some amazing rocks that contain old pebbles. Really old pebbles! Fast-flowing rivers form conglomerate, a type of sedimentary rock, containing rounded pebbles (called *clasts*) usually surrounded by smaller fragments that fill in the gaps. Conglomerates can form in the sea, but the main conglomerate layers in Scotland have formed on land, in mountain areas with steep slopes and fast-flowing water. The most famous conglomerates in Scotland are in the **Torridonian sandstone (1000 million years old)** in the north-west, and the **Old Red Sandstone (400 million years old)**, mainly in eastern mainland Scotland, Orkney and Shetland. These conglomerate layers contain clasts that were pebbles, rolling around in a river, hundreds of millions of years ago. Sediment accumulated on the river bed, and gradually cemented into rock, capturing the pebbles and burying them.

But these old rocks are now weathering at the surface and it is quite common to find pebbles that have been released from the rock and are free to be pebbles again! The conglomerate layers in the Old Red Sandstone are particularly varied, with a mix of tough pebbles of a wide range of metamorphic and igneous rocks. They sometimes include rare pebble types, such as jasper and agate. Sometimes these pebbles have cracks and veins through them, because the rocks were affected by tectonic forces after they were deposited. Good places to explore these old pebbles are on the beaches on the east coast of Scotland, in places like Arbroath, Auchmithie, Stonehaven and Dunbar.

Semi-precious pebbles like agates and jasper are found on some of Scotland's beaches like Dunure in the west and Lunan Bay in the east. These stones are both varieties of silica (quartz) that form in cavities or veins within rocks and exhibit a beautiful range of colours and patterns. They have been used in the manufacture of jewellery, known as "Scottish Pebble Jewellery", for more than two hundred years. At one time, during the 19th century, agates were so common on some beaches that they were nicknamed "Scotch Pebbles"!

Eroding Old Red Sandstone conglomerate releasing 400 million year old pebbles onto the beach, near Dunnottar Castle, Stonehaven

Pebbles of jasper (right) and agate (centre), Lunnan Bay, Angus.
Photo: Katie Strang

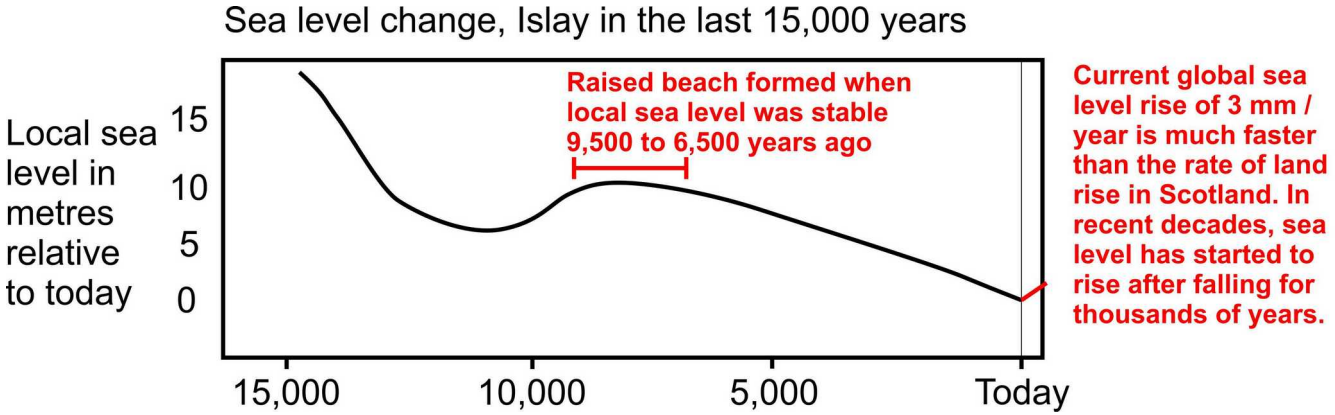
Cut and polished agate pebbles from Lunan Bay, Angus.
Photo: Katie Strang

Agate pebble from Lunan Bay, showing two different phases of silica infilling of a void. Photo: Katie Strang

Changing beaches

If you visit the same beach often, you will be aware that it changes all the time – the level of the sand in different places, the amount of seaweed and litter washed up, areas where you find the best pebbles. All these can change during the seasons and over years. There are lots of different factors affecting a beach: a combination of waves, wind, tides and currents; one big storm can sweep away or pile up sand and change the beach for years, although it will often gradually return to approximately how it was before.

Change also happens on longer time scales. Raised beaches are common around much of Scotland's coast, particularly on the mainland and less so on far-flung islands. These are places with a gently sloping shelf a few metres above today's high tide, with abandoned sea caves, stacks and pebbles. The most obvious raised beach in most places formed between 6,500 and 9,500 years ago, when the land surface was lower because the weight of the last ice sheet had pushed the land down. During this time period, the land gradually rose at about the same rate as sea level, so that land and sea remained at about the same relative position for a few thousand years. In the six thousand years since then, the land has continued to rise slowly while sea level has remained about the same – leaving the old beach high and dry.



Sea level change in the last 15,000 years on Islay, based on Rennie & Hansom Sea level trend reversal: Land uplift outpaced by sea level rise on Scotland's coast, *Geomorphology, 2011*

Buddo Rock, Fife - sea stack on the raised beach, which is used by the Fife Coastal Path.

However, in the last few decades, global sea level rise has eclipsed the rate of land rise around Scotland. Global sea level rise is caused by warming and thermal expansion of sea water, and melting of ice on land. The current rate is 3 mm per year, and is predicted to increase to 10-15 mm per year during this century.

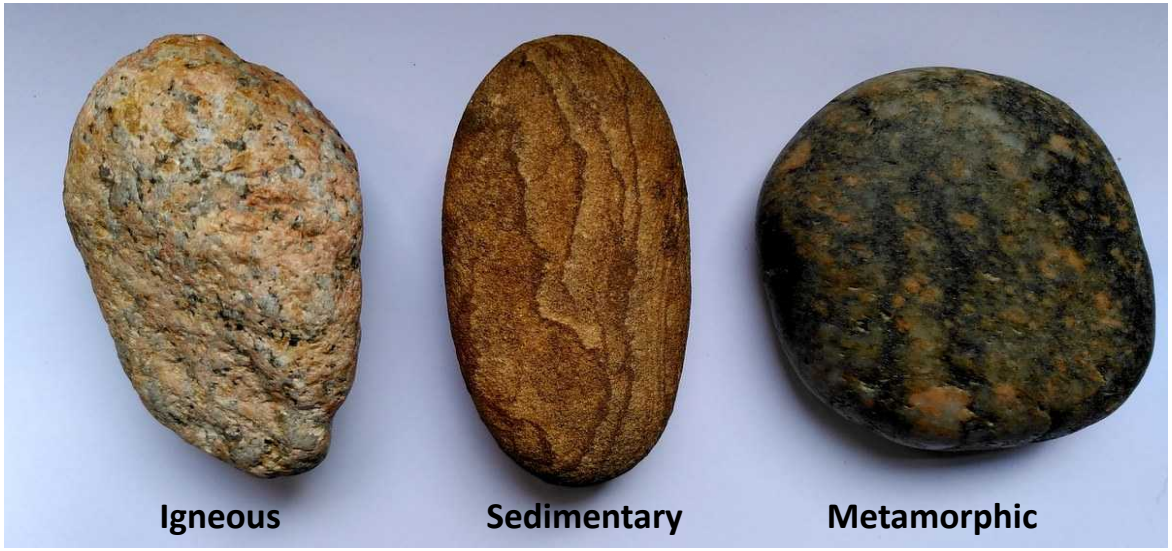
Scotland's beaches will change in the coming decades – not just because of sea level rise, but also because storms and flood events will probably become more common. The Dynamic Coast project (www.dynamiccoast.com) predicts more and faster coastal erosion, which will have an impact on important and valuable resources at the coast – including buildings, roads and railways and other infrastructure.

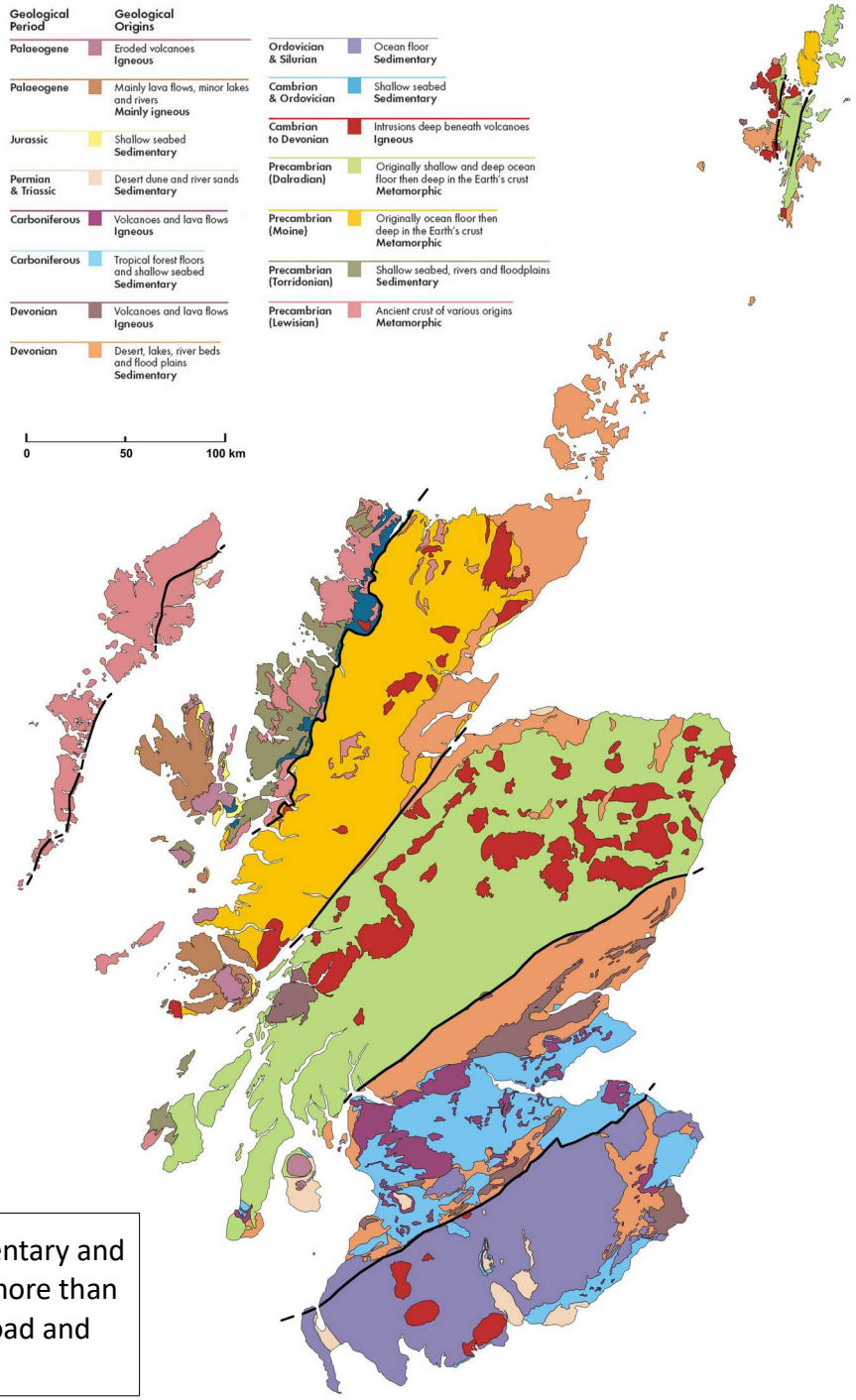
Scotland's geology – an introduction

Scotland's geology is the result of a series of major tectonic events over time. The Earth's continents are forever moving, splitting apart to make new ocean basins and colliding to form mountain ranges. Scotland has been caught up again and again in these processes of plate tectonics, resulting in a wide variety of rock types of different ages. This geological diversity is reflected in Scotland's scenery, in the way that the rocks have been sculpted over millions of years to give the Highlands and Lowlands, the firths and the islands, the glens, lochs and serrated mountain ridges. The final touches were largely provided by the ice sheets and glaciers that covered Scotland during the Ice Age of the last 2.6 million years, while river coastal and slope processes continue to shape the landscape today.

Read more of Scotland's geological story: www.scottishgeology.com/geo/getting-started

The characteristics of the three types of rock – igneous, sedimentary and metamorphic – have a big influence on the kinds of pebble you find on Scotland's beaches.





➲ This simplified **Geology of Scotland map** shows the overall distribution of igneous, sedimentary and metamorphic rocks of different ages, from the Precambrian era (with the oldest rocks being more than 2000 million years old) to the Palaeogene period (starts 66 million years ago). You can download and print your own copy for free from www.scottishgeology.com/geology-of-scotland-map

Pebbles from igneous rocks

Igneous rocks are created from cooling magma or lava. As the liquid cools, crystals form, and these crystals lock together to make a very strong fabric. So igneous rocks tend to be tough and resistant to erosion – indeed, igneous rocks are found at the summits of most of Scotland's highest mountains. And igneous rocks are often found as pebbles on Scotland's beaches. There is a lot of variation in igneous rocks that you can see in these pebbles:

Crystal size The longer that it takes to cool the magma or lava to form an igneous rock, the more time the crystals have to grow. *Coarse-grained* igneous rocks like gabbro or granite form when magma cools slowly. *Fine-grained* igneous rocks like basalt form when lava (or sometimes magma) cools quickly.

Chemistry Most igneous rocks are mainly composed of just a few elements – oxygen combined with silicon, iron, magnesium, calcium and aluminium. The chemistry of magma and lava varies a lot and this influences the types of crystal that can form and the eventual rock type. So granite has a high proportion of silicon and less iron and magnesium, whereas basalt and gabbro have less silicon and more of the rest. Higher silicon levels allow the formation of crystals of feldspar and quartz and so these rocks tend to be light coloured. More iron and magnesium minerals make the rock darker.

All igneous rocks have cracks in them, a lot of these cracks (called *joints*) form as the rock cools and contracts. The most spectacular and obvious of these joints form when basalt contracts as it cools – cracks form in the rock at 120° angles, creating *columnar jointing*. The joints in an igneous rock are its weakness and often control the shape of pebbles. Since igneous rocks don't normally have layering, igneous pebbles are not usually flattened.

Angular boulders of basalt from eroding columns, Isle of Staffa

A heart of stone! Granite pebble from Northmavine, Shetland

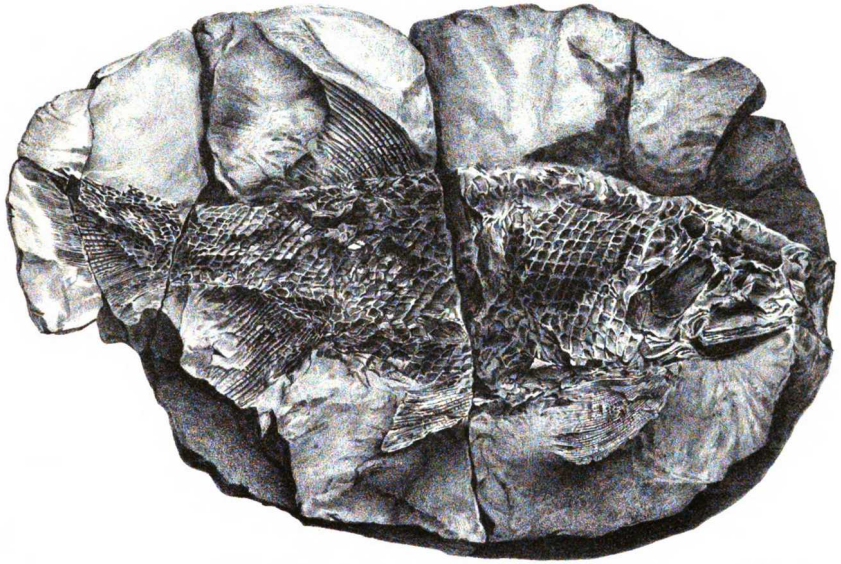
Pebbles from sedimentary rocks

Most of Scotland's sedimentary rocks are made of water-lain sediment, deposited in layers and gradually buried and cemented. The layering of sedimentary rocks is usually prominent and results in flat pebbles. The weak bonds between grains often means that sedimentary rocks are softer than other types, and more easily worn away.

Fossils are normally only found in sedimentary rock, and Scotland's sedimentary pebbles contain many examples of the different lifeforms which lived here in the past. Some fossils are found in nodules; these hard concretions formed around the animal after it died, preserving it.

Limestone is one common pebble type containing fossils, usually the remains of ancient marine organisms like crinoids and corals. These animals tend to live in equatorial latitudes, similar to modern corals; the limestone pebbles you find are evidence that Scotland once lay close to the Equator and some areas were covered by warm shallow seas.

Limestone with crinoid pieces, Fife



Drawing by Phoebe Traquair of the fish *Elonicthys Robinsoni* found in an ironstone nodule at Wardie beach, Edinburgh

Not all sedimentary rocks are soft. The greywacke sandstone of the Southern Uplands breaks up to form tough, rounded pebbles.

Pebbles from metamorphic rocks

Metamorphic rocks are very common in the Highlands of Scotland, where they have formed when existing rocks got buried and heated, causing chemical reorganisation to form new minerals. Much of this metamorphic activity took place in the *Caledonian Orogeny*, between 500 and 400 million years ago, when continents were coming together as the Iapetus Ocean closed. At that time, a lot of sedimentary rocks that had formed under the sea got buried and compressed.

Metamorphic rocks tend to be pretty hard, but most importantly they generally have a fabric caused by lining up of crystals, called a *foliation* or *cleavage*. If the original rock was sedimentary, the sedimentary layering may still be obvious in the rock, but the shape of pebbles is more likely to be controlled by the metamorphic fabric.

One important metamorphic rock, the Lewisian Gneiss, is found in the Outer Hebrides and the North West Highlands. This is an exceptionally tough rock, that will gradually wear down to rounded boulders and pebbles. Overall this rock tends to be so hard that any metamorphic fabric tends not to influence the shape of pebbles. Metamorphic quartzite, and vein quartz which is common in metamorphic rocks, is also a very tough rock usually without layering: commonly making very hard, rounded beach pebbles that are white or glassy.

In contrast schist, a common metamorphic rock in the rest of the Highlands, often forms flattened pebbles because of its metamorphic fabric. Slate isn't quite as common in the Highlands, but exhibits this feature even more dramatically.

Flattened pebbles of schist, Loch nan Uamh, Lochaber Geopark. Note the deformed layering and quartz veins in the large pebble, centre of image.

Slate bedrock and quarry waste getting a pounding from a storm on the west coast of Luing, Argyll. The resulting pebbles are great for skimming!

Hands-on Activities to try on Scotland's beaches

Activity: Which one's mine?

This is a simple activity that helps people of all ages appreciate the variety of pebbles on the beach, and the shapes and textures of rocks. It can be done by one person, or any size of group, and can take just a couple of minutes or be a longer activity with several rounds. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: Identify your pebble from a selection, while blindfold

Preparation

Everyone finds a pebble they like the feel of, and gets to know the size, shape and texture of their pebble.

All participants are blindfold or close their eyes; get groups arranged in a circle so that they can easily and safely pass pebbles around.

For small groups or individuals, put the chosen pebbles in a pile and invite participants to find the pebble by touch. Or give them a selection of pebbles one at a time.

What to do

Pass pebbles around between participants, giving everyone time to carefully feel each pebble, think about its size, shape and texture, and decide if it is their pebble.

When a participant thinks they have found their own pebble they can look to check, and drop out of the group so that the activity can continue until everyone finds their pebble.

Notes

In a large group, make sure nobody is using a favourite pebble that they don't want to lose – they might not get it back at the end.

You might need to specify a maximum size – e.g. no bigger than your fist. Make sure pebbles can be passed around safely.

If you don't have blindfolds, you can get participants to turn their jackets around and use the hood. Or face out of the circle and pass pebbles around behind your backs.

Consider safety – any sharp edges? is there a risk of a pebble being dropped or thrown and injuring someone? Might be safer for everyone to kneel or sit.

Encourage going slowly – explore contrasting shapes and think about the variety. Participants can be encouraged to describe the pebble they are holding and compare it to their pebble. Can they guess what colour it is? What one thing tells them it is not their pebble.

In a group, everyone will get their pebble back at the same time – all they need to do is count the number of people in the group! However, you can repeat the activity with the leader replacing pebbles with others from the beach, changing the order, and you can change the direction pebbles are being passed, etc.

Activities in this section:

Activity: Sorting Pebbles I – how many types

This is a simple activity that can expand and lead into other activities. It helps people of all ages appreciate the variety of pebbles on the beach, to encourage exploration of where pebbles come from and the factors that control the variety of pebbles found.

This activity can be done by one person, or any size of group, and can take just a couple of minutes or be a longer activity, even gathering materials to use in other activities. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: Build piles of similar pebbles, find out how many different pebble types are on the beach, and their relative proportions

Preparation

Very little preparation is required. You might want to set out locations to gather pebbles - mark circles on sand, or lay out e.g. sit mats or pieces of cardboard. Or you can just let the piles develop and rearrange and reposition as you go.

You could provide a sheet of examples and challenge people to find one of each – see the excellent example from Stonehaven on the next page.

What to do

Invite participants to start gathering different kinds of pebble, and build piles of pebbles that are similar.

After a while, stop and inspect the piles. Does everyone agree – discuss why not! What is a pebble – have you found things that definitely aren't pebbles: shells, seaweed, human-made objects, litter?

What determines 'similar'? Is it colour, shape, size? Can you see 'bits' in the pebbles – these might be crystals, or pieces of older rock, or inclusions that formed later.

Notes

Consider safety – any sharp edges? is there a risk of a pebble being dropped or thrown and injuring someone?

A geologist can really help at this stage! But you do a lot without geological knowledge, based on close examination. A hand lens (magnifying glass) can be useful.

Generally, colour is not the best guide to pebble type – the same rock can be different colours, usually due to later alteration. There might be an altered crust that is present on some pebbles but not others. Focussing on any visible 'bits' can really help.

Continue sorting the piles – you might decide to split a pile into two, or combine similar piles.

Look for rarities that don't fit in any pile. Can anyone find another one that is the same?

Review: How many types of pebble are on the beach? Do your piles properly reflect the distribution of pebbles on the beach? Has the most common type of pebble made the biggest pile? Are there some types you haven't collected so many of because they are boring, or too big to move?

What do the pebbles on this beach tell you about local geology? Are all the pebbles from here? Did you find anything that doesn't belong?

Example: Pebbles on the beach at Stonehaven

Prepared by Peter Craig, from *Stonehaven Beach Guide* produced for the Stonehaven Tollbooth Museum. Although every area has different pebbles, you will find a similar mix across much of the Highlands, particularly on the east coast.

A Granite 	B Crawton Lava 	C Porphyry 	D Sandstone 
E Veined Rock 	F Jasper 	G Schist 	H Crinkled Schist 
I Metagreywacke 	J Gneiss 	K Quartzite 	L Banded Quartzite 

Activity: Sorting Pebbles II – size & shape

This is a simple activity that can be stand-alone, or follow on from *Sorting Pebbles I*. It encourages people of all ages to explore pebble size and shape in a creative way, and start to think about why pebbles are the shape they are.

This activity can be done by one person, or any size of group, and can take just a couple of minutes or (much) longer. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: Get creative with sorting and displaying pebbles according to size and shape

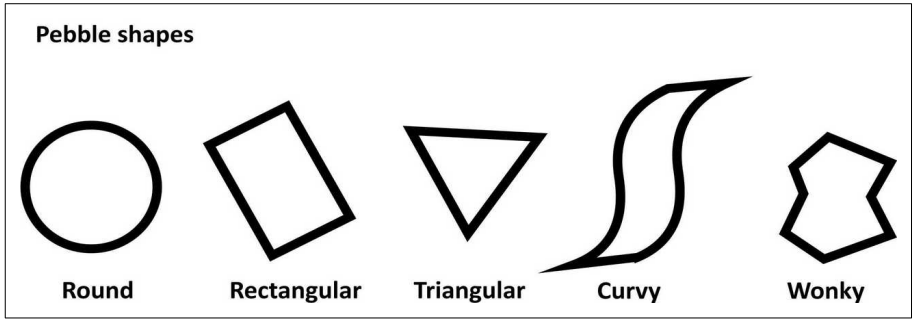
Preparation

Very little preparation is required. All you need is pebbles and space. If there is a sandy or grassy area nearby, you can arrange pebbles there. Or lay out a piece of fabric or cardboard.

What to do

1. Form a pebble snake. Arrange pebbles in size order with the largest pebble making the head. Does it look better if all the pebbles are round? The same colour? If different colours are available, can you have a colour gradation along the snake's body?

2. Classifying by shape. Draw simple areas on the sand , or lay out the boundaries using string or sticks. Find pebbles of each shape and place them in the right area. How well does shape relate to the pebble piles you made in *Sorting Pebbles I*?



3. Geological beach art. Arrange pebbles to make a shape, like an ammonite or a dinosaur, a volcano or a mountain range. Of course, the beach art should really use appropriate geological material – sedimentary rocks for fossils, igneous rocks for volcanoes, metamorphic rocks for mountains. Can you make a rainbow with the colours of the pebbles on the beach?

4. Sandwiches. Can you find pebbles that have different layers, maybe a sandwich with a different layer in the middle? Or make your own sandwich out of flat stones of different types or colour.

5. Scavenger Hunt. Good opportunity to find different colours, shapes or types of pebble and also think about what pebbles are and aren't, by comparing with other natural and human-made objects.

A sandwich stone from Loch Lomond; in this case the 'filling' is a vein of later material that has formed in a crack.

Activity: Every Pebble tells a Story

This is an activity with no bounds, that encourages people of all ages to get creative in thinking about the past, present and future of every pebble, and to explore Scotland's geological story.

This activity can be done by one person, or any size of group, and can take just a couple of minutes or (much) longer. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: Find a favourite pebble, give it a name, and tell its story

Preparation

Very little preparation is required. All you need is pebbles and space. As the activity develops, you might draw / write / record and share the story.

What to do

Pick a pebble. Hold it in your hand and think about its story.

Give your pebble a name. You might be able to find out the 'proper' name for this type of rock – sandstone, basalt, granite, slate etc. Or give it a name you like, or a name that tells you something about its colour, texture, etc.

Try to get beyond the name and the geological classification of your rock, and think about its story – how it has formed, what it tells us about the geological past, how it got here.

You can be fantastical and develop a rich story of dragons and heroes and faraway lands. But with the help of a geologist, you can tell the even more remarkable and unbelievable, but fundamentally *true* story of the faraway lands where this rock was made!

Where has this rock come from? What was the world like when this rock formed? What evidence can you see in your rock of how it formed – was it deep underground or at the surface, did it form slowly or quickly, can it tell you anything about the plants and animals that were alive at the time?

What has happened to this rock since it formed. How has it come to be a pebble on this beach. What will happen to this pebble next?

Notes

"What's this rock called?" Geologists get asked this all the time, it seems to be a human need to name and classify the world. Naming rocks is hard – the same rock type can look very different depending on age, location and alteration, and some very different rock types look very similar to each other. It is not uncommon for geologists to disagree as to whether a particular rock is igneous or sedimentary, for instance!

There are plenty of resources to help you find out the name of a particular rock, or the types of rock found in your area; but no system that will guide you to the right classification all the time.

Most, but not all, of Scotland's rocks formed in the southern hemisphere. Until 330 million years ago the continental crust we now call Scotland was located south of the Equator, moving a few centimetres every year due to plate tectonic activity. Scotland's rocks preserve different parts of this story – there are metamorphic rocks formed deep underground, igneous rocks formed in volcanoes, and sedimentary rocks with fossils.

Activity: Every Pebble tells a Story (continued)

How old is this pebble? There are two different stories here – when was the original rock made, and when did it become a pebble? In fact, there may be more than two stories, for many of Scotland's rocks, especially metamorphic rocks, have complicated histories with formation of the original rock, later changed to a different rock.

A single pebble may have a story with many chapters, involving the original formation of the rock, later changes (often happening deep underground). Then the land gradually eroded away so that the rock is brought to the surface again and broken up – with one of these pieces eventually becoming your pebble.

Activity: Rock stacking and skimming

This is a simple activity that can be stand-alone, or follow on from *Sorting Pebbles I* and *II*. It encourages people of all ages to explore pebble size and shape in a creative way, and start to think about why pebbles are the shape they are.

This activity can be done by one person, or any size of group, and can take just a couple of minutes or longer. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: What shapes stack and skim well? What makes a pebble a particular shape?

Preparation

Very little preparation is required. All you need is pebbles and space. But consider safety, don't leave pebble stacks unattended and give plenty of space to skimmers.

What to do

Stone Stacking Use pebbles you've already collected, or collect new ones and experiment with stone stacking.

Look for inspiration from The European Stone Stacking Championships, held annually in Dunbar http://stonestacking.co.uk/. The website makes interesting points about the process, and the mental and physical health benefits.

Stone stacking is not as easy as it looks. Flat stones are much easier to stack than angular ones.

Notes

There is potential for serious injury from a falling stone stack. As part of an organised activity, you may consider particular rules – no higher than waist height, or set an exclusion zone around each stack (1.5 x height of stack).

Drystane dyke building using pebbles can be a safer alternative.

Leave no trace. Stone stacks below the high tide mark will probably disappear quite quickly, but stacks above high tide may last for a while. Apart from the hazard to small children, many people mind about the visual intrusion of stacks, especially on wild beaches. If you are building stacks as part of an organised activity, ask participants to take responsibility for what they leave behind – take pictures and leave no trace.

Activity: Rock stacking and skimming (continued)

Drystane Dykes Can you see any stone walls near the beach? Are they made of the same type of stone that you can see on the beach? Some dykes are made with a variety of stones gathered from nearby, but the stone is more likely to have come from a quarry and may not match the stone in the immediate area.

Build a section of drystane dyke using the pebbles on the beach. Experiment with different types of pebble, different sizes and different techniques. Check out the Dry Stone Walling Association https://www.dswa.org.uk/ for inspiration.

Stone Skimming Anyone who's tried skimming knows that flat pebbles make the best skimmers. And it helps if they are not completely uniform and round, too – so that you get a good grip and give the stone a fast spin as it leaves your finger. Experiment with the different types of pebble on the beach. Is this a good beach for skimming? The world record distance is over 120 metres, and a throw with 88 skips has been recorded. The World Stone Skimming Championships (https://www.stoneskimming.com/) is held every year in Easdale, an island near Oban entirely made of slate. Previously the island was a centre for slate quarrying, and the natural sea-worn pebbles of slate make great skimmers.

Why are the European Stone Stacking Championships and the World Stone Skimming Championships both held in Scotland? Because of wonderful geology, of course! Most of Scotland's pebble beaches have an amazing mix of different kinds of rocks because the local geology is so varied. So on any beach you are likely to find a variety of pebbles of different shapes, that might be of use to people for different purposes (see *Pebbles used by People*).

Flat pebbles are usually made of layered rocks. Look at the side of a flat pebble – can you see faint lines parallel to the flat surfaces? Geologists love layers, because they can instantly tell us something important about how the rock was formed.

Sedimentary rocks usually have layers – because they have formed by sediment gradually accumulating in flat beds, usually under water (on the sea floor or in a swamp or a river for instance). If there are cliffs around the beach, have a look and see if you can see regular layers in the rock – the layers may not be flat or horizontal any more, but if you can pick out regular straight lines in the rock it may be sedimentary. The junctions between layers are usually weak and allow the rock to be broken into flat slabs (can you see any lying at the foot of the cliff?). As these slabs gradually break up, they tend to make flat rocks and pebbles.

Metamorphic rocks often have layers too. Sometimes this is because the original rock was sedimentary, and although the rock has been changed to make a metamorphic rock, the layers are still there. But often the layering, called *fabric* or *foliation* in metamorphic rocks, is due to the alignment of new crystals that have formed in the rock as it has changed under heat and pressure. Slate is a great example of this – the slatiness, or *cleavage*, of slate is due to the alignment of tiny crystals of mica or chlorite, and is nothing to do with the bedding of the mudstone that was changed into slate.

Activity: Pebbles used by People

This is a simple stand-alone activity, that encourages people of all ages to think about how people have used rock in the past, and continue to do so today. It works best if this activity follows on from *Rock stacking and skimming* and explores other uses of stone beyond building.

This activity can be done by one person, or any size of group, and can be a short exploration or discussion or develop into a longer activity. If you have a selection of pebbles available, this activity could be done at home, in the classroom, playground etc.

Aim: Think about how the different pebbles on the beach could be used by people, and where important resources come from

What to do

Leading Questions	**Some Answers**
What do people use rocks for? Think about the 'stone age' but also what we use rocks for today.	Just about everything! If it hasn't grown (food, wood, leather etc) it has come from rock, and a geologist has helped find it. People use rocks for building (see *Rock stacking and skimming*), for cement, as a source of metal, oil and gas, plastic, jewellery, paints.
Could you build a house with the rock on this beach?	Layered rocks stack well – but if you don't have layered rocks, are the rocks here hard enough to shape into blocks to make good building stone (e.g. granite)? Or are they too wonky, or will they spilt and shatter if you tried to carve them?
Pick up a pebble. What could you use this for? Is it good for stacking? If not, what might we use angular pebbles for? Or round pebbles?	Think about the shape and hardness. Good for stacking? For roads and paths, we tend to use hard, angular stones (aggregate) that lock together for strength and don't create a slippery surface.
What happens when you scratch two different pebbles together? Can you make fire?! Try and find the hardest and the softest pebble on the beach. Can you find a pebble that you could use to chop wood? Can you find a pebble that you can write with?	Sparks are unlikely. But you might find a pebble that can mark other pebbles. It is scratching the other pebble, or is it rubbing off on the other pebble.
Do any of the pebbles on the beach contain metal? How would you get the metal out of the rock? Would it be worth mining these rocks for metal – if not, where would you go to find better rocks?	Yes, every pebble on the beach will contain some metal (iron, magnesium, aluminium, calcium) sometimes only in very small amounts. Almost every pebble also has silicon, a very common metalloid.
What metals do we need for phones, computers and batteries?	Lots – and very few of them are mined in Scotland.

Examples: Pebbles used by People

Granite drystane dyke, Mull

Old Red Sandstone flagstones used for walls and roofs, Caithness

Tough igneous rocks used as roadstone in Edinburgh

Lime kiln in a flooded limestone quarry, Fife

Activity: Make a Map

This works best as a group activity, and it can start simple and expand into a work of art. It sets the pebbles on the beach in their geological context – explaining where most of the pebbles on the beach come from, and invites further discussion about the geology of Scotland and the variable survival of hard and soft rocks on the beach.

You could do a simple version of this activity at home or school, but it is more satisfying on the beach.

Activity: Make a geological map of the local area from pebbles and other beach materials

Preparation

Sketch out an outline map of the local area on a patch of sand, or lay out string or fabric. A tourist map of the area might help. Start with a small area and leave space around to expand if you want. The area you choose will depend on the local geology; rather than making a map of Iona, for example, you might want to map out the local islands.

Set out a few pebbles to illustrate key features – in the Edinburgh example on the right, we've drawn the coastline, and marked the position of Arthur's Seat and Castle Rock with igneous rocks.

What to do

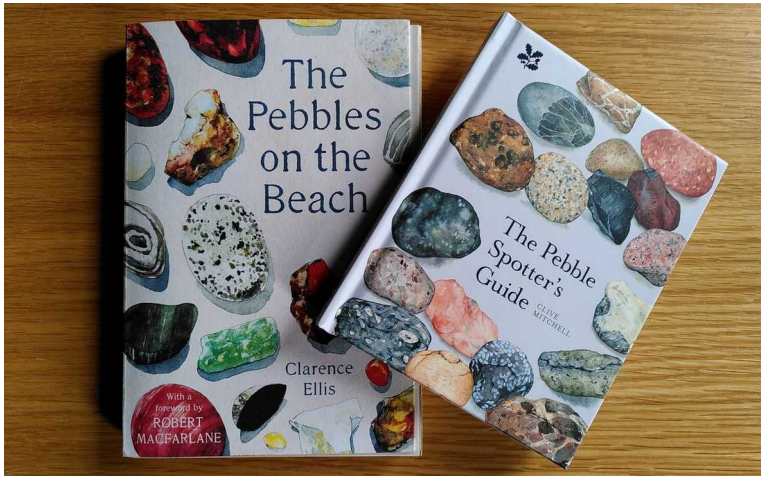
Encourage people to add pebbles and other materials to the map, and gradually build up a three-dimensional depiction of local geology. You can decorate the shoreline and the sea as well.

It will be helpful to refer to a local geological map. As the map builds up you can refine things – move some pebbles around, add features such as igneous intrusions and fault lines (e.g., picked out with quartz pebbles). The overall fabric of sedimentary or metamorphic rocks could be shown by lines of similar pebbles. The map can expand to include a larger area, and you can add in islands and lochs.

Discuss the relative proportions of the pebbles on the beach – are there rocks that cover large areas of the map (e.g. mudstone) that are hard to find on the beach? Make links from bedrock geology to landscape features – hills, headlands, beaches, islands.

Find out more – further resources

The scottishgeology.com website has lots more information about all aspects of Scotland's geology, including fossils, the 51 Best Places to see Scotland's Geology, and links to further resources – this includes links and downloads to introductory books about Scotland's geology and more detailed guides and leaflets to explore the geology in different areas of Scotland.



Two very different Beach Pebble books are widely available. We highly recommend **The Pebble Spotter's Guide** by Clive Mitchell from the British Geological Survey (published by National Trust books in 2021). Dipping into this book is like walking on a good pebble beach, with a beautifully illustrated and lovely mix of pebble types from across the UK.

In contrast, **The Pebbles on the Beach** was originally written by Clarence Ellis in 1954, and was recently republished (2018) with a pretty cover and interesting foreword by Robert Macfarlane. However the text is the original, beautifully written but dating from 1954 when all pebble-lovers were 'he', and 'a description of (the Scottish coastline), even in bare outline, is outside the scope of this book. … It most certainly deserves a book to itself.' We are still waiting – so there's a challenge for someone!

More technical, but fascinating, is **The Planet in a Pebble** by Jan Zalasiewicz (paperback edition published by Oxford in 2012). This book takes one beach pebble of Welsh slate and explores the past, present and future of a pebble and shows how geological science can tease out its stories.

Finally, the quirky and charming children's book **Everybody needs a rock** by Byrd Baylor, was originally published in 1974. It provides ten rules for finding the perfect pebble and might just appeal to someone you know.

The **Scottish Geology Trust** was launched in 2020 to support Scotland's unique geological assets and campaign on behalf of geological societies, Scottish communities, and education. The key objective of the Trust is to inspire people everywhere to understand, love and care for Scotland's incredible geological heritage and its role in creating a sustainable future.

For more information and for events listings throughout the year, visit our w*ebsite www.scottishgeologytrust.org*
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This guide was written in 2021 by Angus D Miller, for the Scottish Geology Trust. Unless otherwise stated, all images are by the author.

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