

## Rocks and landforms

Scotland's rocks and landforms provide a range of benefits and help us to understand how the Earth has evolved. Our protected Earth science features are almost all in good condition, but we know little about the state of rocks and landforms outside protected sites.

### Summary

#### Key messages

- Scotland's rocks and landforms are of national and international importance for demonstrating key geological processes and events in the Earth's history.
- Understanding how rocks and landforms change over time will help us understand and adapt to current issues, such as climate change and rising sea levels.
- Our geodiversity is the foundation of our biodiversity, scenery, and cultural heritage. It provides economic resources and naturally regulates hazards such as flooding.
- Mismanagement of our rocks and landforms could reduce our ability to adapt to the impacts of climate change.
- Some of our rocks and landforms are protected by legislation, and most of these are in favourable condition; however, this is only a fraction of the wider resource.

#### State and trend

**State:** Good - high agreement, low evidence

**Trend:** Stable/declining - high agreement, low evidence

There is an explanation of the diagram and further information on how we carried out the assessments on the [summary pages](#).

- Assessments are of the current "average condition"; some rocks and landforms are in a good condition whereas others are in a poor condition. Equally, the condition of some rocks and landform features is improving, while others are declining or stable.
- Making any overall assessment is necessarily a simplification.
- We have taken account of the scale of any damage to rocks and landforms in these assessments; impacts can be locally damaging, but may have little effect on a national scale.
- We have stated how confident we are in the assessments based on the level of agreement between the specialists involved, and the quality and quantity of the supporting evidence.



## Overview

Scotland has a remarkable diversity of rocks and landforms (geology and geomorphology), created by natural processes over the last 3 billion years.

Rocks and landforms are part of Scotland's rich [geodiversity](#) – the variety of rocks, minerals, fossils, landforms, sediments and soils, and the natural processes that form and alter them (known as geomorphological processes).

The geodiversity found across Scotland, including its sea bed, has led to many globally significant discoveries about how the Earth, and life on it, has evolved. Geodiversity also supports biodiversity, providing the foundation on which plants, animals and humans live.

The distribution of rocks and landforms has shaped human activity in Scotland, influencing land use, settlement sites, water sources and architectural style. Scotland's geodiversity is also the foundation of our varied landscapes and spectacular scenery that today attracts visitors from home and abroad, and provides the background for many recreational pursuits. Additionally, geology provides valuable resources, such as [coal, oil and metal ores](#), which continue to be important to Scotland's economy.

Rocks and landforms, therefore, contribute a wide range of [ecosystem services](#), providing important [economic, social and environmental benefits](#).

Many rocks and landforms are unique and, having formed over very long periods, are effectively irreplaceable. Therefore, appropriate protection and conservation measures must be put in place so that they continue to provide benefits in future.

## The geological record

Scotland is made up of a wide variety of rocks and sediments of different ages including:

- rocks formed from sediments (such as sand and mud) and by volcanic activity [throughout geological time](#);
- some of the oldest rocks in the world (hard rocks deformed by heat and pressure deep inside the Earth over 3 billion years ago);
- deposits left by glaciers a few thousand years ago;
- river, lake and coastal sediments, some still accumulating today;
- fossils, some of which are internationally important;
- economic resources, such as coal and oil, and rare and precious minerals.

Scotland's landforms have been shaped over time by water, wind, waves, ice and landslides.

- The advance and retreat of glaciers have created many of the landforms we see today, such as mountain corries, deep lochs and the crag-and-tail hills on which Edinburgh and Stirling Castles sit.
- Our varied coastline was formed by many processes, including sea-level changes caused by the last ice age. Today, we have the highest cliffs and some of the largest sand dunes in the UK, as well as important mudflats and salt marshes.
- There are many different river features formed by a range of river types, from steep mountain torrents to meandering channels in the lowlands.

## Current processes

Our landforms are still evolving. Water, wind, waves, and freeze-thaw weathering, continually shape the land and coast. Minor earthquakes occasionally shake the ground, and landslides and flooding rivers periodically alter the landscape.

Flooding and changes in the course of river channels are most characteristic of Highland rivers. Lowland rivers also flood, but their channels are generally more stable. The River Tay discharges the largest volume of water of any British river and, along with other large rivers, carries significant amounts of sediment out to the coast.

[Scotland's coasts](#) are made up of 70% rocks and cliffs (hard coasts); 29% gravels, sand and silts (soft coasts); and less than 1% harbours and sea walls. Our coasts are affected by a range of natural processes such as [sea level rise](#) and the natural [addition or removal of sediment](#). There is evidence that these [key coastal processes](#) are changing more rapidly than they did in the last century. For example, Scotland is experiencing [sea-level rise](#), which is already increasing the frequency of coastal flooding, and projections suggest that this will continue at an increased rate over the next few decades. [Coastal sediment supply is at an all-time low](#), partly due to hard riverbank and coastal defences that prevent the erosion of fresh sand and gravel. This affects the stability of soft coasts.

Scotland has a long history of [minor earthquakes](#). The earliest recorded occurred in the 13th century, and the largest, measuring 5.2 on the Richter local magnitude scale, was on 28 November 1880 in Argyll. In 2014, over 60 earthquakes with magnitudes between 0.5 and 3.9 on the Richter local magnitude scale, were detected in Scotland and surrounding waters.

Many recent [landslides](#) on steep slopes have been initiated during prolonged or extreme rainfall. Old landslides can also be reactivated during extreme rainfall, sometimes because the slope has been made unstable due to undercutting by rivers, coastal erosion or even human excavation of the slope. Recent reported landslides include those affecting the A83 at the [Rest and Be Thankful](#) in Argyll, the A890 [Stromeferry bypass](#) near Attadale and the [A82 south of Fort William](#).

## State

Scotland's protected Earth science features are mostly in good condition or being managed to return them to good condition. There are no data available on the state of rocks and landforms outside protected sites.

The principal method of protecting a geological feature or landform of national or international importance is through notification within a [Site of Special Scientific Interest](#) (SSSI).

There are around 895 important rock and landform sites in Scotland (identified by the [Geological Conservation Review](#), GCR). Around 75% of these are protected as notified Earth science features in SSSIs, and their condition is monitored under Scottish Natural Heritage's (SNH's) [Site Condition Monitoring](#) (SCM) programme, which was initiated in 1998. For SCM assessment, the following are considered damaging to Earth science features.

- Physically altering, moving or removing all or part of an Earth science feature (including chemical contamination of the feature).
- Obscuring Earth science features so they cannot be studied, as much of our geodiversity's value lies in what we can learn from studying it.
- Constraining or modifying landform Earth science features that are actively forming, such as rivers and coastal systems.

The SCM programme shows that by February 2015:

- 647 (out of 650) features had been assessed, many more than once, and 94% were in favourable condition, with a further 3% being managed to return them to a favourable condition;
- eleven of the current 650 features had suffered some form of irreversible damage, and two formerly notified features had been entirely destroyed.

The condition of Scotland's geodiversity not protected in SSSIs is not routinely monitored. Therefore, there is not enough information to make an accurate assessment of its overall state. However, expert opinion and anecdotal evidence indicates that some aspects of our geodiversity are improving while others are declining, and suggests an overall state of good with an overall trend of 'stable or declining'.

There is no monitoring of the many benefits that rocks and landforms provide, nor of how these benefits may be affected by the many pressures on them. While locally there have been devastating impacts on geodiversity, these are not thought to be sufficiently widespread at present to influence the overall benefit that Scotland's rocks and landforms provide.

## Pressures affecting rocks and landforms

Loss and damage to rocks and landforms leads to the loss or reduction of the benefits they provide. This can include:

- loss of evidence of past processes, which reduces our ability to understand the impacts of processes happening today (e.g. climate change, sea-level rise, and flooding);
- loss of educational sites and opportunities for outdoor education;
- less tourism and fewer recreation-based activities, which may affect economic development and people's well-being;
- loss of aesthetic value and our sense of place;
- damage to or loss of plants and wildlife that depend on them;
- reduced ability to regulate natural hazards, such as flooding, and adapt to the impacts of climate change.

## Development

Urban and rural development, changes in land use and demand for resources can all put pressure on our rocks and landforms. Some activities that put pressure on our geodiversity may also be beneficial. For example, road cuttings can damage rock outcrops and sediments, but may also provide new evidence of how the area evolved by exposing new rock or sediment sections. In contrast, some activities that are generally considered good for the environment, such as river restoration schemes, may damage our geodiversity if they are not appropriately planned.

## Global processes

Global processes, such as climate change and rising sea levels, can also damage rocks and landforms (e.g. through accelerated coastal or river erosion, more frequent landslides and flooding), as can measures put in place to prevent such direct impacts (e.g. flood-prevention schemes). These changes may also have economic and social consequences. For example:

- more frequent landslides may increasingly disrupt transport routes or damage property;
- more frequent river and coastal flooding may mean that development in flood plains and coastal margins becomes less viable;
- the cost of maintaining flood and erosion defences will increase.

The severity of these consequences can be reduced if they are taken into account during the planning process.

## Specific pressures recorded on Earth science features

The main pressures on notified Earth science features as recorded by SNH's SCM programme are:

- vegetation growth (through neglect or planting);
- dumping of waste material;
- quarrying, mining and gravel extraction;
- coastal protection and river engineering;
- specimen collection (minerals more so than fossils).

Other recorded pressures include the impacts of climate change (e.g. warmer winters affecting the formation of freeze-thaw features) and damaging activities permitted for overriding reasons such as public safety (e.g. safety netting permanently obscuring important rock features but necessary to avoid rock-fall). In these latter cases, damage to rocks and landforms can often be minimised with careful planning.

## Pressures on rocks and landforms outside of SSSIs

It is likely that similar pressures apply to rocks and landforms outside SSSIs as those in SSSIs. However, legislation only provides limited protection to geodiversity outside SSSIs for the following activities:

- housing, commercial and industrial development;
- mineral extraction, landfill and quarry restoration;
- renewable energy developments;
- flood-prevention schemes, riverbank protection and coastal defences.

Therefore, our geodiversity resource outside SSSIs will experience pressure from these activities.

## What is being done

Most of our documented nationally and internationally important geodiversity is protected through '[protected sites](#)' legislation. Geodiversity conservation is also promoted through Scotland's Geodiversity Charter, codes of good practice, and action plans that encourage good management of Scotland's rocks and landforms, now and in the future.

Despite its importance, geodiversity does not have as high a profile as biodiversity. No international legislation covers geodiversity.

## Scotland's Geodiversity Charter

Published by the Scottish Government in June 2012, [Scotland's Geodiversity Charter](#) encourages everyone to work together to raise awareness of, and manage, Scotland's geodiversity; and to ensure its better integration into policy and guidance to meet Scotland's economic, social, cultural and environmental needs.

### Site protection

SSSIs are the main statutory mechanism for protecting rocks and landforms in Scotland. The total number of Earth science features in SSSIs changes over time; features are added or removed for reasons such as scientific review, update of SSSI citations, and the total destruction of features. In February 2015 there were 650 notified Earth science features in Scottish SSSIs. This represents only a small fraction of the national resource, however, and there is currently no programme to incorporate the remaining 200 or so nationally and internationally important Earth science sites into the SSSI network.

[Geoparks, national parks, National Nature Reserves and local nature conservation sites also help protect rocks and landforms](#) and [marine protected areas](#) (MPAs) help protect important sea-bed features.

### Codes of good practice

The [Scottish Fossil Code](#), published in 2008, aims to help protect Scotland's fossils while encouraging public interest and responsible use. Early indications are that most people follow the code when at a fossil site. However, few people ask permission to visit sites or collect fossils, and four incidences of reckless damage have been recorded since the code was published.

The [Scottish Core Code](#), published in 2011 to combat the growing problem of core holes defacing rock outcrops, provides guidance on responsible and environmentally-acceptable rock coring.

### Action plans

At a UK level, the [UK Geodiversity Action Plan \(UKGAP\)](#) provides a broad framework for geological conservation and related activities.

In Scotland, the following areas have completed [geodiversity audits](#):

- Edinburgh;
- West Lothian;
- East Dunbartonshire;
- Glasgow;
- East Lothian.

As yet there are very few local geodiversity action plans (LGAPs) in Scotland. The City of Edinburgh Council has an LGAP within its local biodiversity action plan and, West Lothian has a draft LGAP.

### **Sustainable management**

In cases where rock and landform features may be affected by development, extraction, landfill, landscape restoration or other activities, early communication between all interested parties can help ensure that rocks and landforms are recognised and appropriately incorporated.

Managing active landforms, such as rivers and coasts, appropriately is likely to become increasingly challenging with the prospect of more frequent flooding and rising sea levels (see the [National Flood Risk Assessment](#) and draft [National Marine Plan for Scotland](#)). Building on flood plains is likely to become less viable as the cost of protecting such developments increases. Demand is also increasing for [adaptive management](#) to reduce the cost of protecting developments vulnerable to flooding.