

## Rocks and landforms

**Scotland's rocks and landforms provide economic, social and environmental benefits, and help us to understand our dynamic Earth.**



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### Summary

Scotland's rocks and landforms are of national and international importance for demonstrating key geological processes and events in the Earth's history. Rocks and landforms form a significant part of geodiversity and provide essential ecosystem services delivering economic, social and environmental benefits. However, their importance is not widely understood nor reflected in current policy. Much of geodiversity protected by legislation is in favourable condition, but this is only a fraction of the wider resource. Understanding how rocks and landforms change over time will help us understand and adapt to current issues such as climate change and sea level rise.

### Introduction

Scotland has a remarkable diversity of rocks and landforms (geology and geomorphology), created by a wide range of processes over the last 3 billion years. Rocks and landforms form part of Scotland's rich geodiversity – that is the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes that form and alter them. Here we discuss all aspects of geodiversity, with the exception of [soils](#) and our [economic mineral resources](#).

The geological record preserved in Scotland, both on land and on the sea bed, has led to many globally significant discoveries about how the Earth and life on it has evolved. Scotland's rocks and landforms also have wider values in supporting biodiversity, providing the foundation on which plants, animals and human beings live and interact.

Rocks and landforms also provide the physical basis for our varied landscapes and are a vital component of our cultural and built heritage.

The distribution of rocks and landforms has shaped human activity in Scotland, influencing land use, sites for settlements, sources of water and building stone, as well as architectural style. Geology also provides valuable resources such as coal, oil and metal ores, which continue to be important to the economy of Scotland. Today, the landscape attracts visitors from home and abroad to marvel at and enjoy Scotland's spectacular scenery, and provides the background for many recreational pursuits.

Rocks and landforms, therefore, provide a wide range of [ecosystem services](#), delivering important [economic, social and environmental benefits](#) for the people of Scotland.

Many rocks and landforms are unique and, having formed over very long timescales, are effectively irreplaceable. Therefore, they must be protected to ensure that they continue to provide benefits in future.

We have a range of international, national and local designations that help to safeguard geodiversity, including [Geoparks, National Parks, National Nature Reserves, Local Nature Conservation Sites](#) and, in future, Marine Protected Areas. However, the principal method of protection for a geological feature or landform of national or international importance is through notification within a [Site of Special Scientific Interest \(SSSI\)](#).

## Description of rocks and landforms



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### The geological record

Scotland is made up of a wide variety of rocks and sediments. These range in age from among the oldest rocks in the world (hard rocks deformed by heat and pressure deep in the Earth more than 3 billion years ago); through rocks formed from sediments (such as sand and mud) and by volcanic activity [throughout geological time](#); to deposits left by glaciers a few thousand years ago, and river, lake and coastal sediments accumulating today.

Fossils, some of which are internationally important, are found in rocks in many parts of Scotland. Some of our rocks also contain important economic resources such as coal and oil, as well as 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 has created many of the landforms we see today – for example, mountain corries, deep lochs and the crag and tail hills on which sit Edinburgh and Stirling Castles. Our varied coastline was formed by many forces including sea level changes caused by glaciation. Today we have the highest cliffs and some of the largest sand dunes in the UK, as well as important mud flats and salt marshes. There is also a great variety of river features formed by a range of river types from steep mountain torrents to meandering channels in the lowlands.

Scotland's rocks and landforms provide an exceptional record of landscape evolution and environmental change extending back over much of the Earth's history, and are a unique scientific resource.

### Current processes

Our landforms are still evolving. Water, wind and waves, as well as freeze–thaw weathering, continue to shape the land and coast.

Minor earthquakes shake the ground, and landslides and flooding rivers periodically alter the landscape.

Flooding and changes in the courses of river channels are 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 this and other large rivers carry 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. Seventy-five per cent of coasts are broadly stable, whereas sediment is being added to 8% and lost from 12%. Data are lacking for 5%.

Scotland is experiencing net [sea level rise](#), and projections suggest that this will continue at an increased rate over the next few decades. There is evidence that key coastal processes are also changing more rapidly than they did in the last century. Additionally, coastal sediment supply is at an all-time low, in part due to river bank and coastal defences preventing the erosion of fresh sand and gravel.

Scotland has a long history of relatively [minor earthquakes](#). The earliest recorded Scottish event occurred in the 13th century, and the largest, measuring 5.2 on the Richter local magnitude scale, occurred on 28 November 1880 in Argyll. In June 2012, 11 earthquakes were detected in Scotland, with local magnitudes ranging between 0.8 and 1.5 on the Richter local magnitude scale.

Many recent [landslides](#) on steep slopes have been initiated during prolonged or extreme rainfall events. Old landslides can also be reactivated during extreme rainfall events, sometimes because the slope has been made unstable through undercutting by rivers, coastal erosion or even human excavation of the slope. Recent high-profile landslides include those affecting the mountain side above the A83 at the [Rest and Be Thankful](#) in Argyll.

### **State of rocks and landforms**

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.

The condition of notified Earth Science features is monitored under Scottish Natural Heritage's (SNH's) [Site Condition Monitoring](#) (SCM) programme initiated in 1998.

- by 2005, 594 (out of 612) Earth Science features had been assessed and 90% were in favourable condition;
- by June 2012, 636 (out of 656) features had been assessed, many more than once; 94% were in favourable condition and a further 3% were under positive management to return them to favourable condition;
- since 2005, 12 features have suffered some form of irreversible damage and two have been entirely destroyed.

There is no routine monitoring of the condition of geodiversity outwith SSSIs, so there is insufficient information available to make an assessment of its state. In addition, there is no monitoring of the many ecosystem services that rocks and landforms provide, nor of how the value of these services may be affected by the many pressures on them.

## Pressures affecting rocks and landforms



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There are a wide variety of pressures on rocks and landforms, driven largely by:

- development activities;
- changes in land use;
- demand for resources;
- global processes.

Development activities, changes in land use and demand for resources are driven by economic and social forces that generate the need for minerals, energy (including renewables), waste disposal, housing and industrial development, and by changes in agriculture and forestry support measures that can affect land use decisions (e.g. afforestation and drainage). These can result in:

- inappropriate site development (development that results in important features being concealed or destroyed);
- disruption of natural processes (river, coastal and marine);
- contamination of water courses or [groundwater](#);
- obscuring of rocks and landforms (e.g. vegetation growth, slumping, tipped waste);
- removal or destruction of rocks and landforms (including irresponsible specimen collecting).

Global processes such as climate change and sea level rise can have direct impacts on rocks and landforms, for example through enhanced coastal erosion. Global processes can also indirectly affect rocks and landforms as a result of measures put in place to prevent direct impacts such as erosion and flooding.

All these pressures can damage our rocks and landforms and also put pressure on the ecosystem services they provide.

## Protected sites

The main pressures affecting nationally and internationally important rock and landform sites protected in SSSIs (as recorded by SNH's SCM programme) are:

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

Other documented pressures include the impacts of climate change (e.g. warmer winter conditions affecting formation of freeze–thaw features) and activities that have been consented despite their damaging consequences. Consent is usually granted in these latter cases for over-riding reasons such as public safety (e.g. where safety netting that permanently obscures important rock features is necessary to avoid rock fall) and damage to rocks and landforms can often be minimised in these cases with careful planning.

## Outside protected sites

It is likely that similar pressures to those listed for protected sites will apply to rocks and landforms outside SSSIs. However, pressures relating to development controlled by planning regulations within SSSIs (e.g. housing, renewables, mineral extraction, commercial and industrial development) are likely to be greater outside SSSIs, as planning regulations that protect geodiversity features within SSSIs do not apply to those outside SSSIs.

For example during mineral extraction, landfill and quarry restoration, legislation provides limited protection to geodiversity. This is also the case in the construction of flood alleviation schemes, coastal defences and river bank protection, all of which are likely to have an impact on rocks and landforms.

## Consequences of a change in rocks and landforms



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Loss and damage of rocks and landforms, including loss of, damage to or restriction of active landform systems, leads to a loss or reduction in the [ecosystem services they provide](#). This can include:

- loss of evidence of processes occurring in the past, reducing our ability to understand the impacts of processes acting today such as climate change and other hazards such as flooding;
- loss of educational sites and opportunities for outdoor education;
- reduction of tourism and recreation-based activities, which may impact economic development and well-being;
- loss of aesthetic value and sense of place;
- damage to or loss of dependent biodiversity;
- loss of natural hazard regulation and the reduced ability to adapt to the impacts of climate change.

Additionally, the likely consequences of climate change, such as sea level rise and changes in rainfall, may result in:

- more frequent landslides, which may mean more disruption to transport routes or damage to property;
- more frequent river and coastal flooding, meaning that development in certain locations such as flood plains or coastal margins may become less sustainable;
- increases in the ongoing cost of maintaining flood and erosion defences on coasts and rivers.

The severity of these consequences may be mitigated where they are taken into account in the planning process.



## Response by society



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Despite its importance, geodiversity does not have as high a profile as biodiversity. There is no international legislation covering geodiversity. However, we need to protect rocks and landforms ensuring that they remain in good condition to provide vital ecosystem services and benefits for society. Important rocks and landforms are protected by a range of measures, including site protection, codes of good practice, action plans and incorporation of appropriate management in a range of policy areas.

The most recent step forward for geodiversity conservation was the launch of '[Scotland's Geodiversity Charter](#)' by the Scottish Government in June 2012. This charter encourages everyone to work together to promote and manage Scotland's geodiversity and to ensure that it is better integrated into policy and guidance consistent with Scotland's economic, social, cultural and environmental needs.

### Site protection

SSSIs are the primary statutory mechanism for the protection of rocks and landforms in Scotland. The Great Britain-wide GCR underpins designation of Scotland's geological SSSIs. In June 2012, there were 656 notified Earth Science features in SSSIs in Scotland.

[Geoparks, National Parks, National Nature Reserves and Local Nature Conservation Sites also help protect rocks and landforms](#); and, in future, [Marine Protected Areas](#) (MPAs) will help to protect important sea bed features.

### Codes of good practice

The Nature Conservation (Scotland) Act 2004 resulted in the development of the [Scottish fossil code](#), launched in 2008, which aims to help safeguard Scotland's fossil resource while enhancing public interest and promoting responsible use.

Early indications are that the majority of people are following the code when on-site; however few people ask for permission and incidences of reckless damage are still being recorded (three since 2008).

A [Scottish core code](#) has recently been developed to provide guidance on responsible and environmentally acceptable rock coring in response to the increasing problem of core holes defacing outcrops.

### Action plans

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

Local Geodiversity Action Plans (LGAPs) involve a wide range of contributors agreeing priorities and actions for geodiversity in the local area. In Scotland, the City of Edinburgh Council now has an LGAP within its latest Local Biodiversity Action Plan; there is a draft LGAP for West Lothian; and both of Scotland's National Parks have production of an LGAP as an action in their Park Plans. A prerequisite for the preparation of an LGAP is a geodiversity audit of the relevant area. In Scotland, Edinburgh, West Lothian and East Dunbartonshire have completed full geodiversity audits. By June 2012, an audit was also under way in Dumfries and Galloway, and one was planned for Glasgow.

### Appropriate management

In all cases where rock and landform features may be affected by development, extraction, landfill, landscape restoration or other management activities, early dialogue between interested parties would help to ensure that rocks and landforms are given recognition and incorporated appropriately.

Appropriate management of active landforms, such as rivers and coasts, is likely to become increasingly challenging with the prospect of increased frequency of flooding and sea level rise. Both aspects, and the requirements for planning and management of geodiversity, were considered in the [National Flood Risk Assessment \(2011\)](#) and drafting of the [National Marine Plan for Scotland](#). Development on flood plains is likely to become less viable as the cost of protecting such developments increases. There is also likely to be increasing demand for [adaptive management](#) to reduce the cost of protecting vulnerable developments.

### Policy

The wide range of benefits to people incorporating a contribution from geodiversity receives little mention in current Scottish policy. There is no clear recognition of the wider links rocks and landforms have to a range of policy areas such as climate change, biodiversity conservation, health, recreation, education, greenspace and tourism. There is a need for a clear strategic framework in Scotland to ensure that geodiversity is fully recognised and hence that it is suitably protected, and where appropriate enhanced, for future generations.