Intrusive igneous rocks

Intrusive igneous rocks formed by being intruded (emplaced) as molten rock, or magma, into the surrounding rocks. They are distinguished from volcanic, or extrusive igneous, rocks by having crystallised and cooled at depth within the Earth's crust. Such intrusions include widespread more or less horizontal sheets, known as sills; more or less vertical sheet-like bodies, known as dykes; and very large, often rather irregular, bodies known as batholiths.

Currently protected sites of intrusive igneous rocks within the AONB SSSIs

SSSI Name/GCR Name/Grid Ref.

Upper Teesdale/Whin Sill in upper Tees* [NY 880 285]

*These include:

Cauldron Snout, Upper Teesdale [NY 815 286]

Force Garth Quarry (now known as

Middleton Quarry), Upper Teesdale [NY 873 282]

High Force, Upper Teesdale [NY 880 283]

Low Force and Wynch Bridge, Teesdale [NY 905 279]

Falcon Clints, Upper Teesdale [NY 820 281]

Cronkley Fell [NY 831 282]–[NY 854 282]

In addition, the following important exposures of Great Whin Sill lie within the Upper Teesdale–Moorhouse National Nature Reserve and the Appleby Fells SSSI.

Red Sike and Widdybank Fell, Upper Teesdale [NY 818 296]

Cow Green Reservoir, Upper Teesdale [NY 815 294]

Holwick and Crossthwaite Scars, Teesdale [NY 898 271]–[NY 927 253]

High Cup Nick [NY 745 262]

RIGS

High Cup Nick [NY 745 262]

Croglin waterfall [NY 600 481]

Durham County geological sites

Caledonian minor intrusions:

Cronkley Pencil Mill, Upper Teesdale [NY 848 296]

Great Whin Sill:

Greengates Quarry, Teesdale [NY 934 236]

Horsley Burn Waterfall, Eastgate [NY 975 384]

Killhope Burn, Copthill Quarry and

Wear River at Butreeford Bridge [NY 855 406]

Scoberry Bridge to Dine Holm Scar [NY 910 274]

Widdybank Fell [NY 820 290]

Wynch Bridge, Langdon Beck [NY 820 290]

Other representative sites in the area

Caledonian Minor Intrusions:

Catterpallot Hill, Melmerby [NY 6381 3621]

Dry Sike, Melmerby [NY 6399 3743]

Melmerby Beck, Melmerby [NY 6314 3688]

Dufton Pike, Dufton [NY 6930 2681]

Great Whin Sill:

Middleton Quarry, Middleton in Teesdale [NY 947 245]

Closehouse Mine, Lunedale [NY 850 227]

River Tyne [NY 695 629] — Haydon Bridge Dyke

River Lune, Lunedale [NY 813 207] — Connypot Dyke

Greengates Quarry, Lunedale [NY 933 234] — Greengates Dyke

Wackerfield village [NZ 158 227] — Wackerfield Dyke

Eggleston Burn, Eggleston [NY 9857 2482] — Hett Dyke

Little Whin Sill:

Turn Wheel Linn, Rookhope Burn [NY 949 398]

Palaeogene dykes:

Outberry Bat, Ettersgill, Teesdale [NY 8849 2955] — Cleveland–Armathwaite Dyke

Mirk Holm, Teesdale [NY 9086 2928] — Cleveland–Armathwaite Dyke

Smithy Sike, Teesdale [NY 8920 2950] — Cleveland–Armathwaite Dyke

Coldberry Gutter, Teesdale [NY 930 289] — Cleveland–Armathwaite Dyke

Eggleston Burn, Eggleston [NY 989 249] — Cleveland–Armathwaite Dyke

Intrusive igneous rocks in Great Britain

Intrusive igneous rocks, which are exposed today at the surface due to millions of years of erosion, give vital information on a great variety of geological processes which have operated deep within the Earth's crust over many millions of years of Earth history. A variety of sophisticated analytical techniques can be used to date the crystallisation, and thus the age of intrusion, of these rocks. These dates, when interpreted along with other geological evidence, provide an extremely valuable means of assigning accurate dates to key events in Earth history.

Outcrops of intrusive igneous rocks, which range in composition from basalt and dolerite to granite, crop out over 3,200 hectares, or 1.6%, of the surface area of the AONB. One major intrusion, the Weardale Granite, does not reach the surface and has been proved only in the Rookhope and Eastgate boreholes. It has, however, played a major role in the geological evolution of the North Pennines over a long period of geological time. The intrusive igneous rocks of the area are reviewed briefly here according to their age of emplacement.

Caledonian intrusions

These bodies of intrusive rock were emplaced during the long and complex series of Earth movements, known as the Caledonian Orogeny, which affected the area that was to become the UK, between roughly 500 and 390 million years ago. Within the AONB it is possible to recognise two groups of intrusive igneous rocks which date from this period:

The Weardale Granite

The pattern of mineralisation in the Northern Pennines, and comparisons with areas such as SW England, together with geophysical evidence, suggested that a concealed granite may be present at depth. The Rookhope Borehole, drilled in 1960-61, proved granite at a depth of 390.5 metres. The granite was found to have a weathered top, proving it to pre-date the overlying Carboniferous rocks. Radiometric dating revealed its age of crystallisation of 410 ± 10 million years. Geophysical evidence suggests that the Weardale Granite is part of a very large concealed batholith which is likely to be some 60 by 25 kilometres in extent with several high spots, or cupolas, on its upper surface beneath Tynehead, Scordale and Rookhope. Like the Caledonian granite batholith that underlies the Lake District, it is possible that the Weardale Granite may be one of a number of separate, but related, granite intrusions, or plutons, that together comprise a North Pennine Batholith. The small intrusion of pink porphyritic microgranite, known as the

Dufton Microgranite, within the Ordovician Dufton Shales of the Cross Fell Inlier, may be part of this batholith or may be part of a cupola arising from the roof of the Weardale Granite.

Caledonian minor intrusions

The term 'minor intrusion' is applied to small bodies, or groups of small bodies, of intrusive igneous rock. Caledonian minor intrusions in the AONB include the lamprophyre dykes which cut the Ordovician Skiddaw Group mudstones at Pencil Mill, near Cronkley in Upper Teesdale and parts of the Cross Fell Inlier, and dyke and sill-like bodies of dolerite and pink felste, within the Skiddaw Group mudstones in the neighbourhood of Catterpallot, near Melmerby.

Permo-Carboniferous basic sills and dykes — the Whin Sill Suite and its associated dykes

In late Carboniferous and early Permian times, deep-seated crustal stretching and fracturing allowed huge quantities of magma to rise from deep within the earth. In northern England this magma did not reach the surface, but spread widely as sheets between the layers of pre-existing rocks, where it cooled and crystallised. This extensive suite of intrusive igneous rocks is collectively termed the Whin Sill or the Great Whin Sill.

This complex underlies much of north east England, including most of the AONB. It typically comprises a series of widespread sills with some associated dykes and is composed of quartz- dolerite which exhibits a remarkable continuity in mineralogical and chemical composition across its extensive outcrop. By far the greater part of the complex consists of fine to medium-grained dolerite, though fine-grained rocks occur at the contact and very coarse-grained dolerite pegmatite veins and segregations occur locally. The sill reaches its maximum known thickness of around 70 metres in

Teesdale and under parts of the Allen Valleys; it is significantly thinner on the North Pennines escarpment.

Radiometric dating gives the Whin Sill an age of around 290 million years. Palaeomagnetic studies reveal that at the time of its crystallisation the area lay within tropical latitudes. Several dykes associated with the sill may have acted as feeders during its emplacement. Some of these have been given local names in the geological literature. These include the Haydon Bridge Dyke, the Greengates Dyke, the Connypot Dyke and the Hett Dyke.

The intrusion of such huge volumes of molten dolerite at temperatures of around 1000°C had a profound effect on the surrounding rocks, resulting in widespread intense alteration, or metamorphism, with the formation of a variety of metamorphic minerals (see Metamorphic Rocks). A variety of minerals which occur as joint linings within the sill, formed during the final phases of cooling.

Over much of the AONB the Whin Sill exists as a single, roughly horizontal, sheet. However, in the Rookhope and Stanhope area of Weardale, a much thinner upper leaf of the intrusion, known as the Little Whin Sill, is present. Both leaves of the sill were proved in the Rookhope Borehole.

Palaeogene intrusive igneous rocks

During Palaeogene, or Tertiary times, Earth movements associated with the opening of the Atlantic, caused cracking of rocks in a radial pattern for many miles away from volcanic centres in what is today the Hebrides. As they developed deep beneath the surface, these cracks were filled with basaltic magma, forming a series, or swarm, of extremely long dykes. These may be traced across much of northern England, the most prominent being that known as the Cleveland–Armathwaite Dyke. These dolerite intrusions may be distinguished from those of the Whin Sill by their porphyritic character, with small phenocrysts of feldspar and pyroxene set in a dark grey fine-grained matrix. A minimum age of around 55 million years has been established for these rocks. Although these rocks have extremely small outcrops, they are the only rocks of Palaeogene age in the AONB.

Impact on the landscape

The buoyancy effect of the Weardale Granite within the basement rocks of the North Pennines has long influenced the geological history of the area throughout much of Carboniferous and later time. It is this continued buoyancy which partly accounts for the upland nature of the area today.

Because of its hardness and resistance to erosion, the outcrops of the Whin Sill comprise some of the area's best known and most dramatic landscape features. Most extensive and impressive are the Teesdale outcrops where it forms the sombre cliffs of Crossthwaite, Holwick and Cronkley Scars, as well as the waterfalls of High Force, Low Force and Cauldron Snout. On the North Pennine escarpment, where it is significantly thinner, it forms the rim to the spectacular rocky amphitheatre of High Cup Nick and lines of low grey crags in Scordale and elsewhere.

The Palaeogene dykes belonging to the Cleveland–Armathwaite Dyke suite, have extremely small outcrops and make little or no contribution to the landscape character of the AONB.

Impact on biodiversity

Where free, or almost free, of superficial cover, the Whin Sill typically gives rise to rather thin acid soils. These locally support populations of bell-heather, together with ling, bilberry, cowberry and some bearberry. The Whin Sill block screes may locally host parsley fern, which is a rarity on the east side of the Pennines.

Fissures between larger blocks of Whin Sill dolerite provide refuges for trees such as aspen, rock whitebeam and juniper, which represent relics of former woodland. At higher altitudes these blocks may provide habitats for arctic-alpine herbs.

Tall cliffs of Whin Sill provide nesting sites for a number of birds as indicated by the names Falcon Clints and Raven Scar: ring ouzels and wheatears may also be present.

Economic use

The Weardale Granite has only ever been sampled in the Rookhope and Eastgate boreholes and has never had any economic uses, though its potential as source of feldspar for the ceramics industry was contemplated at Cambokeels fluorspar mine during the 1980s.

Very small amounts of rock from several of the Caledonian minor intrusions are incorporated into a few drystone walls, along with other locally available materials.

The hardness and roughness of the dolerite of the Great Whin Sill, the Little Whin Sill and associated dykes, makes these good sources of roadstone and aggregate, which have been worked in numerous quarries. Most conspicuous are those in the Great Whin Sill outcrops of Teesdale between Middleton and High Force. Force Garth Quarry, near High Force, is the sole remaining producer of Whin Sill dolerite in the AONB. Large tonnages of roadstone are produced here, mainly for use outside the AONB.

The Palaeogene dykes have not been worked within the AONB, except for extremely local use in farm walling, though they have yielded significant quantities of roadstone from quarries a few miles to the east.

Wider importance

The discovery of the pre-Carboniferous age for the Weardale Granite marked an important advance in understanding the geological evolution of northern England and led to substantial re-appraisals of the origins of ore genesis in this and comparable orefields worldwide. The buoyancy effect of the granite within the Lower Palaeozoic basement rocks of the North Pennines explains the persistence of the Alston Block as a positive feature throughout much of Carboniferous and later time.

The Whin Sill is regarded as the original 'sill' of geological science and therefore must be viewed as one of the key natural heritage features of the AONB. It takes its name from the north of England quarryman's term 'sill', meaning any generally horizontal body of rock, and 'whin' meaning a hard, intractable black rock. The recognition, in the 19th Century, of its intrusive origin, quickly led to the term 'sill' being adopted by geological science throughout the world for comparable concordant horizontal intrusive bodies of this kind.

The Paleogene dykes give important clues to geological processes which operated far beyond the North Pennines.

Conservation issues

Natural exposures of these rocks within the AONB are generally robust and none appear to be under any threat. Abandoned quarries are at risk of becoming overgrown or degraded.

Backfilling as landfill sites, or as part of other land reclamation schemes, may threaten to damage or destroy them. Whilst such activities are unlikely to occur in the AONB, sites should be monitored to ensure that important exposures are not lost.

Selected references

Arthurton and Wadge, 1981; Burgess and Holliday, 1979; Dunham, 1990; Johnson, 1970; Mills and Hull, 1976; Stephenson, Bevins, Millward, Highton, Parsons, Stone and Weadsworth, 1999; Stephenson, Loughlin, Millward, Waters and Williamson, 2003; Stone et al, 2010; Trotter and Hollingworth, 1932

Figures

(Figure 29) Outcrop of intrusive igneous rocks.

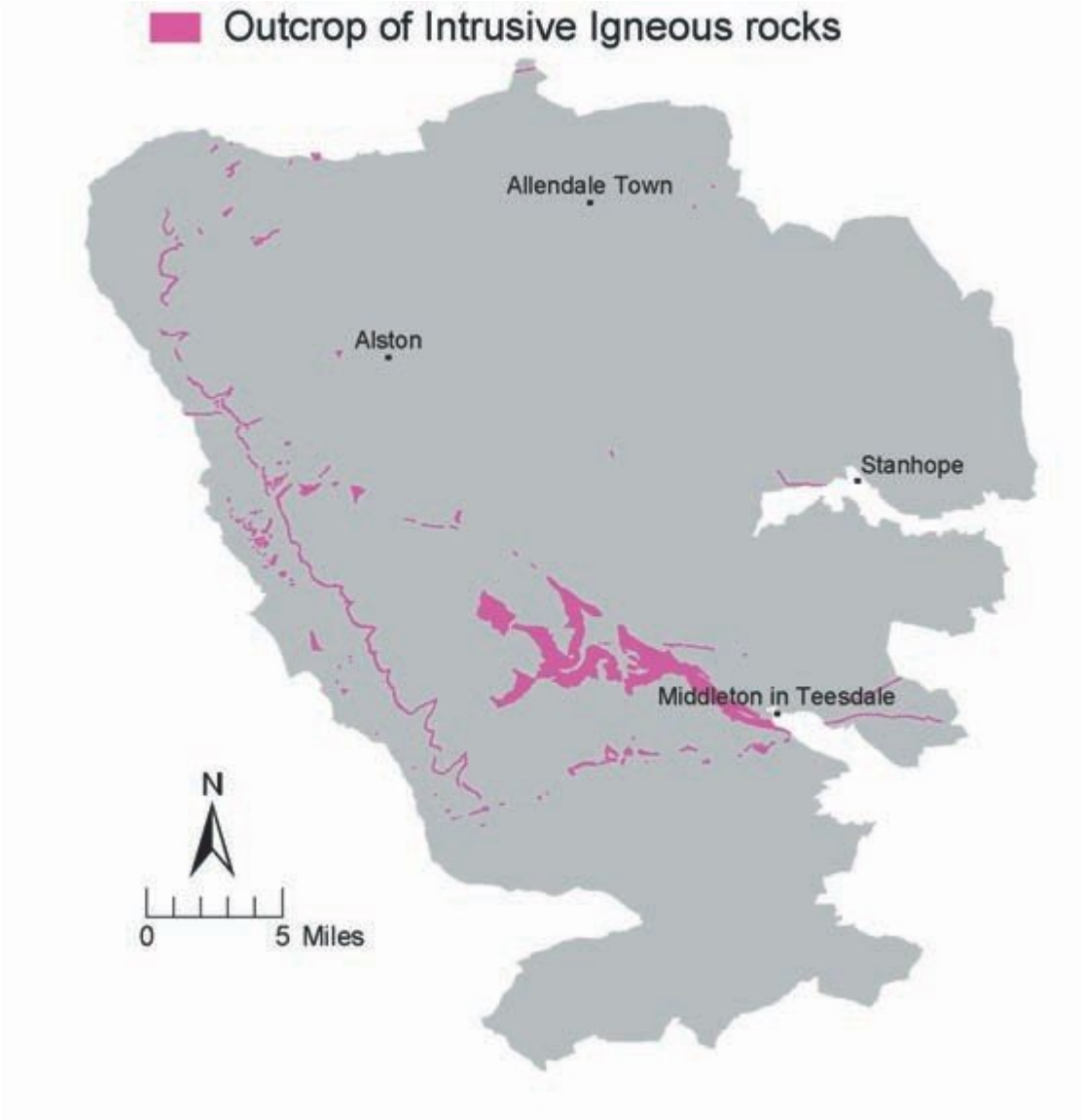
(Figure 30) Photomicrograph of thin section of Weardale Granite © H. Emeleus, Durham University.

(Figure 31) High Force, Whin Sill overlying Tynebottom Limestone © NPAP.

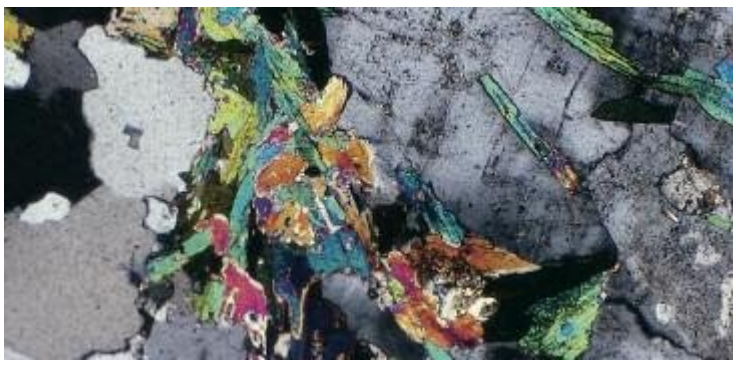
(Figure 32) The Little Whin Sill exposed in the abandoned Greenfoot Quarry, Weardale. © B. Young, BGS, NERC.

(Figure 33) Crags of columnar jointed Whin Sill, Holwick Scar, Teesdale © BGS, NERC.

Full references



Outcrop of intrusive igneous rocks.



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