GEOLOGY
Brian Young

The underlying rocks, and the earth processes that have created them over millions of years, are an essential part of any area's natural history. The variety of rocks shapes the landscape, provides the foundation for soils – and thus plant and animal life – and profoundly influences the lives of human inhabitants.

Nowhere is this connection clearer than in Upper Teesdale. Whereas there is much of interest in the rocks, fossils and minerals themselves, an understanding of this geological diversity is also vital to fully appreciating the ecological, social and economic character of this beautiful Pennine valley.

The significance of its geology figures prominently in Upper Teesdale's place within the Moorhouse–Upper Teesdale National Nature Reserve and the North Pennines Area of Outstanding Natural Beauty (AONB) which coincides with the UNESCO-designated North Pennine Geopark. Numerous sites and features within the Dale are scheduled as Sites of Special Scientific Interest (SSSIs) specifically for their geological importance.

Upper Teesdale has attracted research interest since the earliest days of geological science, resulting in a voluminous technical literature. Drawing upon this, and following a brief outline of the Dale's geological history, this chapter introduces some of the most important aspects of the rocks and landscape we see around us today, including places where geological features of interest may be seen, and highlights the relevance of these to other aspects of the Dale's natural and human history. For readers wishing to explore Upper Teesdale's geology in greater depth, a list of useful texts is offered.

Low Force. The dolerite of the Whin Sill here forms rapids in the River Tees: © Steve Gater

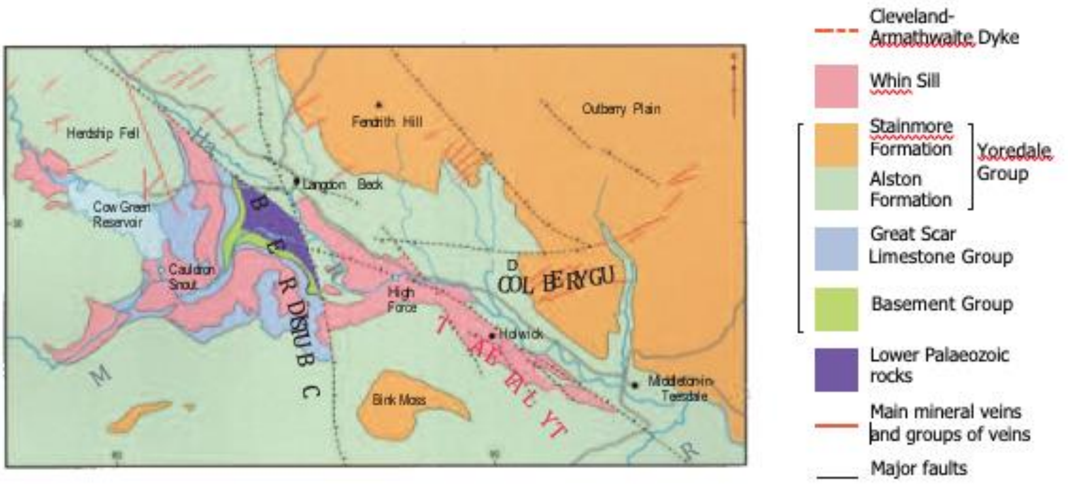
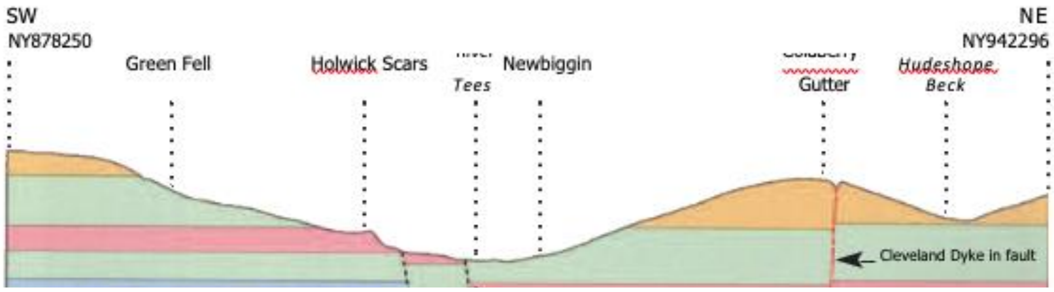


Figure 1: Simplified geological map depicting the bedrock geology of the Dale.
NB. For clarity, many mineral veins and some faults are omitted.



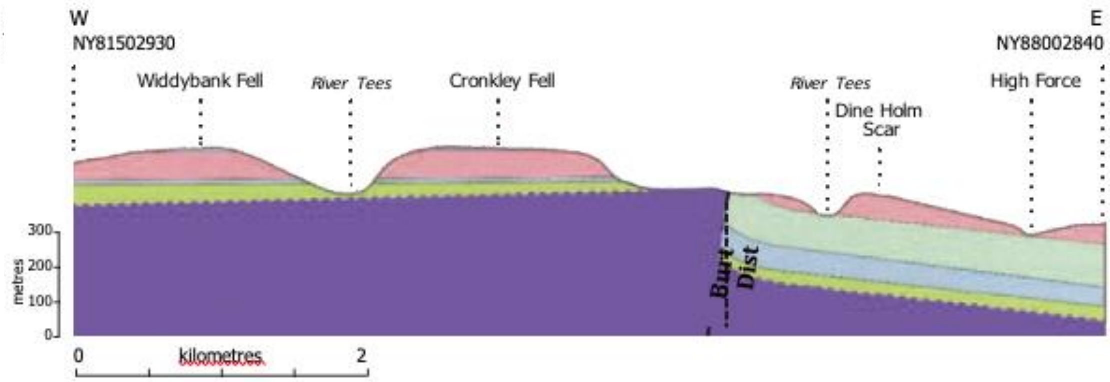


Figure 3: Simplified section through Burtreeford Disturbance

A brief geological history

The rocks visible today in Upper Teesdale record almost 500 million years of earth history.

The periods of earth history represented, together with the materials formed at those times are:

Superficial (drift) deposits: *more detail is given in the section on Geomorphology and Quarternary glacial legacy.*

(Unconsolidated deposits, mainly formed by glacial action and later processes within the past 2.6 million years, and which mantle and conceal the underlying bedrock - commonly referred to by geologists as 'Drift' deposits).

Bedrock:
(The hard, bedrock formed over millions of years of geological history – commonly referred to by geologists as 'Solid 'deposits)

Palaeogene (Tertiary)
Basalt of the Armathwaite-Cleveland Dyke

Upper Palaeozoic
Late Carboniferous-Early Permian
Mineral veins Dolerite of the Whin Sill
Carboniferous
Beds composed mainly of limestone, shale, sandstone and some thin coal seams, many times repeated with beds of pebbly conglomerate at the base.
Devonian
Emplacement of Weardale Granite into Ordovician rocks of the Northern Pennines

Lower Palaeozoic
Ordovician rocks
Volcanic rocks and slates

The oldest rocks known in Northern England date from the Ordovician and Silurian periods of earth history, between 480 and 420 million years ago. At this time the portions of the Earth's crust that would eventually become Britain lay south of the equator on either side of a deep ocean, known by geologists as the Iapetus Ocean. To the north of the ocean lay the ancient continent of Laurentia, which included the area that would become Scotland; on its southern side lay Avalonia, which included the area destined to include England and Wales. Movement of the Earth's tectonic plates caused these two continents to move inexorably closer, eventually colliding around 420 million years ago, resulting in the major mountain-building episode known as the Caledonian Orogeny.

Muds and sands, deposited on the floor of Iapetus were squeezed and deformed to form hard sandstones and slates, and volcanic eruptions caused by the collision created vast volumes of lava and ash. In addition, huge masses of molten rock, or magma, which never reached the surface, solidified to form enormous bodies of granite, including the Weardale Granite that underlies much of the Northern Pennines. A huge mountain chain was thus created over what is now Scotland and Northern England. These are the rocks we see today forming the mountains of the Lake District. Exactly similar rocks of this age lie hidden at depth beneath most of Northern England but, as a result of later Earth movements, small slices of these have been pushed to the surface along the Pennine escarpment and in Upper Teesdale.

Following this dramatic episode, continuing movement of the tectonic plates gradually brought the area close to the equator by about 350 million years ago, at the beginning of the Carboniferous period. By then, millions of years of erosion had worn down these mountains to their roots, in what is now Northern England, though substantial mountains remained in the area now occupied by the Scottish Highlands, the northern North Sea and Scandinavia. Much of what was to become Northern Britain was gradually submerged beneath a shallow tropical sea. Rendered more buoyant by the huge underlying mass of the Weardale Granite, the earth's crust beneath the area destined to form the Northern Pennines initially remained as an area of relatively higher land, though with time even this became submerged beneath the extensive Carboniferous sea. Within the clear warm waters of this sea an abundance of marine life created thick accumulations of limestone.

Instability caused by continuing Earth movements caused huge rivers draining the mountains to the north and north east to carry enormous amounts of mud and sand into the sea, repeatedly building extensive coastal swamps and deltas upon which lush tropical rainforests developed. Over the ensuing 50 million years, continuing instability and repeated episodes of global climate change resulted in flooding by the sea alternating with the growth of deltas and coastal swamps. The result was a series of cyclical successions, known as 'cyclothems', with the cycle of limestone, shale, sandstone and coal repeated many times. Limestones and shales were formed as marine sediments and the coals and many of the sandstones formed under freshwater swamp and deltaic conditions. With time, the marine intervals became fewer and briefer, resulting in more numerous sandstones and coal seams, culminating towards the end of Carboniferous times with extensive swamp forests that formed the coal seams of the Coal Measures.

At the beginning of Permian times, stretching of the Earth's crust caused huge volumes of molten rock (magma) to rise up from the earth's mantle. This did not reach the surface, but spread out horizontally between the layers of Carboniferous rocks where it cooled and crystallised to form the bed of rock known as the Whin Sill.

Holwick Scars.The Whin Sill here forms high crags in which columnar joining is conspicuous: © Brian Young

Heat from this magma severely altered, or metamorphosed, the rocks into which it came into contact, baking limestones to form marble, known locally as 'sugar limestone'. Specialised analytical techniques enable us to date the cooling and crystallisation of the Whin Sill at around 295 million years ago.

At about this time, earth movements bent the Carboniferous rocks into a gentle dome-like structure sometimes referred to as the Teesdale Dome. In consequence, over much of Upper Teesdale the Carboniferous rocks dip gently to the east. This folding was accompanied by some fracturing of the rocks to create faults – fractures along which the rocks have been displaced relative to one another. Two of these, illustrated in Figures 2 and 3, are very significant in shaping the Teesdale landscape.

The Teesdale Fault is a major northwest-southeast trending fracture along which the rocks on its northern side have been displaced downwards by up to several tens of metres relative to those on its southern side (Figure 2). In consequence, the Whin Sill, so conspicuously seen on the south side of the Dale, lies far beneath the surface on its northern side. Like many such large faults, the Teesdale Fault is a belt of roughly parallel fractures.

The course of the River Tees has been largely determined by the relative ease by which the fractured rocks adjacent to the fault have been eroded. The second major structure to affect Teesdale's landscape is the rather complex north-south trending belt of folding and faulting known as the Burtreeford Disturbance, a major structural feature that bisects the Northern Pennines. As may be seen in Figure 3, this displaces the Carboniferous rocks downwards by several tens of metres on its eastern side. Geological mapping reveals that this displacement occurred both before and after the intrusion of the Whin Sill. Because there are very few exposures of the Burtreeford Disturbance it remains a poorly understood feature of the local geology.

Upper Teesdale's rocks are cut by numerous smaller faults which, soon after the intrusion of the Whin Sill, were filled with minerals to create the mineral veins which were the basis for the Dale's long history of metalliferous mining.

From the formation of the Whin Sill and the area's mineral veins at around 295 million years ago, the record of geological events that affected Teesdale's geology falls silent until about 60 million years ago in the Palaeogene period. By then plate tectonics had moved the area close to its present latitude. Stretching of the earth's tectonic plates created a new split in the crust which heralded the opening of the Atlantic Ocean. This fracturing was accompanied by violent volcanic activity in what is now the Hebrides and Northern Ireland. Fractures radiating from the volcanic centre on the Isle of Mull extended as far as Northern England and acted as conduits for basaltic magma. One of these basalt-filled fractures, known as the Cleveland-Armathwaite Dyke, crosses the Northern Pennines and crops out at several places in Teesdale. The emplacement of this dyke marks the final recorded event in the history of Upper Teesdale's bedrock, or 'solid', geology. Chapter 4 covers the last 2.6 million years of landscape development.

Ordovician Rocks

Whereas throughout the Northern Pennines Lower Palaeozoic rocks almost everywhere lie deeply buried beneath the younger Carboniferous rocks, they crop out at the surface on the Pennine escarpment and in Upper Teesdale. Elsewhere they have been proved in a handful of deep boreholes.

Fragments of partially formed slate pencils collected from the spoil heaps adjacent to the old Pencil Mill: © Brian Young

In Upper Teesdale, rocks of Ordovician age crop out beneath Cronkley Scar near Langdon Beck in an area known to geologists as the Teesdale Inlier. Although this extends over several square kilometres, it is mostly concealed beneath later Quaternary deposits with exposures limited to the banks and bed of the Tees between Cronkley Scar and Widdybank Farm.

Pale greenish-grey slates are exposed in an old quarry on the south side of the river at Pencil Mill [NY84802960] where they were once worked for the making of slate pencils, known locally as 'Widdies'. Rare fossils of the graptolites Didymograptus and Glyptograptus, together with samples of the microfossils known as acritarchs, collected here, indicate that these are of Lower Ordovician age and thus equivalent to parts of the Skiddaw Slates of the Lake District. The slates are cut by several vertical bodies, or dykes, of an igneous rock known as lamprophyre, which here form conspicuous low craggy exposures in the bed and banks of the river.

In the bed of the Tees a short distance upstream [NY83857966] is a very small exposure of silicified volcanic ash, or tuff, which is regarded as the equivalent of the volcanic rocks of the Borrowdale Volcanic Group of the Lake District.

Devonian Rocks

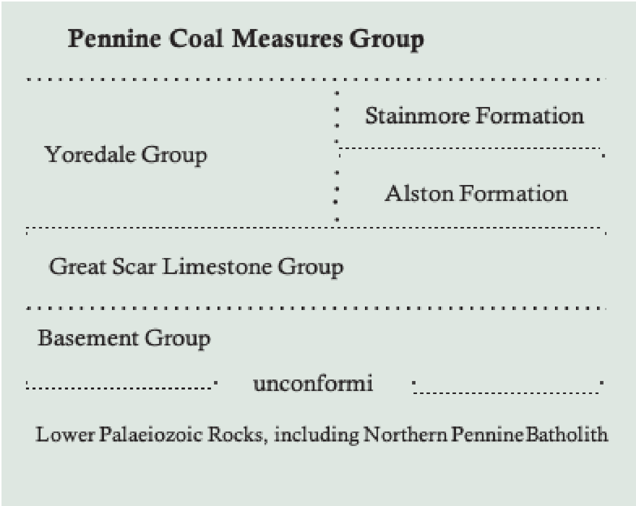
Lying within the Lower Palaeozoic rocks of the Northern Pennines is the Weardale Granite, proved in a deep borehole drilled in Rookhope, Weardale, in 1961. Radiometric dating of this rock reveals that it was intruded, or emplaced, about 399 million years ago during the Devonian period of earth history. Although the granite nowhere reaches the surface, as noted above, it influenced the deposition of the overlying Carboniferous rocks and played an essential role in the formation of the area's mineral veins.

Although very small areas of Devonian sedimentary rocks occur locally in a few parts of the Pennine escarpment, no such rocks of this age are known from Upper Teesdale.

Carboniferous Rocks

Since previous editions of this book, research into the Carboniferous geology of the UK has resulted in major revisions of the understanding and naming of these rocks.

The following is a simplified summary of the current classification of these rocks within Upper Teesdale:



Within these Carboniferous rocks, all of the limestones, many of the sandstones, and some of the shales have names which reflect some characteristic feature of that unit. The names are a legacy of the area's mining and quarrying past and were coined by generations of miners and quarrymen who developed a sophisticated knowledge of the local Carboniferous stratigraphy. Many of the names survive as the formal names in use today in geological science.

Although the term 'Millstone Grit' was previously applied to sandstone-rich parts of the Northern Pennine Carboniferous succession, these sandstones are distinctive both in their character and depositional environment from the classic 'Millstone Grit' of the South Pennines and Derbyshire and the term is inappropriate in this area. These Northern Pennine sandstones are today included within the uppermost parts of the Stainmore formation.

Basement Group

Whereas the unconformable junction of the Carboniferous beds with the underlying Ordovician rocks is not exposed in Teesdale, the Carboniferous Basement Group which includes conglomerates composed predominantly of pebbles Skiddaw Slate and vein quartz, together with thin beds of shales and sandstones, crop out on Cronkley Scar and in the banks of the Tees adjacent to the Pennine Way at Falcon Clints [NY83402900].

Great Scar Limestone Group

Overlying the Basement Group is a thick limestone known, from its type location on the Pennine escarpment, as the Melmerby Scar Limestone. In Teesdale this is up to 38 m thick and is typically a pale grey, thinly- to thickly-bedded marine limestone, commonly with thin clay partings and locally with a rather rubbly appearance, especially near its top.

The Melmerby Scar Limestone, together with the much thinner overlying Robinson and Peghorn limestones and the intervening thin beds of shale and sandstone, which are today correlated with the Great Scar Limestone Group of the Yorkshire Pennines, correspond with the Lower Limestone Group of earlier classifications. Good exposures of them may be seen on Cow Green [NY815310], Widdybank [NY825300] and Cronkley fells [NY843290] where they are much altered adjacent to the Whin Sill (see below).

Yordale Group

This group of Carboniferous rocks, which occupies the greater part of Upper Teesdale, comprises a succession of distinctive rock sequences repeated many times. As outlined above these record the repeated effects of crustal instability and global climate change over a period of roughly 50 million years. The resulting individual repeated sequences of sedimentary rock, or 'cyclothems', are known in the Pennines as 'Yoredale cyclothems' from Yoredale, the old name for Wensleydale in Yorkshire, where they were originally recognised and studied in great detail.

A highly simplified section through a typical Yoredale cyclothem with interpretations of the conditions under which each rock type formed: © Elizabeth Pickett

Although marine fossils, including brachiopods, corals and crinoids, are comparatively abundant in most limestones, they are not always easily seen, and are usually more conspicuous on weathered surfaces. Some of the sandstones contain fossilised animal trails or burrows and fossilised plant roots and stems are also common, especially in so-called 'seatearths' (fossil soils) which may be overlain by a thin coal seam.

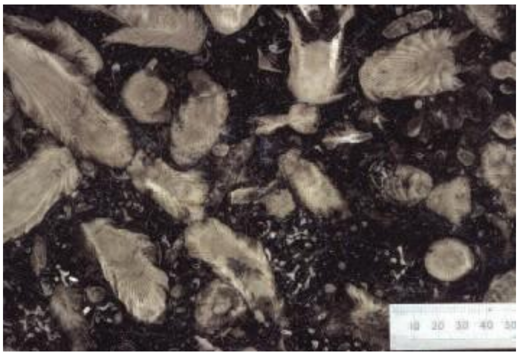
The Yoredale Group corresponds roughly with the Middle and Upper Limestone groups of earlier classifications, and includes those beds previously termed 'Millstone Grit'.

The Yoredale Group is divided into a lower division referred to as the Alston Formation, in which numerous limestones are major components of the succession.

Above the Great Limestone is the division known as the Stainmore Formation in which limestones are fewer and much thinner, with sandstones typically much more numerous and thicker; thin coal seams, some of which have been worked locally, are more common in the Stainmore Formation.

Dark grey cyclindrical shafts of Frosterley Marble in the thirteenth-century Early English Gothic pillars of the Chapel of the Nine Altars, Durham Cathedral: Reproduced by kind permission of the Chapter of Durham Cathedral

Examples of Yoredale Group limestones include the Tynebottom Limestone which forms the bed of the River South Tyne near Alston, the Scar Limestone which forms distinctive scar-like features locally, the Five Yard Limestone which is usually around 4.5 m thick, and the Great Limestone, the thickest limestone within the Yoredale Group. This latter limestone, typically up to 18 m thick, is of interest for several distinctive beds within it which can be recognised widely across the area. Particularly distinctive is the so- called 'Frosterley Band', a bed, up to about 1m thick approximately 6 m below the top of the limestone, rich in fossils of the solitary coral Dibunophyllum bipartitum. It has been worked as an ornamental stone, under the name of 'Frosterley Marble', fine examples of which can be seen in many churches, most notably Durham Cathedral. The Four Fathom Limestone, typically close to 7.3 m (4 fathoms = 24 feet) in thickness, recalls the local lead miners' practice of measuring in fathoms.

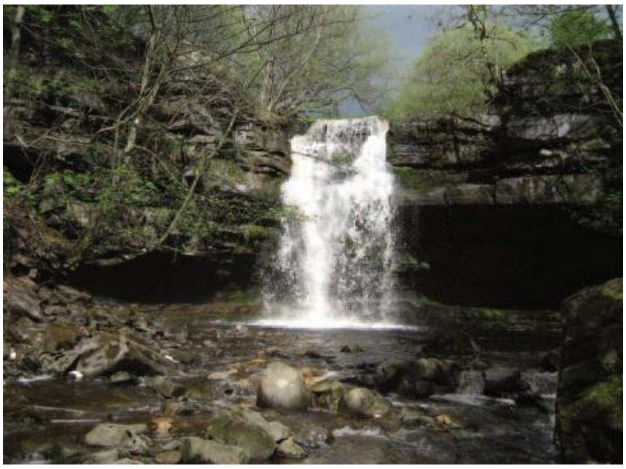


A polished slab of Frosterley Marble showing sections through the coral *Dibunophyllum bipartitum*. The scale bar is in cms: © Brian Young

Most of the Dale's limestones have been worked to make quicklime for use as mortar or as a soil improver and small ruinous limekilns may be seen adjacent to many old quarries.

Within Upper Teesdale the Tynebottom Limestone forms the base of High Force [NY88002838] where at water level it has been eroded into a series of solution cavities. The Cockleshell Limestone is spectacularly exposed on the north bank of the Tees at Scoberry Bridge [NY91042734] where large shells of the brachiopod Gigantoproductus and crinoid stems are conspicuous on the water-worn surfaces.

The Scar Limestone is seen in the old quarry adjacent to Langdon Beck Youth Hostel [NY86023048] and in Bowlees Quarry [NY90762842] alongside the footpath to Gibson's Cave. The Five Yard Limestone forms the lip of Summerhill Force at Gibson's Cave, Bowlees.



Gibson's Cave, also known as Summerhill Force. The Bowlees Beck here tumbles over the overhanging ledge formed by the Five Yard Limestone. The underlying shales and sandstone are visible in the 'cave' behind the fall: © Brian Young

The Great Limestone forms the conspicuous scarp of High Hurth Edge [NY86503130] where the entrance to the Teesdale or Moking Hurth Cave, also in this limestone, may be seen. The old quarries in Hudeshope [NY94852725], north of Middleton, worked the Great Limestone. Typical fragments of the coral-rich Frosterley Band can sometimes be seen in old lead mine dumps further up this valley.

Many of the sandstones, known colloquially by the miners as 'hazle', were also given distinctive names, for example the Six Fathom Hazle (from its thickness), the Nattrass Gill Hazle (from its type location near Alston) and the Slaty Hazle (from the ease with which it could be split into thin slabs suitable for roofing).

To those unfamiliar with Northern Pennine rock nomenclature many of the sandstone names may seem curious as they are commonly referred to as 'sills', for example the Grindstone Sill (from its use in making grindstones), the Firestone Sill (from its use in making hearths and furnace linings) and the Slate Sill (from its breaking into thin slabs). 'Sill' was originally a Northern Pennine miners' term for any roughly horizontal body of rock. As will be explained below, its use to describe what we now know as the Whin Sill led to its adoption as the term for such intrusive bodies worldwide.

Sandstone has long been the stone of choice for building both in Teesdale and across the Northern Pennines. Many of the sandstones provided blocks suitable for farm buildings as well as the many miles of drystone walls. A few easily-split sandstones were worked to give the distinctive sandstone roofing slabs still seen on many of the Dale's older buildings. A hard siliceous sandstone known as ganister, used both for building and for refractory furnace linings, was worked in extensive quarries on either side of the road at Harthope Pass [NY86054476] between Teesdale and Weardale.

Good exposures of the Low Brig Hazle, the sandstone between the Scar and Five Yard Limestone, may be seen in the Bowlees Beck [NY90902858] between Bowlees and Gibson's Cave. The Firestone Sill forms prominent scarp features along the northern side of the Dale north of Langdon Beck [NY86503200] and above High Hurth Edge. The Low Grit Sills sandstone is exposed in the north walls of Coldberry Gutter [NY93102895] and both the Low and High Grit Sills sandstones form conspicuous bench features on the sides of the Hudeshope Valley.

Much of the scenic character of the Dale's landscape results directly from the character of these rocks.

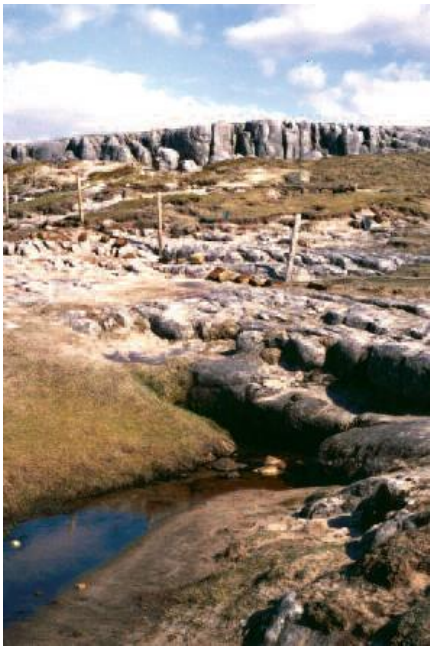
Resistant rocks such as limestones and sandstones typically form steep, and in places craggy, bench-like features on hillsides or flat summits to many of the fells, for example Cross Fell [NY687343]; weaker rocks such as shales characteristically weather to gentle slopes, or slacks, between the benches.

Coal Measures

The Stainmore formation is overlain by a succession of similar sandstones and shales distinguished by the relative abundance of persistent coal seams, and known today as the Pennine Coal Measures Group, formerly extensively worked in the adjacent Durham Coalfield. Whereas Coal Measures rocks are present in the easternmost parts of Teesdale, because their outcrops are small and have little influence on the landscape, they are not considered further here.

The Whin Sill

Some of the most characteristic features of Teesdale's landscape, which distinguish this from all other Pennine dales, are extensive outcrops of the Whin Sill. Composed of the hard dark-grey igneous rock dolerite, this comprises a roughly horizontal sheet-like body that underlies much of North East England, including the Northern Pennines, and central and eastern Northumberland. As already noted in the discussion of geological history, the Whin Sill was intruded into the area's Carboniferous rocks as molten magma towards the end of Carboniferous times, about 295 million years ago. In Upper Teesdale it is up to 75 m thick. Because the molten magma from which it crystallised was injected at temperatures of around 1100˚C, the adjacent rocks were severely altered, or metamorphosed.



Sugar Limestone. At the White Well on the top of Cronkley Fell, a spring rises from the junction of the crumbly weathering white marble with the underlying dolerite of the Whin Sill: © Brian Young

Limestones such as the Melmerby Scar Limestone were altered to coarse-grained white marble, known from its characteristic crumbly weathering as 'Sugar Limestone'; shales were baked to form a very hard rock known as hornfels. The local lead miners referred to this as 'whetstone', though it is not known whether it was ever used for making sharpening stones, or whetstones.

Recent research has revealed the presence of widespread occurrences of magnetite in the altered Carboniferous rocks adjacent to the sill on Cronkley Fell, Cowgreen and beneath Falcon Clints.

The Whin Sill is of interest as being the original 'sill' of geological science. It takes its name from the north of England quarryman's term 'sill' for any more or less horizontal body of rock, combined with the term 'whin', meaning a hard black rock that was difficult to work, and which is said to derive from the 'whinn…… ' noise made when fragments are broken from it. The recognition of its intrusive origin, in the nineteenth century, led to the term 'sill' being adopted by geological science worldwide for all such horizontal intrusions of this sort.

The resistant Whin Sill dolerite gives Teesdale its famous waterfalls at High Force [NY88002838], Low Force [NY90302800] and Cauldron Snout [NY81402868]. The sombre line of dark grey crags, in which vertical columnar joints are conspicuous, at Holwick [NY903269] and Cronkley Scars [NY841294] on the southern side of the Dale, reflect the effects of the Teesdale Fault which displaces the sill down by several tens of metres below present levels of exposure on its northern side (Figure 2). Unusual rendzina soils, developed on the 'Sugar Limestone' at Cow Green [NY815310] and Widdybank Fell [NY825300], support parts of the 'Teesdale assemblage' of rare Arctic-Alpine plant species, including Teesdale's beautiful iconic flower, the vivid blue spring gentian (Gentiana verna). Fine examples of the baked shale or 'whetstone' may be seen alongside the footpath to High Force and adjacent to the Pennine Way downstream from Wynch Bridge [NY90702760].

Whin Sill dolerite has long been an important source of roadstone and aggregate and large abandoned quarries scar its outcrop on the southern side of the Dale between Middleton [NY949246] and Holwick [NY897272]. Extraction continues from a large, but well-screened, quarry [NY87252830] a short distance upstream from High Force.

The Cleveland-Armathwaite dyke

Completing the Dale's suite of 'solid' rocks is the Cleveland-Armathwaite Dyke, an intrusion of dark-grey basalt of Palaeogene age which forms part of the swarm of intrusions centred upon the Hebridean island of Mull. This dyke crops out intermittently across northern England between the Solway and Yorkshire coasts, including at several places on Alston Moor. In Teesdale, it crops out near Ettersgill [NY8846 2954], in Coldberry Gutter [NY92922894] and in Eggleston Burn [NY98972512].

Recent research has identified a hitherto unknown portion of the dyke within the Teesdale Fault in the Harwood Valley [NY805342], concealed at shallow depth beneath Carboniferous rocks and Quaternary deposits.

Mineral veins

The Carboniferous rocks and Whin Sill are cut by numerous small faults which, soon after the intrusion of the Whin Sill, acted as channels for the passage of mineral-rich solutions warmed by heat from the concealed Weardale Granite. As these cooled their contained minerals crystallised within the fault channels to form the mineral veins which provided the basis for the Dale's long history of mining.

The veins, which vary in width from a few millimetres up to over 10 m in rare instances, typically consist predominantly of assemblages of gangue, or 'spar' minerals including fluorite, baryte and quartz, accompanied by smaller amounts of ore minerals such as galena and sphalerite. Adjoining many veins within limestone wall-rocks, the host limestone has been partially replaced for up to several metres on either side of the vein by mineralising solutions, creating extensive bodies of mineralisation known as 'flats'.

A distinctive feature of this orefield is the marked zonal distribution of some of the minerals. A central zone, which includes much of Alston Moor, Weardale and parts of Teesdale, in which fluorite is extremely abundant, is surrounded by an outer zone in which barium minerals, including baryte and witherite, predominate. It was this zonation that first invited speculation on the presence of a concealed granitic body at depth and of its likely role in the formation of the ore deposits. The granite was proved in the Rookhope Borehole drilled in 1960-61. Although the granite was shown to be older than the Carboniferous rocks, its high heat flow is believed to have driven the convective flow of the mineralising fluids that created the area's veins.

Much of Teesdale lies close to the southern margins of the fluorite zone. Lead has been worked from numerous mines in the Dale, the largest of which lie north and north-west of Middleton.

Small amounts of zinc ores were extracted locally and prospecting for this metal was pursued around Ettersgill [NY89052910] during World War II. Attempts to rework old Teesdale lead mines for fluorspar yielded only modest amounts. By contrast, large tonnages of barytes were extracted from mines at Cow Green [NY81053053] and Closehouse [NY85002260], the latter of which closed in the 1990s.

Cowgreen Mine. Miners working underground in a stope in 1949. The baryte vein is clearly seen in the roof: © Friends of Killhope Archive

Mining has left an indelible mark on Upper Teesdale with spoil heaps, ruined buildings and opencast workings, including 'hushes', locally conspicuous. 'Hushes' are wide trench-like opencast workings, traditionally regarded as an early form of hydraulic mining, excavated by the repeated release of torrents of water from specially created reservoirs. However, critical examination of many hushes suggests that they are more likely to have been created by manual excavation followed by flushing with water released from such dams. Notable areas of long abandoned mining in the Dale, perhaps of some antiquity, include the Grasshill Mines in the Harwood valley [NY82103570], the Pike Law Mines on Newbiggin Common [NY90103200] and the extensive old workings around Coldberry at the head of the Hudeshope valley [NY94402930].

One of the Dale's most conspicuous landmarks, the huge trench-like Coldberry Gutter that breaches the watershed between the Bow Lee and Hudeshope valleys [NY92702890–NY93902910], has traditionally been regarded as a particularly large hush. However, it has recently been suggested that the 'Gutter' may be a glacial meltwater channel with only minor modifications due to mining.

Coldberry Gutter, looking west towards the upper part of the Dale. The prominent rock to the left of the hammer is a fine exposure of the Cleveland-Armarthwaite Dyke.Traditionally regarded as a large lead mining hush, the gutter is now thought to be a glacial meltwater channel, excavated along a major fault and mineral vein: © Brian Young

Much of Middleton-in-Teesdale was remodelled in the nineteenth century by the London Lead Company, the main mining company, whose headquarters were at Middleton House [NY9450 2580], the prominent building that dominates the western outskirts of the village.

Communities of (Calaminarian) plants, adapted to thrive on soils associated with heavy metal deposits are discussed elsewhere in this book.Geological maps

Teesdale is covered by British Geological Survey (BGS) 1:50 000 and 1:63 360 scale sheets 25 (Alston), 31 (Brough-under-Stainmore) and 32 (Barnard Castle) with 1:25 000 scale coverage for part of the Dale on Sheet NY82 (Middleton-in-Teesdale).

Further reading

The reader wishing to explore any aspect of the Dale's geology in greater depth may find the following publications useful. References to even greater detailed descriptions in other technical publications are given in most of these:

- Burgess, I C and Holliday, D W, 1979, Geology of the country around Brough-under-Stainmore. Memoir of the Geological Survey of Great Britain, England and Wales, Sheet 31. HMSO, London.
- Dunham, K C, 1990, Geology of the Northern Pennine Orefield (2nd edition); Volume 1 Tyne to Stainmore. Economic Memoirof the British Geological Survey, England and Wales.HMSO, London
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