Introduction

Download full colour PDF North Pennines AONB geodiversity report

Partly in recognition of the area's special geological significance, though also in recognition of local efforts to conserve and interpret Earth science, the North Pennines AONB was the first area in Britain to be awarded the UNESCO-endorsed status of 'European Geopark' in June 2003.

Following that designation, and in order to establish a sound framework and knowledge-base for ongoing programmes of geologically related interpretation, conservation and other activities, in 2003 the AONB Partnership commissioned the British Geological Survey (BGS) to prepare a comprehensive Geodiversity Audit of those geological features present within the AONB. Based upon this audit, and in close collaboration with staff of BGS, the North Pennines AONB Staff Unit prepared a detailed Local Geodiversity Action Plan (LGAP) to guide their work in furthering the interests of geodiversity within the AONB. The Audit and Action Plan were published as a joint document in 2004 (AONB, 2004), the first document of its kind for a protected landscape in Great Britain.

With many of the objectives and action points identified in this original Action Plan successfully completed, a new Action Plan is required for the next five years.

Fundamental to, and underpinning, the framing of any such action plan is an authoritative and comprehensive modern audit of all of those features which comprise the geodiversity resources of the area being considered. Here in the North Pennines, the AONB Partnership believes that the original Audit, published with the LGAP in 2004, provided just such a foundation. Indeed, as was intended at the time of its compilation, the Audit was designed to stand as a reliable reference source for many years beyond the scope of the first Action Plan. With the launch of the new Action Plan, the opportunity has been taken to prepare this revision of the original Audit to incorporate major new work on the area's geology published since 2004, to take into account developments undertaken in response to the original Action Plan, and to reflect such changes as the pattern of mineral working. The Audit is here presented as a separate document intended to inform not only the new Action Plan, but to serve as an authoritative reference source to all who need access to expert information on the wide range of geological features, materials and processes which have shaped and continue to shape, the geodiversity of the AONB.

Revision of the Audit has been undertaken by Brian Young, retired BGS District Geologist for Northern England, in collaboration with Chris Woodley-Stewart and Elizabeth Pickett of the North Pennines AONB Partnership.

A geodiversity audit

Geological time

The rocks of the North Pennines are a tangible record of long past events and earth processes that created, shaped, and continue to shape, the landscape we see today. The events recorded by these rocks date back over almost half a billion years. In order to appreciate, and place these rocks in their true context, it is useful to look very briefly at geological time.

The earth is currently known to be almost 4600 million years old. Because such an immense span of time is almost impossible to conceive, it is helpful to represent the whole of Earth history by a single day. On this basis, the oldest rocks present within the AONB, which date back to about 495 million years ago, were formed at around 10.00 in pm; the limestones and sandstones that make up much of the fells date from between 10.30 and 11.00 pm; the Quaternary ice ages started at about one minute to midnight and the whole of human history took place within the last two seconds to midnight.

For convenience of description and interpretation, geologists, like historians, divide time into manageable units to which they give names. Geological time is divided into Era and Periods, as shown in the diagram. Those geological periods, or parts of periods, represented by rocks within the AONB are highlighted. Significant events in the geological history of the

AONB are indicated alongside the column.

The geological evolution of the North Pennines AONB

Before examining in detail the varied rocks and geological features that together comprise the AONB's geodiversity, and in order to help view these in their true context, it is worth considering briefly the main processes and events which, over geological time, have shaped the area we today know as the North Pennines. Of necessity, this is a very brief summary; more detailed accounts can be found in the literature references cited in the bibliography.

The diversity of North Pennines rocks, their composition, structure, the fossils and minerals they contain, enable geologists to decipher the history and evolution of the area. It is a story which can be traced back over almost 500 million years. However, the record, as contained in the rocks, is incomplete. The diagram opposite illustrates the main periods of geological time and indicates those periods for which there is clear evidence preserved in the rocks of the AONB. For much longer periods of time, the area contains no rocks and thus no direct evidence of events or conditions. For any interpretation of these periods we must rely upon information gathered from the rocks formed elsewhere at these times.

The oldest rocks known in the AONB date from the Ordovician and Silurian periods of Earth history, between 495 and 418 million years ago. The configuration of landmasses across the earth was then very different from today. At this time the area which was to become the North Pennines lay south of the equator, where it formed part of a deep ocean, known to geologists as the Iapetus Ocean, on the northern edge of a continental plate, known as Eastern Avalonia. Mud and sand, which accumulated in this ocean, are preserved today as the mudstones and sandstones of the Skiddaw Group. Eastern Avalonia was then moving gradually northwards towards another huge continent, known as Laurentia, which included what would eventually become Scotland and much of North America. Huge stresses in the earth's crust, caused by the movement of these continents, resulted in the enormous volcanic eruptions which created an enormous thickness of volcanic rocks, known as the Borrowdale Volcanic Group. Further accumulation of muds and sands formed the vast thickness of rocks known today as the Windermere Supergroup. As these continents finally collided, the Iapetus Ocean was destroyed and crumpling of the rocks brought into being a new mountain chain across what is now northern England.

Associated with the creation of these mountains was the emplacement, about 410 million years ago, deep beneath the surface, of a huge body of granite known as the Weardale Granite. This granite was to have a profound influence on the area's subsequent geological history and upon the formation of its mineral deposits.

The Ordovician and Silurian rocks, which are known to underlie the whole of Northern England, are best seen at the surface today in the Lake District, but are also exposed along the foot of the North Pennine escarpment and in a small part of Upper Teesdale, where they emerge from beneath their cover of Carboniferous and younger rocks. They have also been proved in a handful of deep boreholes in the North Pennines and adjoining areas.

There are few rocks in northern England which can be reliably dated to the period of earth history known as the Devonian period, between about 400 and 360 million years ago. However, conglomerates exposed locally on the Pennine escarpment may represent accumulations of boulders and gravels deposited amongst the eroding mountains.

By the beginning of the Carboniferous Period, around 360 years ago, our area had moved to a position almost astride the equator. At this time much of what is today northern England began to be progressively submerged beneath a wide, shallow tropical sea, in the clear, warm waters of which beds of limestone accumulated. Periodic influxes of sand and mud, deposited by deltas building from a landmass to the north or north east, periodically established swamp or delta top environments, occasionally with the development of lush tropical forests. The evidence for these conditions is preserved today as the layers of sandstone, mudstone and coal seams of the Carboniferous rocks. As Carboniferous times progressed, tropical forest cover become much more frequent, the remains of which are preserved today as the coal seams of the Coal Measures.

The Weardale Granite exerted a strong influence on the nature of Carboniferous rocks across the area, particularly in early Carboniferous times. Granite is less dense than most rocks in the earth's crust. It is therefore rather buoyant, tending to rise relative to the rocks which surround it. Because of this, as the area which was to become the North Pennines gradually subsided at the beginning of the Carboniferous Period, the 'block' of Ordovician and Silurian rocks, together with the Weardale Granite, tended to subside less rapidly than the surrounding areas. As a result a much thinner succession of Carboniferous limestones, mudstones and sandstones accumulated on this 'block' than in the adjoining areas. Geologists term this area the 'Alston Block'. A similar 'block', also partly underpinned by an old granite, comprises the area known as the 'Askrigg Block' of the Yorkshire Dales. The North Pennines AONB encompases much of the Alston Block and the very northern most parts of the Askrigg Block. Separating these, in the Stainmore area, is the belt of much more rapid Carboniferous subsidence, and thus of much thicker Carboniferous sediments, known as the Stainmore Trough.

Towards the close of Carboniferous times, about 295 million years ago, continuing stretching of the earth's crust allowed the up-welling of huge volumes of molten rock from deep within the earth. This basic magma did not reach the surface, but spread out as sheets and layers between the existing Carboniferous rocks. As it cooled and crystallised to form the dolerite of the suite of intrusive rocks collectively known as the Whin Sill, its heat profoundly altered many of the adjoining rocks, turning limestone into marble and shales into 'hornfels', or as it is known locally,'whetstone'.

Shortly after the formation of the Whin Sill, mineral-rich waters, warmed by heat from the Weardale Granite, began to circulate through cracks and faults in the rocks deep within the earth's crust. Their dissolved minerals crystallised within these fissures, forming the veins and associated deposits of the North Pennine Orefield.

Major earth movements towards the end of Carboniferous times once more created mountains across what became northern England. By about 280 million years ago, during the Permian Period, the area which was to become the North Pennines lay within tropical latitudes and became an arid desert. Rapid erosion by flash floods built up fans of debris at the foot of the mountains; shifting sand dunes developed on the flatter ground. We see these today as the Brockram and Penrith Sandstone respectively, in the Vale of Eden.

By the onset of Triassic times, about 245 million years ago, the area which is now Cumbria was a wide plain crossed by vast meandering rivers, building up the deposits we know today as the Eden Shales and the St Bees Sandstone.

From about 230 million years ago evidence for the area's geological evolution falls largely silent. We know that during the Palaeogene Period, about 65 million years ago, narrow dykes of basaltic rock were injected into fractures as distant manifestations of the vast volcanic activity associated with the opening of the Atlantic Ocean that was then shaping the Hebrides and Northern Ireland. Apart from this we have no tangible evidence of our area's geological history until the deposits left by ice sheets during the glacial period which began here about 2 million years ago. Much of the form of the present day landscape derives from the effects of this prolonged period of ice cover and its subsequent melting.

Centuries of human occupation and exploitation of the area's natural resources, have further modified the landscape into that which we see today. This landscape is still evolving through continuing human influence. The challenge for the conservation of the area is to encourage beneficial change without detracting from its overall character.

Selected references

Dunham, 1990; Johnson, 1970, 1995; Stone et al, 2010.

The North Pennines' place in the development of geological science

Geological science developed in large part from the observations and deductions made by practical miners and civil engineers. Their observations and deductions relate to geological sites and features which may still be visible today.

As one of the earliest worked, and economically most important, of Britain's metalliferous orefields, the North Pennines was an important centre for the application of geological principles long before geological science, as we recognise it today, emerged.

There can be little doubt that much successful mineral exploration and working in early centuries was made possible only by the skilful application of hypotheses developed through systematic observation by countless unknown and forgotten miners. By the early 19th Century, several local figures emerge in the contemporary scientific literature as significant leaders in what was eventually to be seen as geological science. Notable figures include Westgarth Forster, William Wallace and Thomas Sopwith. Although many of their ideas are now outdated, and in some instances discredited, their contributions to the development of understanding of North Pennine geology are undeniable, and stand as important milestones in the wider development of geological science.

Throughout subsequent years the area has been a fertile source of inspiration for research. Particularly notable is the seminal work of Sir Kingsley Dunham, who together with research colleagues such as Professor Martin Bott, developed the hypothesis of a buried granite beneath the North Pennines to explain the origins and nature of the area's mineral veins. The proving of this granite in the Rookhope Borehole was to prove a major milestone in the evolution of thinking on ore-forming processes worldwide.

The north of England has given geological science one of its most familiar terms. To the North Pennine miner a 'sill' was any more or less horizontal body of rock. The name 'whin', meaning hard, black and intractable, was applied to one particular unit. When, in the 19th Century, the intrusive igneous nature of the Whin Sill was recognised, the term sill was soon adopted worldwide for intrusive bodies of this sort. It is not known exactly where in northern England the term Whin Sill was first used by miners and quarrymen, though the North Pennines seems highly probable.

The AONB also includes the type locations for four mineral, and several fossil, species, first discovered here.

The area is still, and is likely to remain, a focus for much significant geological research both in its own right and as a component part of the geology of Great Britain and Europe.

This Geodiversity Audit and its first accompanying Action Plan was the first such document published for any protected landscape in Great Britain.

Selected references

Dunham, 1990; Forbes et al, 2003; Forster, 1809; Johnson, 1970, 1995; Sopwith, 1833; Stone et al, 2010; Wallace, 1861.

Figures

(Figure 1) Map of the North Pennines Area of Outstanding Beauty

(Figure 2) Jeffrey's chimney above Ramshaw Elizabeth Pickett/NPAP

(Figure 3) North of Nenthead — Charlie Hedley © Countryside Agency.

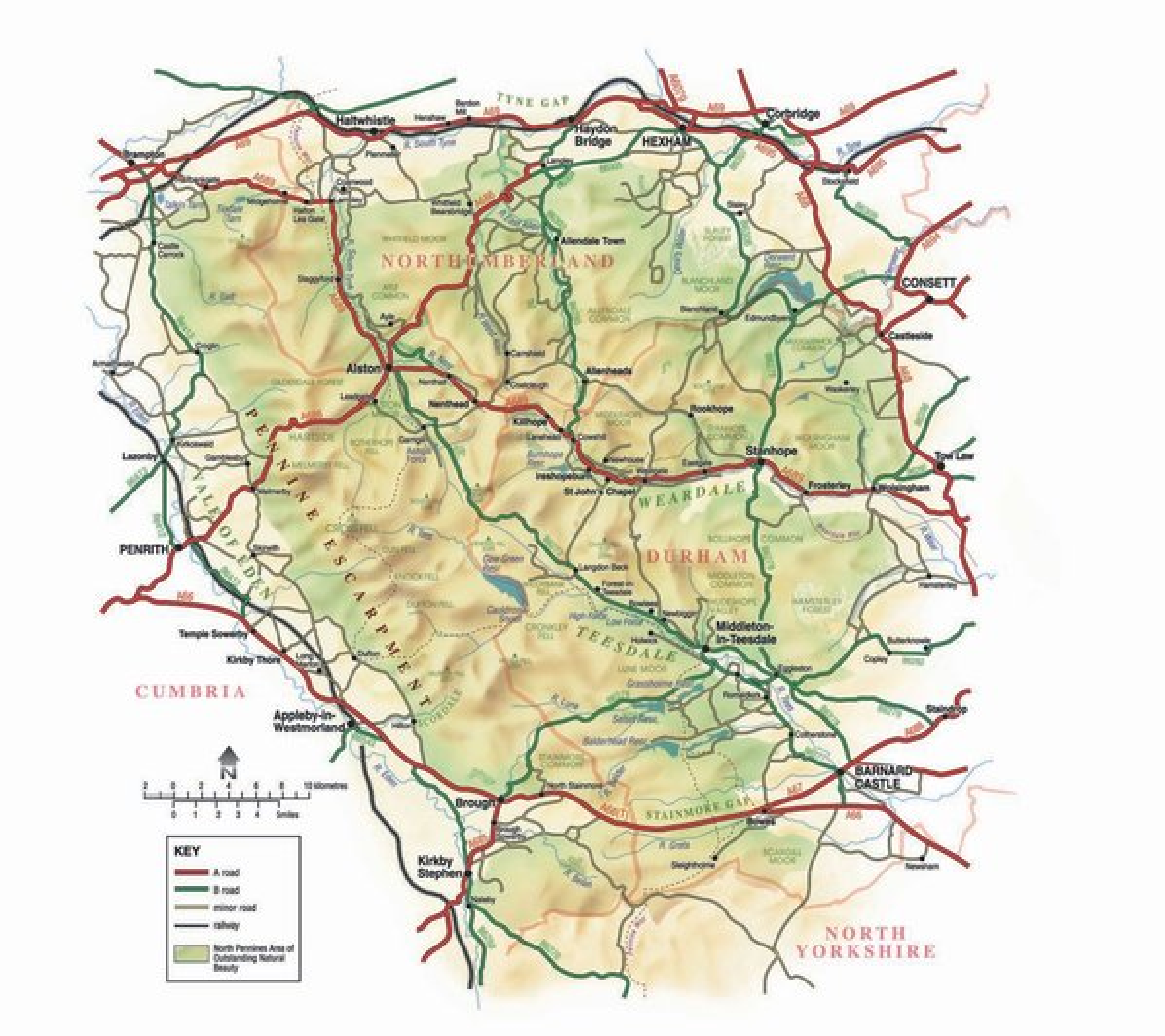
(Figure 4) Dufton Pike (left), Knock Pike (right) and Dufton Fell — Charlie Hedley © Countryside Agency.

(Figure 5) Geological time. Stratigraphic column

(Figure 6) A simplified geological map of the North Pennines AONB

(Figure 7) Park Level, Killhope © Elizabeth Pickett/NPAP

Full references

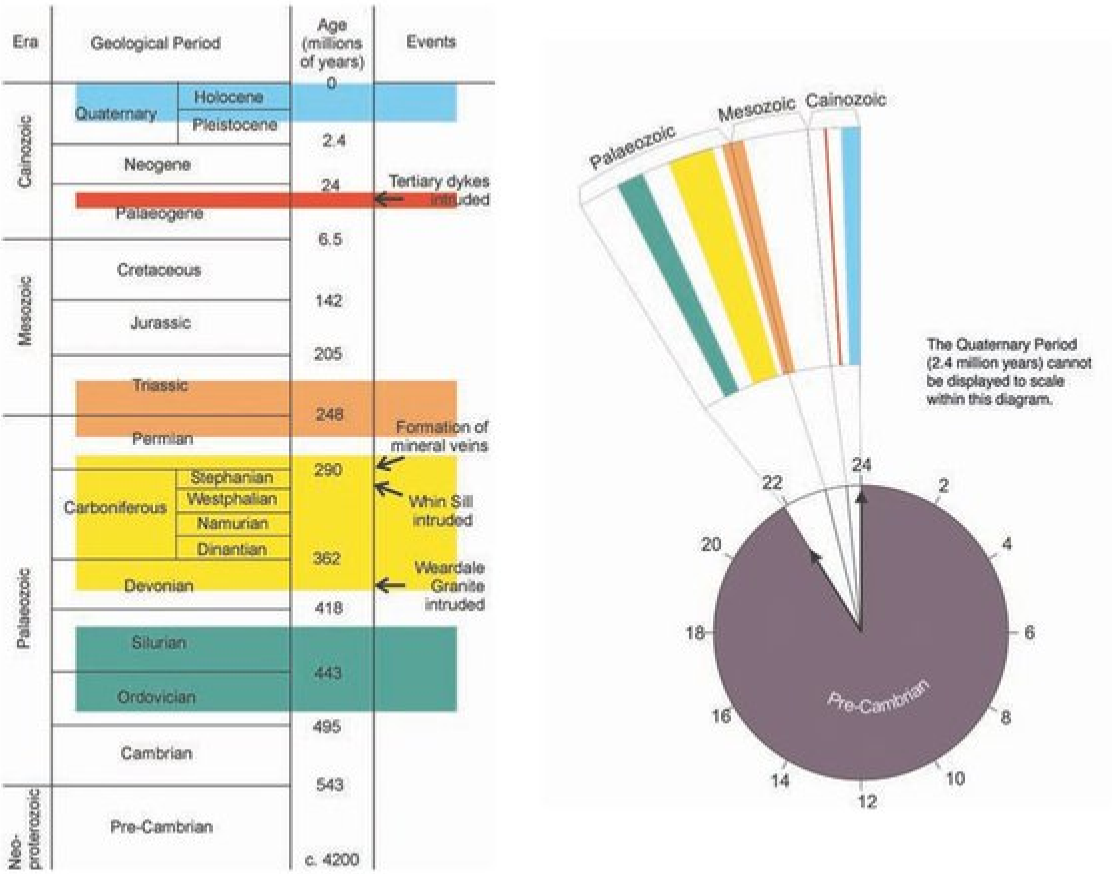


Map of the North Pennines Area of Outstanding Beauty.

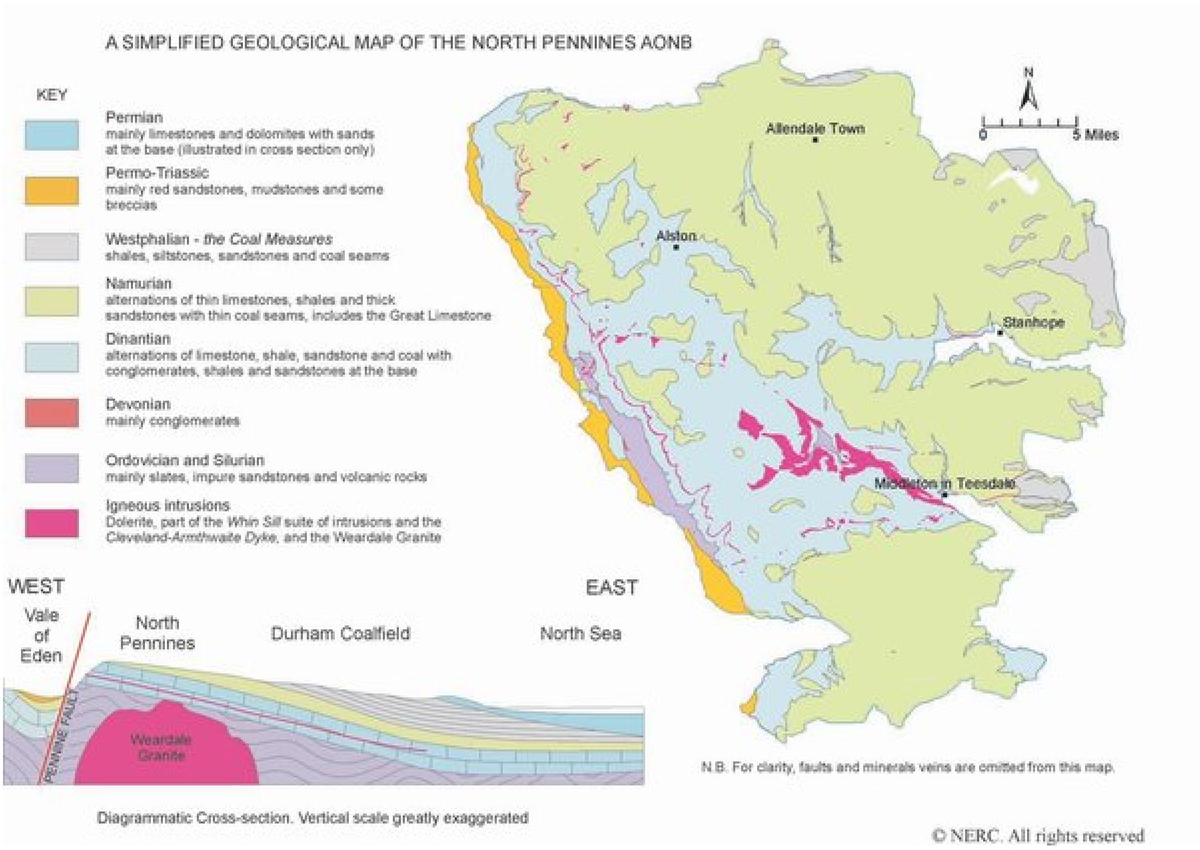
Jeffrey's chimney above Ramshaw Elizabeth Pickett/NPAP.

North of Nenthead – Charlie Hedley © Countryside Agency.

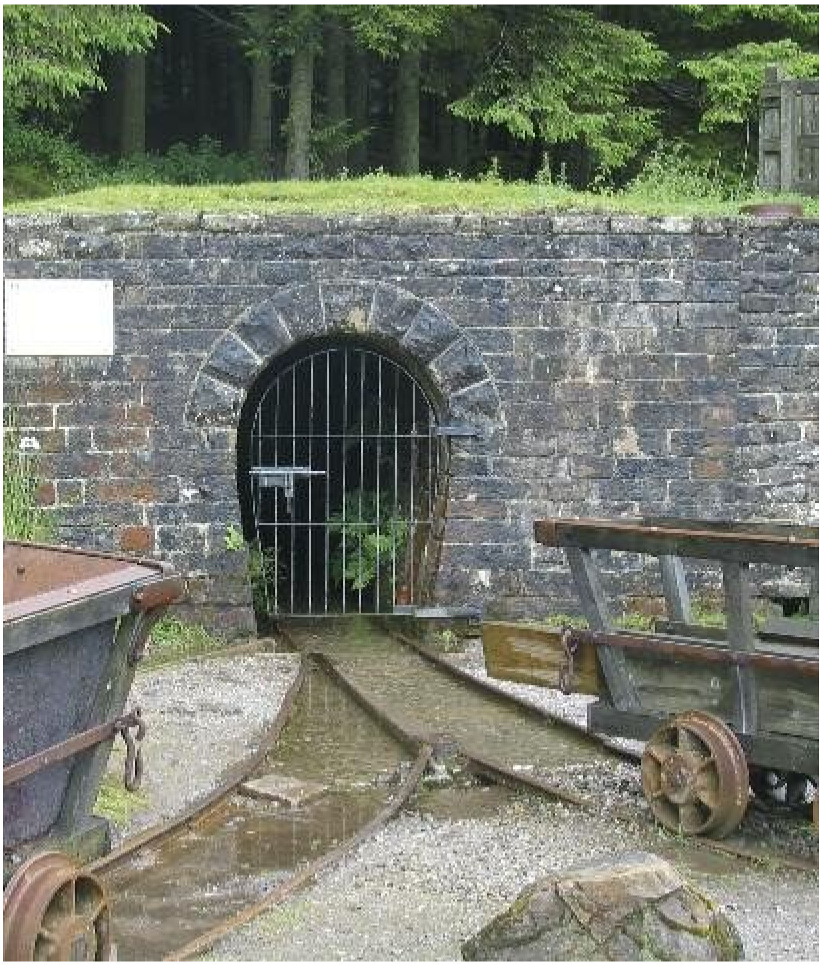
Dufton Pike (left), Knock Pike (right) and Dufton Fell – Charlie Hedley © Countryside Agency.



Geological time. Stratigraphic column.



A simplified geological map of the North Pennines AONB



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