

The Geology of Calderdale

Calderdale is underlain by rocks which date from the **Upper Carboniferous period** and are about **310 million years old**, as shown by the arrow on the table. They fall into two groups. The older group, the **Millstone Grits**, form the high Pennines and consist of sandstones and mudstones. The rocks to the far west of Calderdale and to the east of Halifax are called the **Coal Measures** and they are slightly younger than Millstone Grit rocks. The thickness of sandstones in the Coal Measures is reduced and mudstones become predominant. Amongst the mudstones are many seams of coal, hence the name.

AGE	GEOLOGICAL PERIODS	LATITUDE OF BRITAIN	MAJOR EVENTS	mountain uplift
2Ma	QUATERNARY			
	TERTIARY			
100Ma	CRETACEOUS	54° N	Extinction of dinosaurs	
		40° N	Chalk formation	
200Ma	JURASSIC	20° N	Dinosaurs Limestone formation	
	TRIASSIC		Salt, potash formation	
300Ma	PERMIAN	10° N	Desert conditions	
	CARBONIFEROUS	equator	Coal Measures Millstone Grit Carboniferous Limestone	
400Ma	DEVONIAN	20° S	Semi-desert	
	SILURIAN		Shale, mudstone (now slate)	
500Ma	ORDOVICIAN	60° S		
	CAMBRIAN		Early invertebrates	
600Ma	PRECAMBRIAN		Early life	
4600Ma	FORMATION OF EARTH			

Ma – Millions of years

The rocks of the Millstone Grit Series

These rocks were laid down in **deltas** on the edge of a large continent, with mountains to the north and south. Sands and muds were deposited in shallow water by large rivers. The sandstones and grits are made of sand grains which can be seen in fresh, unweathered rock. With a hand lens you can see quartz grains which are a grey colour, while feldspars are pink, white or cream.



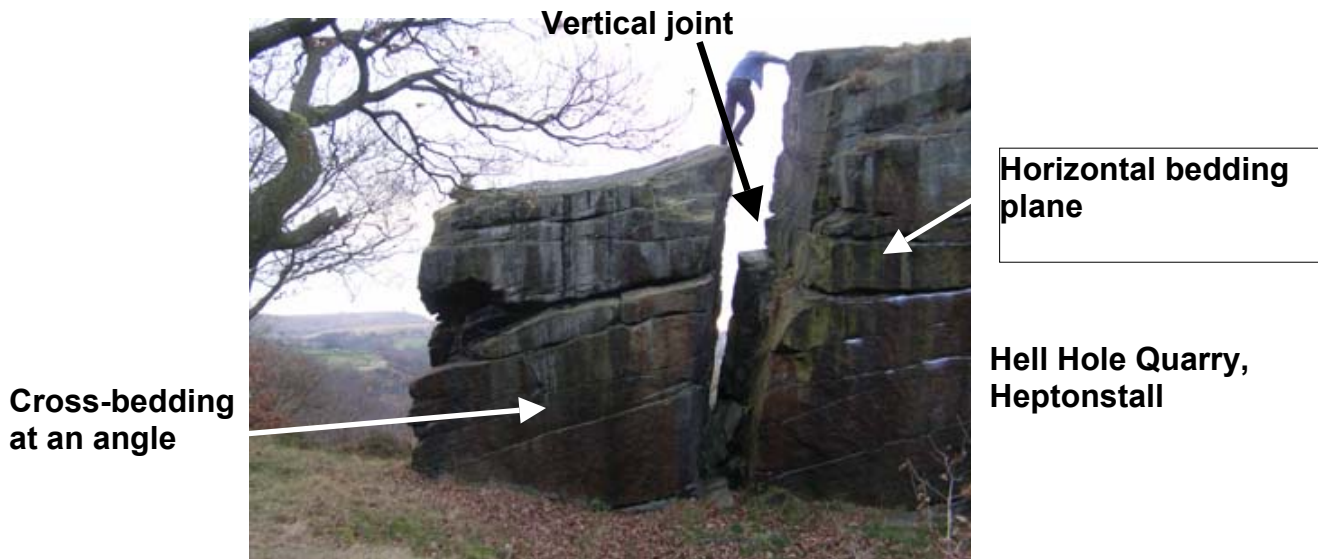
These rocks are made from sands deposited in a river delta. Many of the sand grains are large in size and angular in shape when you look at them through a hand lens. Rivers tend to transport sand grains during flood times only. That means that most sand grains remain angular instead of becoming rounded, because they are not subjected to collisions with other sand grains or the river bed except during occasional floods. Sandstones with coarse, angular sand grains are called **grits** or **gritstones**.

Photo of Rough Rock sandstone with small ripples, formed by movements in gentle river currents

In most quarries in Calderdale you will see that the sandstones have lines on the rock faces which run in two directions. The horizontal lines are called **bedding planes** and show that there were times when the river flow slackened and sand deposition temporarily ceased. Between some of the bedding planes are other lines which slope at a gentle angle. These represent sand banks in the river channel. This feature is called **cross bedding** and is common in river sandstones.

Cross-bedding is formed in a river channel in which sand grains are being rolled along the river bed by fast flowing water. The grains avalanche down the front face of sand banks and settle at an angle of about 15° – 20°. Generally, each cross bedded set has been eroded by another flood of water, so the top of each sand bank has been washed away, truncating the cross-bedding.

In Hell Hole Quarry, Heptonstall, a massive exposure of Lower Kinderscout Grit is seen in a 20m high quarry face. The site shows cross bedding on an enormous scale, containing beds dipping at approximately 30° within the nearly horizontal bedding planes. These cross-bedded sets represent the sandbanks in an enormous river channel, probably equivalent to those of the Mississippi or the Nile rivers, as



Some sandstones show **slump bedding**, with interesting contortions of the cross bedding surfaces. As the wet sand of the delta was being covered by more sediment, the water in it was able to escape upwards, distorting the bedding surfaces. This might have happened suddenly, perhaps due to an earth tremor. These features are called **soft-sediment deformation structures**, as shown in the photo to the right.



Mudstones

Mudstones (which are often called shales) were deposited from fine clay particles, usually in lakes or swamps between river channels. The photo to the left is of mudstones in the quarry below Beacon Hill, Halifax.

These are rocks made of clay particles, which are microscopic in size. The clay particles have a complex chemistry, compared with sandstone which is largely made of quartz. Soils which develop on mudstones are usually more fertile than those which develop on sandstones.

Turning sediments into rock

After the sediments were formed in shallow water close to or just above sea-level, they were **buried** by hundreds of metres of sediment and **compressed** so that the water was squeezed out. This water moving through the sediments carried minerals which **cemented** the sand and mud grains together to make **sandstones** and **mudstones**.

After the river sands had been turned into a rock by being deeply buried, compressed and cemented, earth movements fractured the brittle rock and caused cracks, called **joints**, to develop. These are often near-vertical and cut through the bedding planes and the cross-bedding. A joint which has been weathered is shown on the photo of Hell Hole Quarry, Heptonstall.

Many Millstone Grit sandstones are yellow or pale brown. This is because iron has been washed through the rock later. The iron is probably **leached** out of the mudstones which lie between each sandstone. The clay particles in the mudstones are rich in chemical elements and because iron is soluble in some conditions, it gets washed out of the water in the sediments as they are compressed. The iron is then free to **migrate** into the pore-spaces in the sandstones, giving them the characteristic yellow/brown colour when they are fresh.

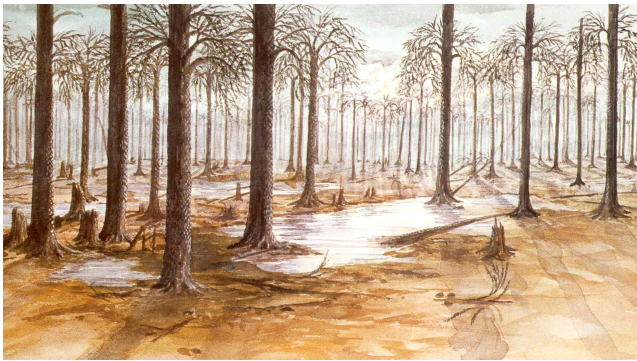
Sandstones in Calderdale

As you can see from the geology map, Calderdale has four main sandstones in the Millstone Series. The oldest sandstones are the **Upper and Lower Kinderscout Grits** which are characteristically coarse sandstones, with rounded quartz pebbles. The rivers which deposited these sandstones were probably moving fast, as their velocity was great enough to drag pebbles along the bottom of the channel, when the river was in flood. Kinderscout Grits make up the high moorlands of the tops of the Pennines, such as Heptonstall Moor and Bridestones Moor.

Midgley Grit is the next youngest in the sequence and is found to the east of the Kinderscout Grits. It is seen in the moors about Ripponden and on Midgley Moor itself. In Lancashire, the sandstone of the equivalent age is called the Gorpley Grit and forms a thin band running north-south along the western flanks of the Pennines. It is one of the sandstones which form waterfalls in Gorpley Clough.

The **White Rock** (called the Holcombe Brook Grit in Lancashire) is not particularly white, but is certainly paler and finer-grained than some of the other sandstones. It forms a narrow outcrop around Barkisland, Sowerby Bridge and Wainstalls.

The youngest of the Millstone Grit sandstones is called the **Rough Rock** and is very extensive in the east of Calderdale. It is a thick sandstone which is ideal for building stone so it is quarried wherever it is found in West Yorkshire. Elland, Halifax and Ovenden all stand on the Rough Rock, which forms gently-sloping platforms dipping to the east.



Carboniferous forests, from *Atlantic Geoscience*



Kinderscout Grit at Widdop

Coal Measure rocks

To the east of Halifax and Elland and in the very west of Calderdale around Todmorden, the rocks are slightly younger than the Millstone Grit rocks and are called the **Coal Measures**.

The Coal Measures comprise sandstones and mudstones, with the addition of **coal seams**. By this time, the delta that was building out from the high mountains over Scotland was extensive and stretched into the English Midlands. Most of the landscape of the area which is now Scotland and Northern England lay in the marshy, muddy swamps on the top of the delta and was above sea-level for much of the time.

Because the continent on which Britain now lies, was close to the equator 310 million years ago, the climate was warm and wet, so that tropical rain forest flourished. Dead plant material became trapped in stagnant swamps between river channels. Over time it was buried by muds and sands as the rivers in the delta changed position and built up more deposits. The water, oxygen and hydrogen were driven out of the plant remains, leaving only the carbon in **coal seams**.

The sandstones formed in this environment tend to be finer-grained than the sandstones of the Millstone Grit series. They have bedding planes which are more closely spaced and often do not contain large-scale cross-bedding. It is thought that they represent the silty grains carried by rivers, deposited in lakes or sandflats, rather than in river channels, like the Millstone Grit sandstones were.

The best example of these rocks is the **Elland Flags**, the famous sandstones found to the east of Halifax, around Rastrick, Brighouse, Southowram and Northowram. They are ideal for use as flagstones and roofing slates, so were quarried and mined in many areas. They have closely spaced bedding planes and are a green or grey colour, so can be easily distinguished from the Millstone Grit sandstones which are usually buff or yellow when they are fresh. However, weathering turns most sandstones to a darker shade, so it is difficult to tell them apart unless you see a freshly hammered rock.

Coal mining

The coal seams in the Coal Measures vary in thickness. Thin, black, crumbly coal seams, often only a few centimetres thick, are seen in mudstones from time to time. However, coal seams in Calderdale can reach 30 – 50 centimetres and are thick enough to have been worked economically in the past. Nowadays, coal seams need to be at least 1 metre thick to be worked by machinery, but when most of the coal extraction was done by hand, thinner coal seams could be exploited.

As an example, adits (tunnels) can be seen in Godley Cutting, just east of Halifax, where the 36 Yard Coal outcrops. There are several coal seams which have been exploited in the Beacon Hill and Shibden Dale areas, probably for several hundred years. They are all less than 1m thick, so became uneconomic. The mine ventilation chimney and furnace above Cunners Wood, built in the 1820s, is a scheduled ancient monument. There were many **coal pits** in this area, which are recorded on maps and in place names. Sometimes there is still evidence of disturbed ground or a **shaft top**.

Todmorden Moor lies just on the edge of the Lancashire coalfield and has many coal seams lying between mudstones and sandstones. The coal seams (often called 'mines' in this district) include the 6 Inch Coal, followed by the Bassy Coal, the Lower Foot Coal, the Lower Mountain Coal, the Upper Foot or Bullion Coal and Upper Mountain Coal. They vary in thickness from 15cm up to about 60cm.

There is often a layer of grey clay above and below a coal seam. This is called **fireclay** and is the remains of the soil layers in which grew the trees and ground vegetation that formed the coal. Many of the coal seams on the Todmorden Moor area were underlain by several metres of fireclay, which was exploited for use as refractory bricks, for instance, at Saunder Clough, in Dulesgate.

Fossils in Millstone Grit and Coal Measure rocks

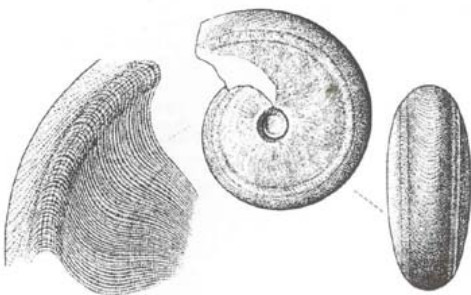
Some sandstones have surfaces which are covered with fossils of **tree branches**. These would have been abandoned on a river sand bank, when a flood washed tree trunks and branches downstream. The branches were then covered by another layer of sand which has preserved them as impressions.

Quarrymen were not generally enthusiastic about using blocks of sandstones containing tree fossils for building. The fossil would have been a weakness in the block of stone, so they used them in field walls instead, which is why it is not difficult to see tree fossils on stone walls when walking in Calderdale.



Plant fossils in Ogden Kirk quarries, near Ogden Water, Halifax

Goniatite



Goniatite - Reticuloceras bilingue x 1 1/2

Drawing from *Palaeozoic Fossils*, Natural History Museum

Between the sandstone beds are mudstones, which were laid down in quiet water on the delta top in marshes or lagoons. They often contain very good plant fossils from the surrounding forests. Sometimes however, the sea-level rose, so sea-water flooded across the low parts of the delta. Marine animals were washed inland and often fossilised in the mudstones.

These thin beds of mudstone which include marine fossils are called **marine bands**. Geologists are particularly interested in these marine fossil beds, which allow correlation between coal seams in other parts of the Lancashire and Yorkshire coalfields.

The most important fossils in the marine bands are **goniatites**, which were animals that floated around oceans. They had shells like the present day *Nautilus*, which is still found in warm oceans. Goniatites are ancestors of the ammonites, a very well-known group of fossils which are found in rocks of the Jurassic and Cretaceous periods.

Todmorden Moor has many marine bands interspersed with coal seams. These have been fossilised in an unusual way, because carbonate minerals from sea-water have deposited around the fossils in the marine bands, forming rounded nodules. Many of the mine spoil tips on the moor yield goniatite fossils within carbonate nodules.

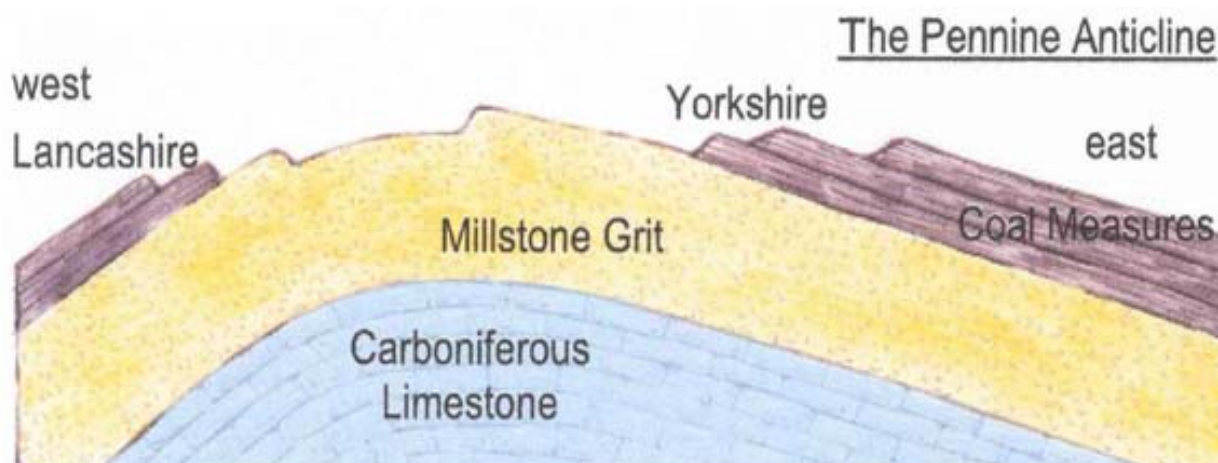
The carbonate minerals also soaked through into the coal seams and deposited around the plant fossils which ultimately formed coal. These nodules are called **coal balls** and are not made of coal, but are found in coal seams. They were very inconvenient for the coal miners because they were heavy and had to be moved out of the way as waste. However, nineteenth century geologists realised that the nodules contained excellent plant fossils, many of which had their cell structure preserved perfectly. Discovery of these plant fossils led to the study of **palaeobotany**.

A coal ball found on Todmorden Moor which contains perfectly-preserved plant fossils



Variscan mountain building

This episode of mountain building culminated at the end of the Carboniferous period, when there was a major collision between two tectonic plates. It resulted in the uplift of a high mountain range across Europe. This affected south-west England more than the rest of Britain. However, northern England was uplifted into the **Pennine anticline**, which is an upfold. So the present Pennines were formed at the end of the Carboniferous period as a range of hills trending north-south from the Midlands to southern Scotland.



In the 300 million years or so since the Variscan orogeny, the Pennine anticline has been eroded as you see from the diagram above. Younger rocks, which include most of the Coal Measures, have been worn away from the top of the anticline by weathering and erosion. Calderdale lies across the top of the anticline, so the rocks in the Halifax area dip very gently eastwards.

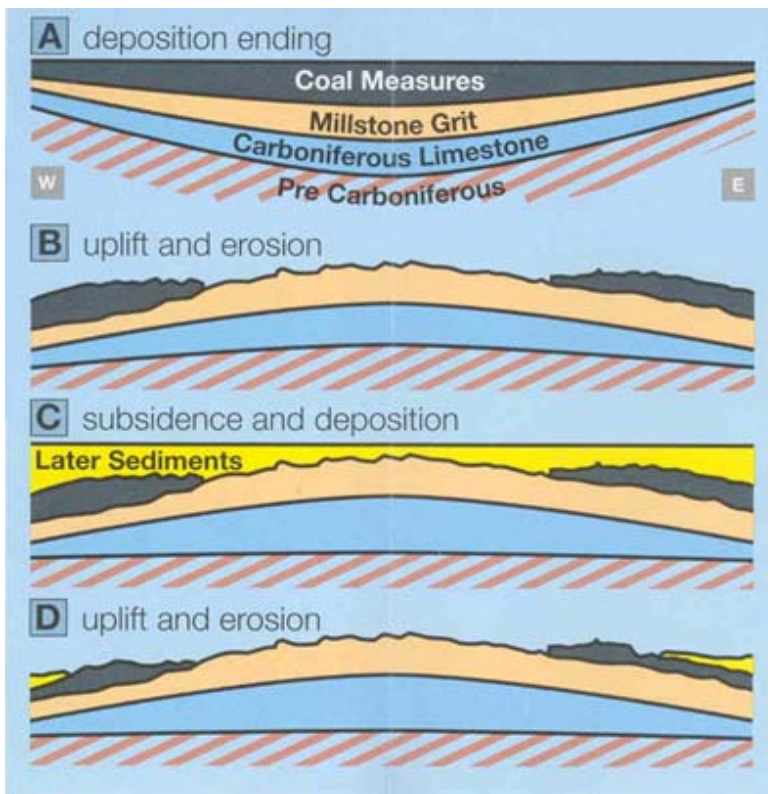
At the same time, the brittle crust underneath northern England was under tension, so Variscan plate movements caused it to fault and fold. The geology map shows the **Todmorden Smash Belt** which probably developed at this time. It consists of many small **faults**, running generally north-west to south-east along what is now the Cliviger valley. Because the rocks along the faults are broken up by movement (which would have caused earthquakes when they occurred) the ground is weaker, so rivers have easily been able to erode the steep-sided valley.

The rocks on the west side of Calderdale dip westwards as can be seen in the sandstones in Gorpley Clough and on the hillside below Stoodley Pike. The diagram below shows the sequence of events which formed the Pennine Hills.

The missing 280 million years

For the last 280 million years, northern England has been an upland area on a continent which has been moving slowly northwards from the equator. As the area remained above sea-level for most of that time, only thin layers of sediments were deposited, and the main activity has been the weathering and erosion which formed our present landscape.

Vegetation flourished in warm times and animal life developed, as birds, reptiles and mammals evolved. However, because any sediments and rocks have been eroded away, there is very little evidence to show what happened from the late Carboniferous period until the onset of the ice ages 1.8 million years ago. So dinosaurs may have roamed the Pennines during the Jurassic and Cretaceous periods, but we have no evidence of that!



Glaciation

During the last 30 million years global climate has been cooling, culminating in the development of huge **ice-sheets** in the last 1.8 million years, which is called the **Pleistocene** period.

Global temperature fluctuated during Pleistocene, times resulting in many advances and retreats of ice sheets over Northern Europe. Ice sheets grew in cold times in high mountain areas and advanced into the lowlands. However, most of the evidence of early ice advances has been obliterated by later events.

The last glacial stage, called the **Devensian**, was at a maximum about 17,000 years ago and ice covered the high ground to the north of Calderdale. As temperatures rose, ice melted and ice sheets became thinner. In the final stages of the glacial event, the thickest ice was confined to the valleys, particularly in lowland Lancashire and the Vale of York.

Calderdale was not covered by ice during the last glacial stage, though it would have been in previous ice advances. Glacial till, which is the material deposited by ice sheets as they melt, is found in the area around Holme Chapel, so it is clear that ice advanced some way along the Cliviger valley from the Lancashire lowlands.

There is evidence that melt-water from the Lancashire ice sheet was able to find its way through the Cliviger valley and down the Calder valley, probably eroding down the line of weakness of the Todmorden Smash Belt.

How Holme Chapel in the Cliviger valley would have looked about 17,000 years



Landslipping

Landslides are very common all along the steep slopes of the Calder valley and its tributary valleys which have alternating sandstones and mudstones. This is inherently an unstable situation, which is made worse by the fact that many of the valley slopes in this area are already very steep. When the sandstones become heavy because they are saturated with water, they slide over the softer, unresistant mudstones.

The steep slopes of many of the valleys were modified by landslipping after the ice sheets in northern England had melted, about 14,000 to 12,000 years ago. The climate was still very cold so there was little vegetation to stabilise valley slopes.

Trees reduce the likelihood of further landslipping, because they take water from the ground so reducing the lubrication in the soil. Their roots support the subsoil and find their way into joints in the solid rock.

During winter, water in the rocks and subsoil would have frozen but in the summers it melted, so that sandstones at the top of the slope would have been able to slide down a weakness in the lubricated mudstones. Even now, landslides are still common, particularly after wet winters.

Curved landslip scars are visible on many valley sides, such as below Stoodley Pike. Gorpley Clough had four small landslips during autumn 2010, probably because of heavy rainfall.



Stoodley Pike



Landslip above Lobb Mill in 2005

Landscapes in Calderdale

The **landscape** of West Yorkshire is largely controlled by underlying geology. The Rough Rock is a thick, resistant bed of sandstone which forms many gently sloping plateaux in the Huddersfield and Halifax areas. Sandstones are more resistant than mudstones and they form the upland moors, while the mudstones are less resistant and are weathered and eroded more easily, so are exposed in cloughs and valleys.

This pattern of erosion of the sandstones and mudstones is common and gives West Yorkshire its characteristic landscapes of flatter moorlands, formed by sandstones and steeper slopes, formed by mudstones.

Many of the moors are covered with **peat deposits** which started to form during the Atlantic climatic period about 7000 to 5000 years ago, when the climate was particularly cold and wet. The peat is up to 2 or 3 metres deep in some places.

View from Albert Promenade, above Scarr Wood, Halifax, showing the benches formed by sandstones beds, contrasting with the steeper slopes which are made of mudstones, protected from weathering and erosion by the overlying sandstones.



Quarrying for sandstone

All of the Millstone Grit sandstones are excellent **building stones** because they have regular joints and bedding planes. These made it easy for the quarrymen to break the stone into blocks that could be transported, without needing any blasting with dynamite which would have damaged the stone. Clearly most quarries were located near to the main settlements, so that stone did not have to be transported too far. However, small quarries were opened up wherever there was a need for them, so there are many small pits or delphs near hamlets and farms on the moorlands.

All the sandstones were used for building stone and for setts and kerbs for roads and yards. Large blocks of rock were taken off the quarry faces with cranes or crowbars. The blocks would have been very large and were probably split into smaller sections using **plugs and feathers**. The stone would have been shaped into building stones by stone masons with hammers and chisels. Any irregular stones would have been used for building field walls and any waste left over was probably crushed for sand and gravel for making tracks and roads

Rough Rock, found in the east of Calderdale as well as Kirklees and Bradford, can be worked into an excellent building stone so has been widely quarried throughout West Yorkshire. The **Elland Flags**, which have a green/grey colour, have also been exploited widely, particularly in the Northowram, Southowram and Hipperholme areas. They were used for flagstone and roofing slates, as the bedding planes are close together so the rock splits evenly.



Wood Head Quarry, Hipperholme, is one of several quarries in the area where the Elland Flags were mined as well as quarried. There is a small mine entrance, which should not be entered, at the base of this privately owned quarry.

Use of building stones

Heptonstall shows the use of the building stones very well, although all the old settlements in Calderdale would have used their local stone. The biggest blocks of stone could be sawn into lintels and mullions for doors or windows, while more finely bedded blocks were used for flag stones or roofs for outhouses. The thinnest flags were split for roofing.



Heptonstall churchyard to show the use of local sandstones