

CHAPTER 4

Making Mountains

The convection currents within the mantle continued to drive the two tectonic plates carrying Avalonia and Laurentia towards one another, even after the Iapetus oceanic plate had been fully subducted. The result was a collision of continents and the building of the Caledonides, a massive mountain range which included the mountains of the Lake District.

This mountain range is named after the Scottish Highlands which were created at the same time and in the same way, as were the Welsh mountains, those of Scandinavia and, on the eastern flank of northern America, the Appalachians.

We saw in the last two chapters how the collision of the Iapetus oceanic plate with the Avalonia continental plate had led to subduction of the oceanic plate and the generation of



Photo 4.1 | The view north from Scafell, depicting the rugged heart of Lakeland's mountainous scenery (Great Gable, centre right).

volcanic activity. Something similar had happened in the west, where the Iapetus Ocean was also subducted under the Laurentian continental plate, again leading to volcanic activity.

When the oceanic plate had been fully squeezed underground by the converging continental plates, the continents were crumpled up against one another. The solid layers of rock making up the continents were subjected to enormous forces over a very long period of time. As previously pointed out, the plates move only a few centimetres a year. Over several million years, however, this amounts to considerable distances of 20 to 100 kilometres every million years.

We know from experience that rock is likely to shatter if subject to a sudden force, say from being struck hard with a hammer – it is brittle. However, when rock is subject to long but relentless pressures it can behave very differently. It behaves in a 'ductile' fashion, that is it can fold and even flow (as also happens in the mantle to create convection currents).

The collision of the continents was initially fairly restrained. The outer parts of the continents, the thin continental slope and volcanic 'island arcs' met first and began to fold and crumple. Then the main, much thicker, parts of the continents were driven closer to each other. The rocks piled unrelentingly into one another, crushing and buckling the weaker rocks more than the tougher rocks, but all were affected. The area where the continents meet gets

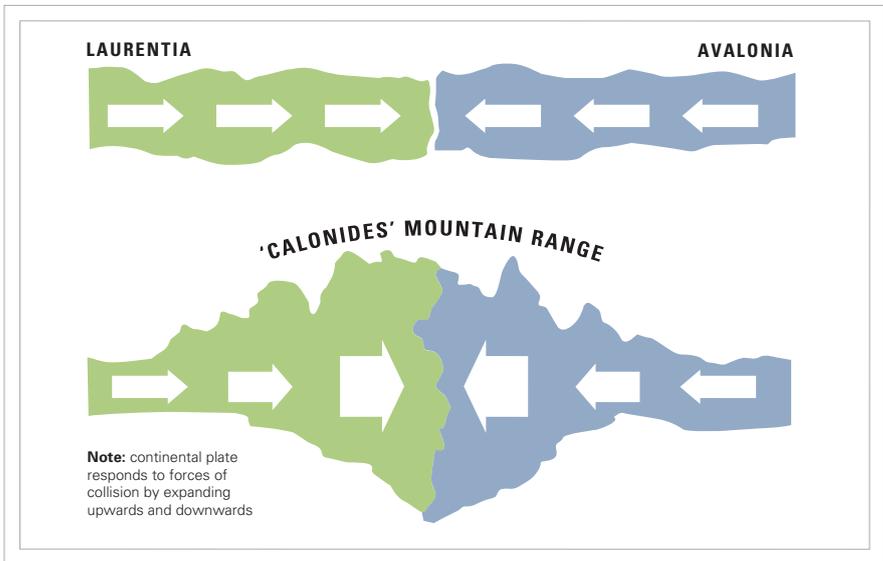


Diagram 4.1 | Continental plate collision.

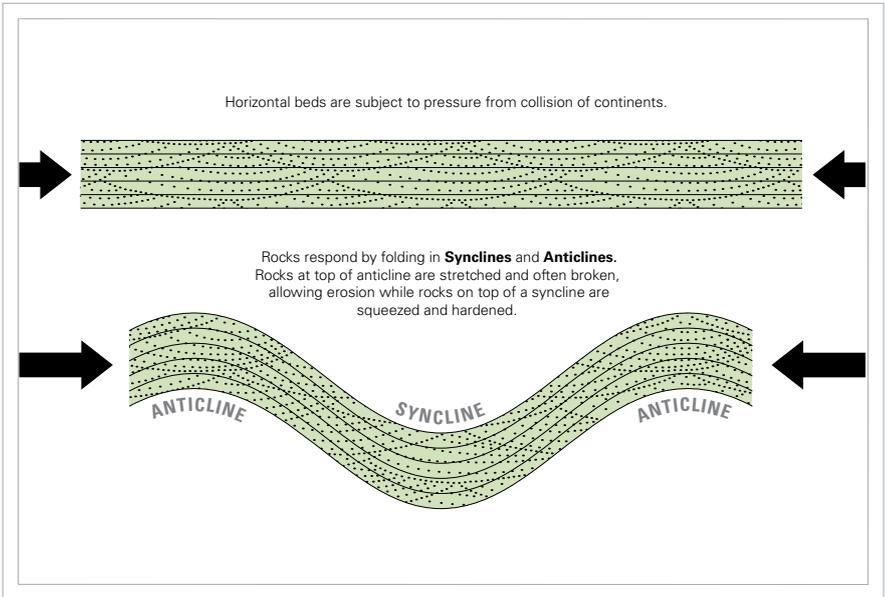


Diagram 4.2 | Synclines and anticlines.

progressively thicker, pushing up some of the rocks into massive mountain ranges (and also thickening downwards to an even greater extent than upwards). Faults are reactivated or created anew and sometimes, as happened with the Skiddaw Group rocks, deeper layers of rock were thrust up on top of newer layers. The intense pressure and heat caused some melting of the lowest part of the plate to become molten magma that then rose, if at all, only some way up through faults before getting stuck and cooling to become granite (a thick-grained 'rhyolitic' rock). The heat also 'cooked' some of the rocks causing chemical changes, and the enormous pressures generated and imposed on the rock turned fine-grained rocks into slate. These last two effects are known as types of 'metamorphism' where rocks are transformed in their state in some way.

The beds of rocks were folded into dips ('synclines') and rises ('anticlines') that can sometimes be detected into today's scenery. Some were shattered (most likely along existing fault lines) and others thrust above one another, even turned upside down. We can see this process of mountain-building happening today before our very eyes in the Himalayas (a result of India impinging on Asia) and in the closer to home Alps (a result of the clash of Africa with Europe).

Powerful pressures were exerted close to the continental edges including, of course, the area that became Lakeland. The sedimentary Skiddaw Group rocks were softer and less able to resist the pressures exerted by the collision than the harder volcanic rocks of the Borrowdale Volcanic Group (BVG). The result was that the Skiddaw Group rocks were intensely folded and broken up with major sections thrust upwards above younger rocks along fault lines. The evidence for this can be discerned in places, especially in Gasgale Gill and on Hopegill Head and Whiteside, the ridge which forms the northern side of the gill. The thrust line is clearly visible at the base of Gasgale Crags, high up the valley side (see Walk 1).

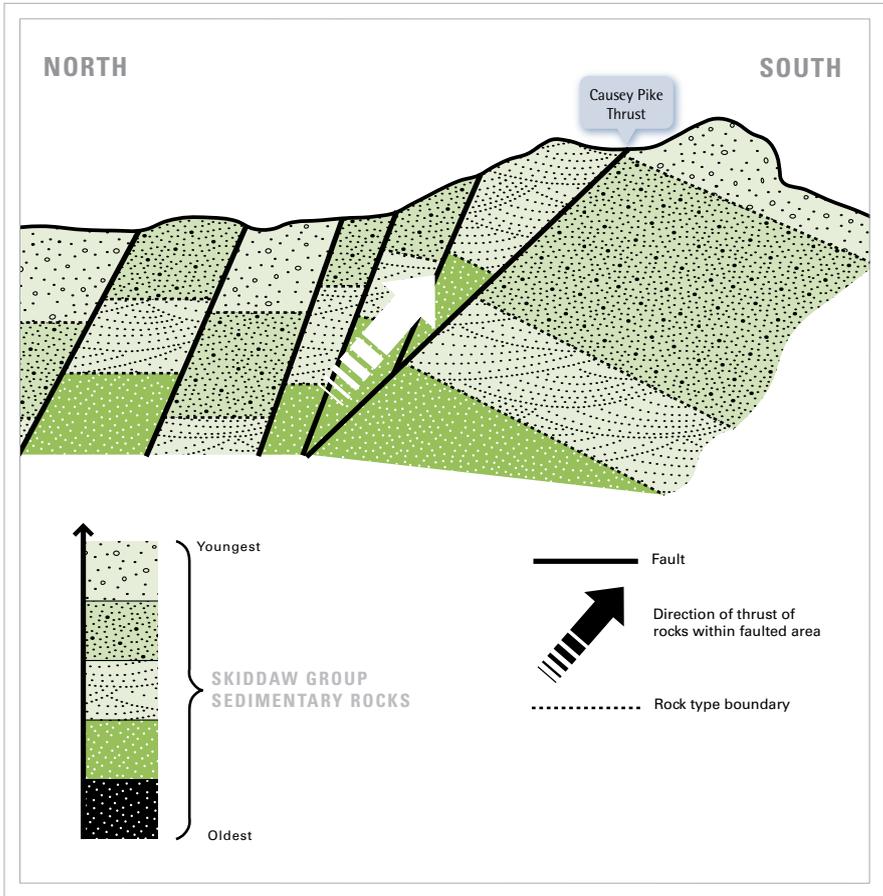


Diagram 4.3 | Folding and thrusting in Skiddaw Group rocks.

Photo 4.2 | Syncline in Skiddaw Group sedimentary rocks exposed on the summit of Hopegill Head.

Photo 4.3 | Small-scale folding in Skiddaw Group sedimentary rocks, Whiteside.



It is also possible to spot in places some of the folds in the rocks and the several anticlines and synclines that run across the Hopegill Head/Whiteside ridge. Indeed, just a few metres west of the summit of Hopegill Head, it is possible to look back up to the summit along the ridge line to see that the top-most rocks are the base of a syncline (see Photo 4.2). The Gasgale Thrust can also be detected further east, cutting through Hopegill Head, Grisedale Pike and the ridge that heads into Hospital Plantation.

Another major thrust line is known as the Causey Pike thrust and runs right across the district. It trends from west-south-west to east-north-east from Crummock Water (on the southern slopes of Rannerdale Knots, Wandope, Sail and Scar Crag) before heading north through the summit of Causey Pike, then resumes a west-south-west to east-north-east trend, eventually petering out near Swinside (south-west of Keswick). Two further thrust

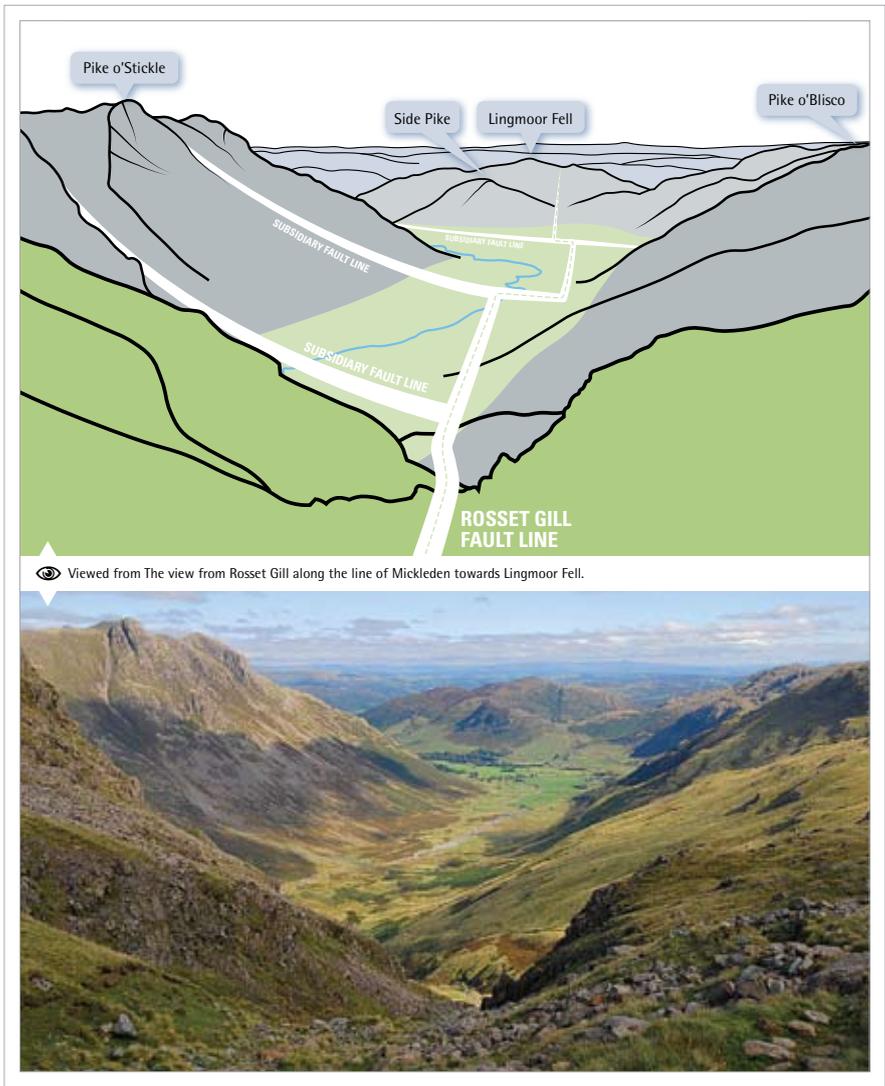


Diagram 4.4 & Photo 4.4 | Looking along the line of the Rosset Gill fault from Rosset Gill, along Langdale towards Lingmoor Fell. The line of the fault can just be seen as a dark streak on Lingmoor Fell.

faults are found a bit further north-west between the Gasgale Thrust and the present-day town of Cockermouth.

It's worth pointing out that when rocks are folded into anticlines and synclines, the rocks on the top of an anticline are stretched, being on the outer side of a curve, while the topmost rocks of a syncline are compressed (and vice versa for the underside rocks in each case). The stretching of the topmost rocks on an anticline weakens them and cracks them open, giving a head start to the forces of erosion, opening up the lower layers of rock to eventual exposure on the surface. On the other hand, the topmost rocks of a syncline are compressed and thus hardened, making them more resistant to erosion.

This leads to the counter-intuitive effect of anticlines often (but not always) being found in well-eroded areas and synclines often (but not always) being found at the higher points (such as on the summit of Hopegill Head, as seen in Photo 4.2). Both Scafell and Snowdon, the respective highest points in their own regions, are centred close to synclines created by mountain-building forces along calderas created by volcanic activity which took place along those ancient faults – lines of tectonic weakness.

The Scafell syncline trends from north-east to south-west and accounts for the general tilt of bedding that is often seen in rocks in the area (for example on Bowfell as seen on Walk 6). This is a wide and fairly shallow syncline, not a sharp and closely spaced one as seen in the sedimentary Skiddaw Group rocks. This is because the volcanic rocks were more resistant and could better withstand the forces generated by the collision of the continents. Another major syncline, the Ulpha syncline, cuts across often rolling moorlands of Ulpha Fells to the south.

The great pressures exerted by continental collision also caused up and down movements along re-activated ancient faults and on new ones. One particularly important fault, the Rosset Gill fault, runs right against the general trend from north-west to south-east. Its effects on the landscape are obvious in many areas, from Ennerdale, Aaron Slack, Esk Hause, Rosset Gill, Mickleden and across the south-western flank of Lingmoor Fell.

Other major faults run through Eskdale, Upper Langdale, Whillan Beck, Greendale, Greenburn, Grassguards, Baskill, Park Gill, Stockdale, Coniston and Brathay. Sideways earth movements of up to 75m are not unusual (for example, on the Broad Stand fault on the south-east of Scafell) and up to 900m in a few instances (on the Great Langdale Fault). Elsewhere, there have been vertical earth movements along faults of as much as 500m in the granite areas (see below) and among the southern sedimentary rocks.

The faults can often be traced in the landscape over a range of features that together form a longish line. The Eskdale fault runs up through Eskdale, the Wrynose pass and Little Langdale area until it terminates on the Coniston fault zone. It cuts through the granites exposed in the area as well as the Borrowdale Volcanic Group rocks. Some of the Lower

BVG rocks are displaced vertically against one another in the Hard Knott/Wrynose area, with the rocks on the northern side of the fault about 70m lower than their equivalent on the southern side. These faults have often been the site of later deposition of metallic minerals, later mined for copper and lead (see Chapter 8).

The Coniston Fault zone is another of the major fault structures in Lakeland, stretching some 40km from north to south. Major features are spread along the fault zone, including the valleys of St John's in the Vale, Thirlmere (rising to a high point at Dunmail Raise), the valley of the Rive Rothay to Grasmere (another high point at the shoulder between Loughrigg Fell and Silver Howe) and down to and beyond Coniston Water. This major fault zone is believed to have been 're-activated' around 250 million years ago, becoming the site of later earth movements.

The slightly curved Grassguards fault runs from just south of Grassguards Gill, Longhouse Gill and Brown Pike. This is thought to be the northern limit of the basin created by the final eruptions of the Upper BVG rocks, the Duddon Basin Succession. The vertical movement along the fault is over 500m, with the rocks to the north of the fault line being lower than those to its south.

As well as the major faults, there are scores of minor ones where earth movements have been less catastrophic, but have still contributed to the shaping of the present day landscape, resulting in minor crags and shallow hollows. These often occur in complex patterns as earth movements along faults have shunted softer and harder rocks into complex arrangements. The faults themselves have also been exploited by forces of erosion, especially ice, to create gullies and valleys.



Photo 4.5 |
Piers Gill on
Scafell Pike.



Photo 4.6 | Tilted rocks seen on Bowfell.

One consequence of all these earth movements along fault lines has been to smash the rocks on either side of the fault and to create what geologists call a 'fault-breccia'. These can be up to 100m wide and during the ice ages provided weak points along which glacial ice could carve deep gullies into the rock. This is a common feature of the Lakeland landscape. Such gills are seen on Walk 3 (following Piers Gill on Scafell Pike) and Walk 6 (following Hell Gill on Bowfell, Walk 5, descending Aaron Slack between Great Gable and Green Gable on the line of the Rosset Gill fault).

The folding, tilting and faulting during the mountain-building episode have had a considerable effect on the shape of the landscape that we see today. The great tilt of the rocks forming the Scafell syncline are often quite easy to see, such as on Bowfell or the Langdale Pikes (see Photos 4.7 and w7.7).

Another consequence of the forces generated by continental collision, the creation of slate, has less immediate effect on the topography. The very great pressures generated by the collision of the continents squeezed the tiny minerals making up the fragments of deposited particles in sedimentary rocks. This caused the minerals to change their positions so that they all ended up with their flat faces lined up in the same plane; what is called the 'cleavage plane'. These rocks then split easily along the cleavage planes, producing slate. Some of this slate is worth extracting for roofing or building material, but only a small proportion of it.



Photo 4.7 | View of Crinkle Crag and Bowfell. The general tilt of the beds from upper left to lower right is clearly visible, as are deeply incised glacial meltwater channels along fault lines.

The finer the mineral grains (as found in mudstones), the more effectively that good cleavage planes are created and the more likely the rocks are to produce good slate. Slightly bigger mineral grains (as found in siltstones) are less likely to produce good slate, but may well still display cleavage. Coarser mineral grains (as found in sandstones) may not produce any cleavage at all.

I wrote a few paragraphs above that the creation of slate has a less immediate effect on the landscape than thrusting, folding and faulting. However, slate does have consequences for scenery in the longer term. First, cleavage planes in general tend to provide a form of weakness which can be exploited by the forces of erosion. Second, slate is attractive for human use and has led to the development of slate quarries which have left pretty conspicuous effects on the landscape and in the style and colour of the buildings of the area. As the extraction of saleable slate usually involves the quarrying of up to nine or ten times as much unusable slate material, it also involves the creation of large waste tips near slate quarries and mines.

It is worth noting that slate is indeed mined as well as quarried. It is often assumed that a mine in the Lakeland area must be the site of metal extraction, but this is not necessarily

the case. Slate is, or has been, mined at Honister and on the southern flanks of Loughrigg Fell, Coniston and elsewhere. Several old slate mines are passed when walking along Loughrigg Terrace, leaving only waste tips and bigger or smaller mine entrances. The waste tips are worth looking at (with very great care if you are tempted to clamber up onto them) for small lumps of the beautifully bedded rocks of the Seathwaite Fells formation.

The story of the collision of the continents does not end there. Underlying the whole area are believed to be substantial sheets of an intrusive rock: granite. The biggest concentrations of granite are thought to have been intruded about 450 million years ago. Some smaller areas (such as the granite around Shap) were probably intruded later, towards the end of the mountain-building events, possibly when the lowest extension of the continental plate during downward thickening of the plate was turned into molten magma.

Granite is a large-grained rock, a feature that arises because of its slow cooling low down in the Earth's surface. It is also a rhyolitic, light-coloured rock (often pinkish in colour). Although such granite is believed to lie underneath the whole of the Lake District it is only exposed in a few places, mainly to the west (see Walks 11 and 14). Where it does crop out, it generally produces a low, rolling moor-like landscape that is found in places such as Ulpha Fell and Birker Fell.

The presence of granite under much of the Lakeland area is inferred from 'gravity anomaly' readings performed by geophysicists with sensitive gravity measuring devices. The results led

Photo 4.8

Looking out from a slate mine entrance on Loughrigg Fell, now closed to the public because of recent rock falls.



them to believe that the granite formed a single massive blob (a 'batholith') underlying the whole Lakeland area. This presented them with a problem, in that this blob would have had to have been far, far greater in mass than all the erupted material. However, according to the theory of volcanic systems and continental plate collision, this could not really be the case as granite is thought to be produced in comparatively small volumes at the end of the cycle, not in vastly greater amounts.

The interpretation of the magnetic anomaly readings has been revised and it is thought today that the granite consists of separate sheets intruded between layers of rock ('laccoliths'). The combination of the sheets plus their sandwich filling of sedimentary or volcanic rocks are now thought to give the same type of gravity anomaly reading as a single granite mass.

The mountain-building era lasted for several million years, eventually drawing to a close some 300 million years ago. By then, the area had been shaped into part of the Caledonides. This was a massive range of mountains, at least as high as the Alps and possibly even as high as the Himalayas. The very process of crushing and twisting the rocks into such mountains had, at the same time, the effect of opening the rocks up to erosion.



Photo 4.9 | Granite outcrop, Low Rigg; High Rigg in the right background.



Photo 4.10 | Birker Fell: granite topography with tuff terrain of the central fells in the distance.

In the millenia since then, the area has at times been above sea level and sometimes below it. When it was above sea level, it was subject to erosion. When it was below sea level it was subject to deposition of sediments and thus, over time, to the creation of new rocks.

Few traces of those new rocks are left (except for some mineral deposits in fault zones) as they have been fully eroded away. For instance, it is believed by many geologists that during the era known as the Cretaceous, there must have been such widespread deposits of sediments that the whole of Britain would have been covered by chalk. This white rock only now outcrops in southern and eastern England and, if geologists are correct, it has been entirely eroded away from the rest of Britain including the Lake District. The same may also apply to other rocks.

The overall course of events has been the erosion of rock in the area, slowly exposing the deeper and deeper layers of rock, uncovering the ancient layers of the Borrowdale Volcanic Group rocks and the even earlier sedimentary rocks of the Skiddaw Group. The net effect of earth movements and erosion has been to expose, along the surface of the Earth, a slice through what was originally a vertical layer of rock, bringing to our attention the oldest through to the youngest rocks of the area.

This process took place about three hundred million years. It is of course impossible to appreciate fully what such long periods of time actually mean. Castlerigg stone circle is about 5,000 years old. At roughly the same time, stone axes were being hewn out of the volcanic rocks of the Langdale Pikes. Both are 'pre-history', reaching way back before even any retained folk memories let alone written records. However, 5,000 years is nothing, a mere momentary twinkle, compared with 3 million years (let alone 300 million). The net result is that we really have little or no idea what the landscape looked like a long time ago.

The last ice age ended about 10,000 years ago and was only the latest of a long run of ice ages that stretches back somewhat more than a million years. We will look in the next chapter at what the ice age did to the landscape and at the multiplicity of features that it produced. However, as to the original shape of what the glaciers did their work on, we have really very little to go on.

A few hints are gained from the gentle curving slopes of the eastern flank of the Helvellyn range or the summit area of High Street. These are probably surviving pre-glacial surfaces and suggest that the millions of years of erosion since the events described in the last chapter and this chapter left a rounded upland plateau area with gentle slopes and shallow valleys. These dips probably followed the course of present day valleys by and large. However, the scenery was probably nothing like the landscape we know and love today with its sharp plunging slopes and deep glacial trenches.