Lake District Geology *in* Ambleside’s Building Stones

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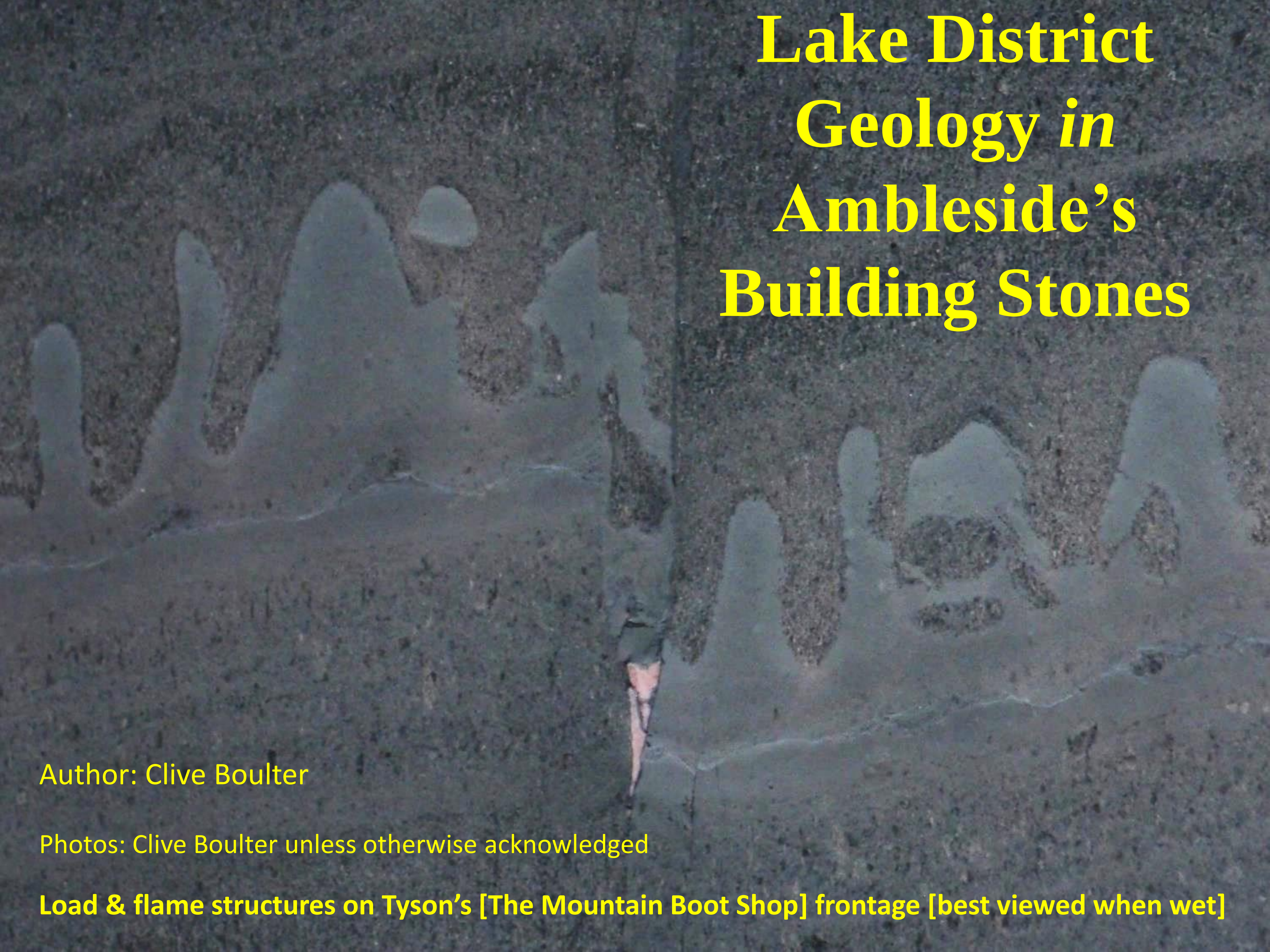
Photos: Clive Boulter unless otherwise acknowledged



Load & flame structures on Tyson’s [The Mountain Boot Shop] frontage [best viewed when wet]

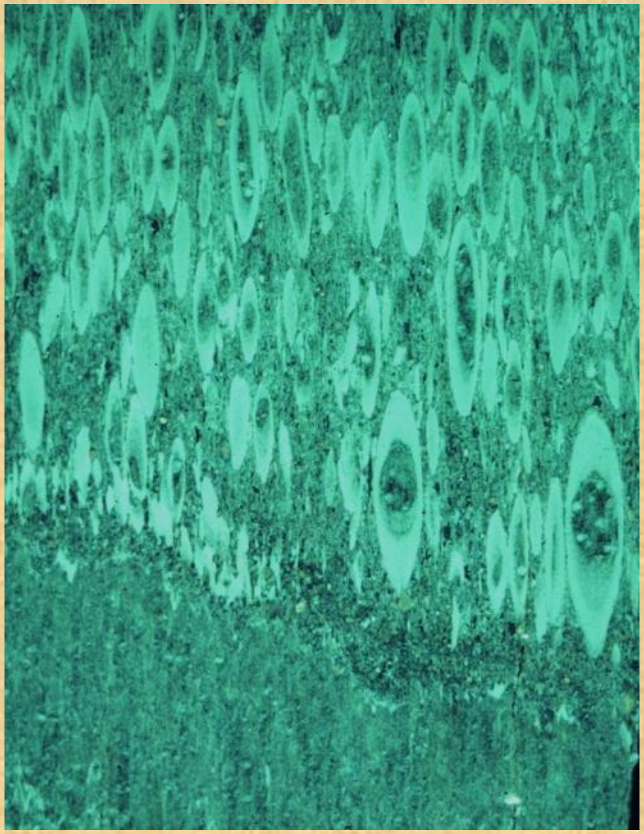
Ambleside was mainly built from imported rocks. The town sits on the Borrowdale Volcanic Group yet the majority of its building stone comes from the Brathay Formation of the Windermere Supergroup, just south of the BVG outcrop. The stone was quarried between the Drunken Duck pub and Pullwood Bay on Windermere. Despite being a siltstone these are very dark, almost black, rocks because of a high organic content. The predominance of Brathay Formation building stones in Ambleside has led to descriptions of the town's aspect along the lines of sombre, foreboding, and gloomy. The depths of despair are alleviated in many of the black slate buildings by having lighter quoins and lintels of green slate and other brighter rocks. Also the blackness of the slates is relieved by lighter coatings on many joint surfaces. Some of Ambleside's buildings are entirely of green slate or with minor other components.

Please note building works are constant in the town and some features mentioned here may be removed in the cause of progress!

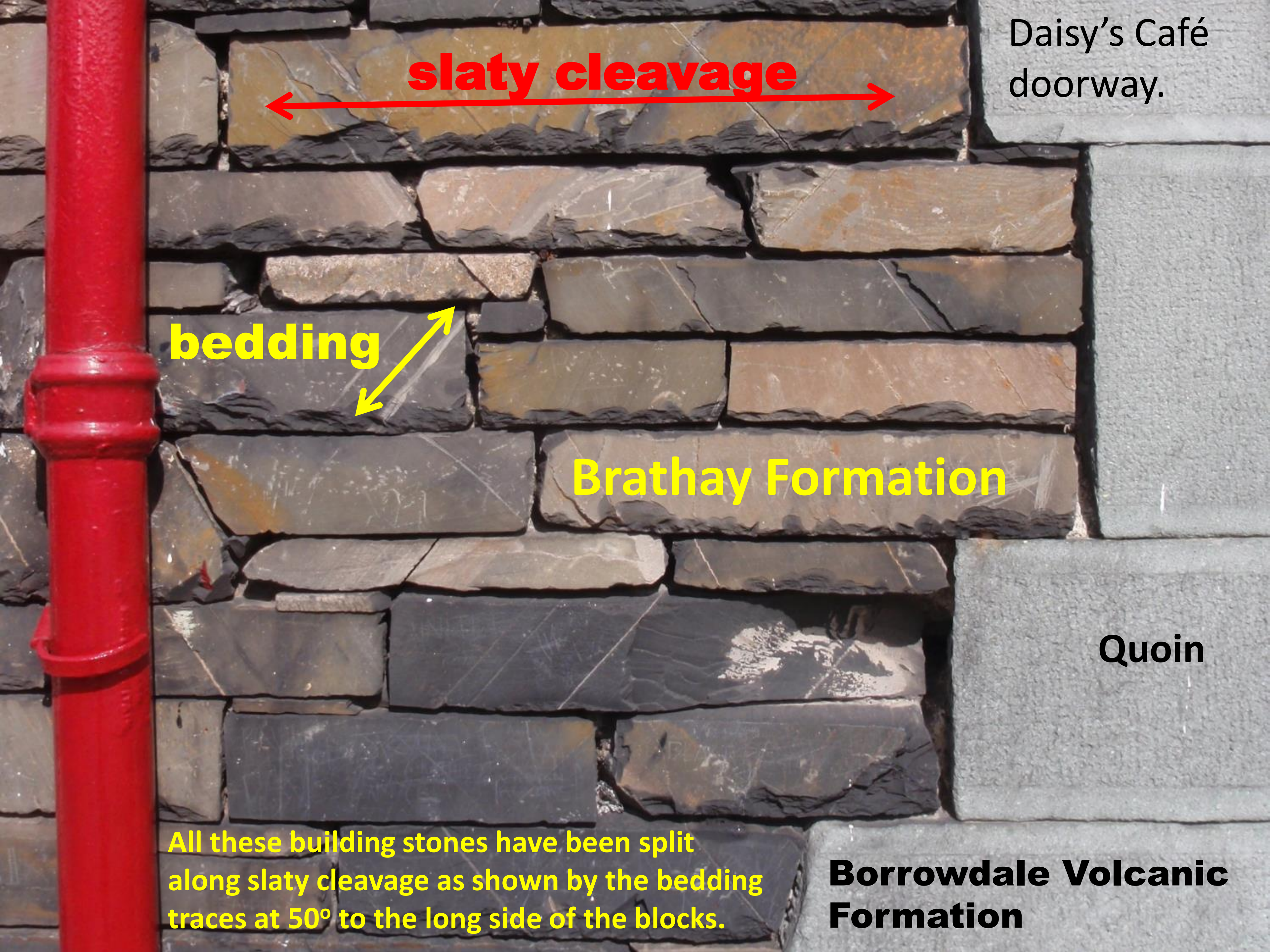
Low angle sunlight highlighting the contrast between the largely green slate former Methodist Church and some Brathay Formation houses.

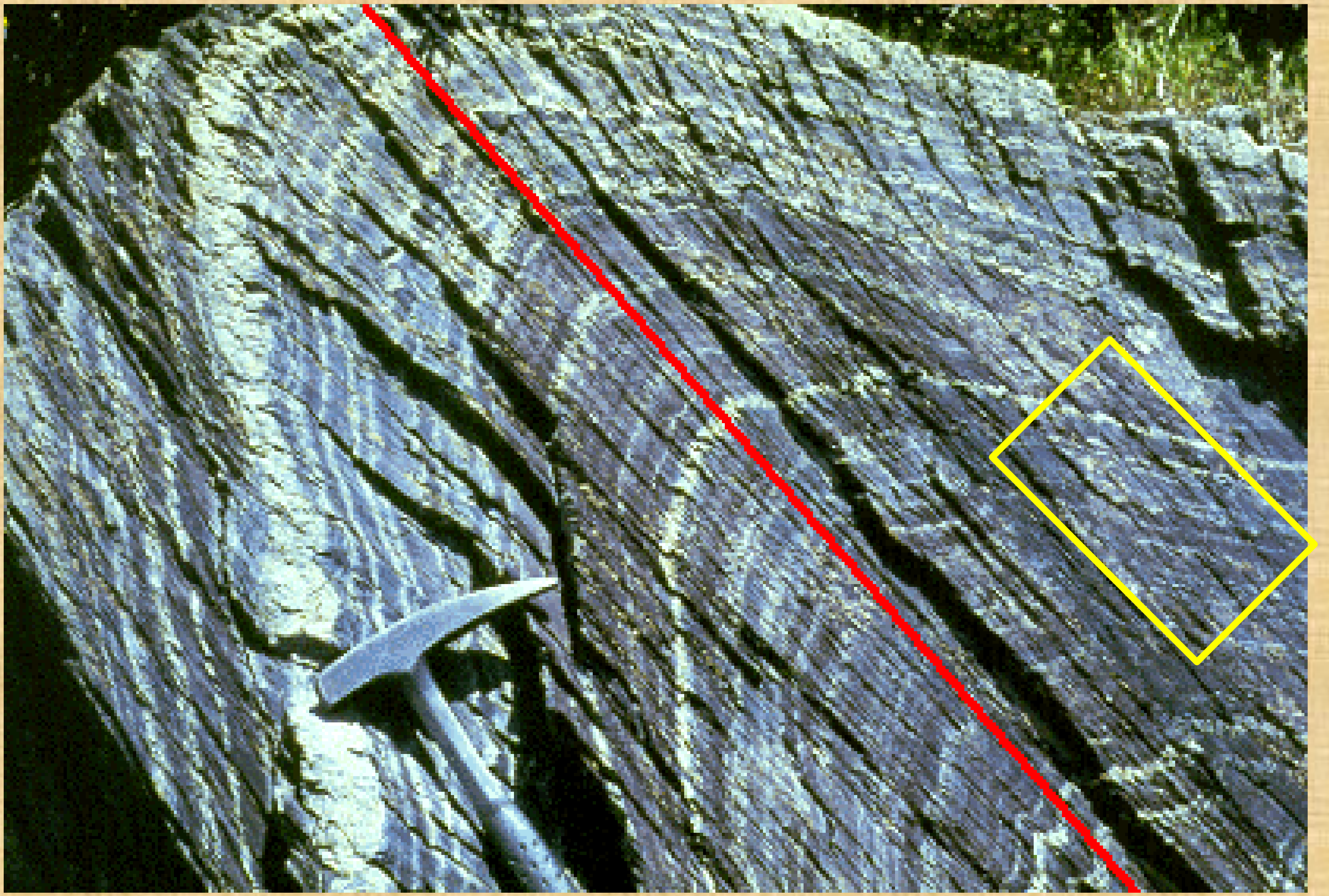
Slaty Cleavage

Slaty cleavage is the fabric in fine-grained rocks that allows them to be split into thin slabs independent of original [pre-tectonic] features such as bedding. In detail, when viewed with microscopes, there is considerable variety in the grain arrangements that give rise to slaty cleavage which in turn generates much debate about the processes responsible for forming this property of being able to be split. Despite the many responses at the grain-scale, it is well established that you have to significantly shorten rocks [**strain**] to produce high-quality slates for quarry workers to exploit. The famous North Wales roofing slates were shortened by around 60% perpendicular to the cleavage plane and similar figures have been recorded for the green slates in the Borrowdale volcanics.

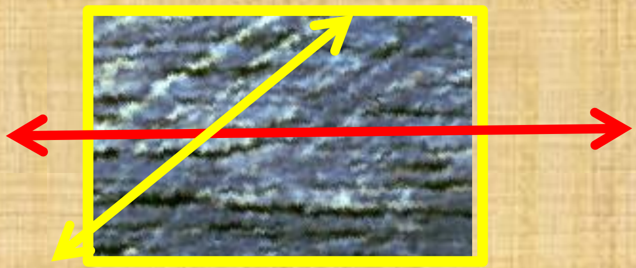


Top Photo: Slate splitting and trimming, Wikimedia Commons, Scanned by Rhion Pritchard 01/09/2006 from "Dinorwic Slate Quarries, Portdinorwic" an album of photographs published by the Dinorwic Quarry.
Bottom Photo: Bird's eye tuff from a slate quarry in Kentmere. This accretionary lapilli tuff from the Tilberthwaite Formation was shortened about 60% in the Acadian Orogeny to create the slaty cleavage which is at a high angle to bedding and hence later.

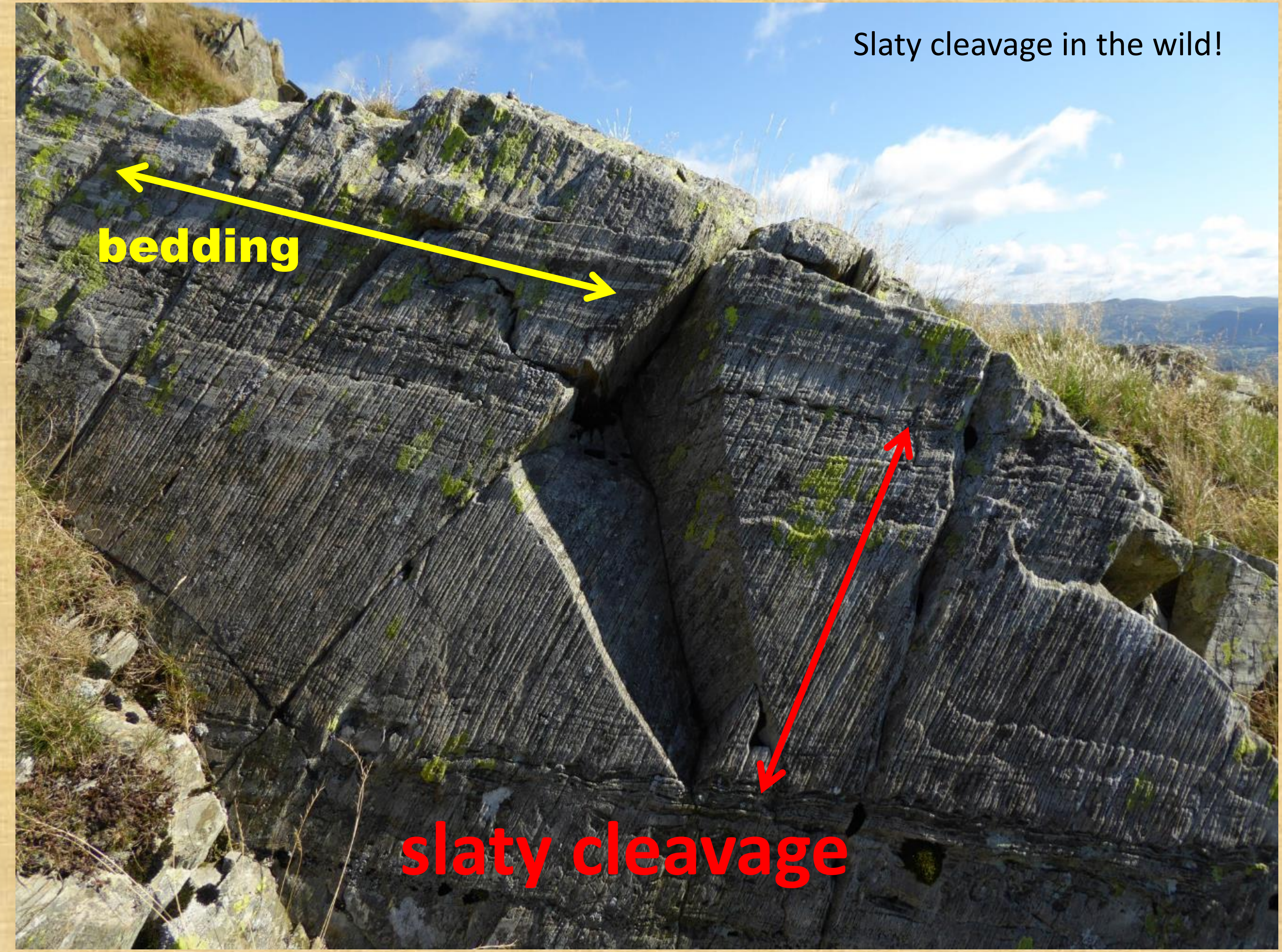

slaty cleavage
Daisy's Café doorway.
bedding
Brathay Formation
Quoin
All these building stones have been split along slaty cleavage as shown by the bedding traces at 50° to the long side of the blocks.
Borrowdale Volcanic Formation



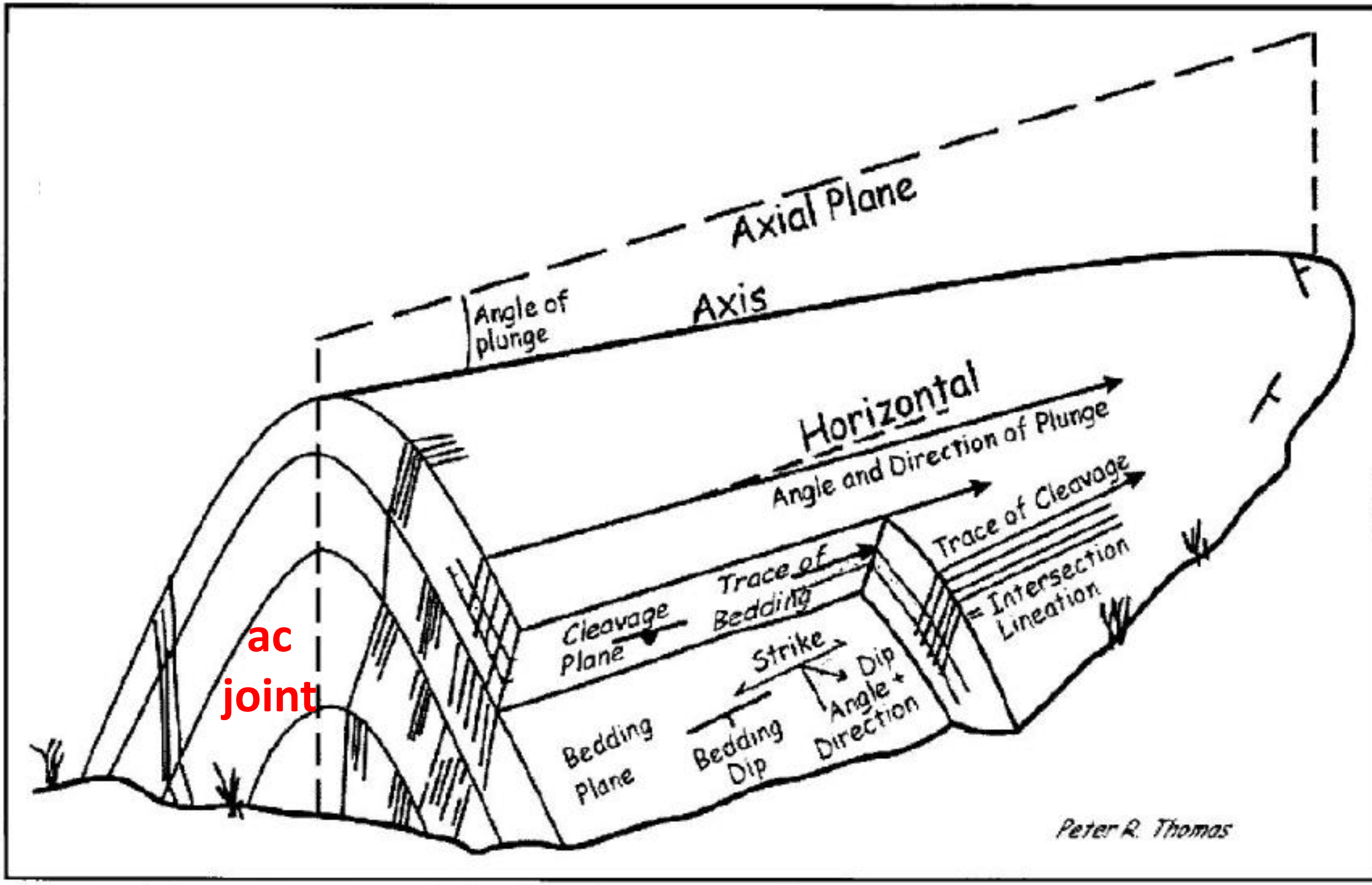
The angle between bedding and cleavage varies with position on a fold; it is high at the fold closure and lower on the fold limbs. If a block is taken from the yellow outlined area it would look, in a wall, like the image to the right. Folded & cleaved sedimentary rocks, Sardinia. Photo: J G Ramsay.



Slaty cleavage in the wild!



Lingmoor Fell – Borrowdale volcanics – a high angle between bedding and cleavage in slate.



The trace of the bedding on the cleavage plane, or cleavage on bedding, is the lineation caused by the intersection of bedding and cleavage. AC joints form roughly perpendicular to the fold axis.

From: P Thomas 2002 The Winster Valley: aspects of the WGS mapping project. Proceedings of the Westmorland Geological Society, pp. 46-50.

Steps leading to a bench outside St. Annes.

This block has been split along the slaty cleavage plane. The trace of the bedding on the cleavage plane is the cleavage/bedding intersection lineation shown in purple.

The block has been split along cleavage. The trace of bedding on the vertical side of the slab shows a small angle between bedding and cleavage indicating the slab came from a fold limb rather than the fold closure.

Intersection lineations [bedding on cleavage] in Borrowdale volcanic quoins. The irregular traces indicate soft-sedimentary deformation.

The Brathay Formation blocks to the right of the window mainly have light coloured joint coatings whereas those to the left mostly show the sombre colour of the slate.

Whittakers that was; now Rattle Ghyll Fine Food and Deli.

Roofing slates – Broughton-in-Furness

Slaty-cleavage/bedding intersection lineations in abundance!

The face of each slate is the slaty cleavage plane – bedding in all the slates is inclined to the roof surface.

Provenance: like to be from Walna Scar Quarries.

Fractured Rock: joints

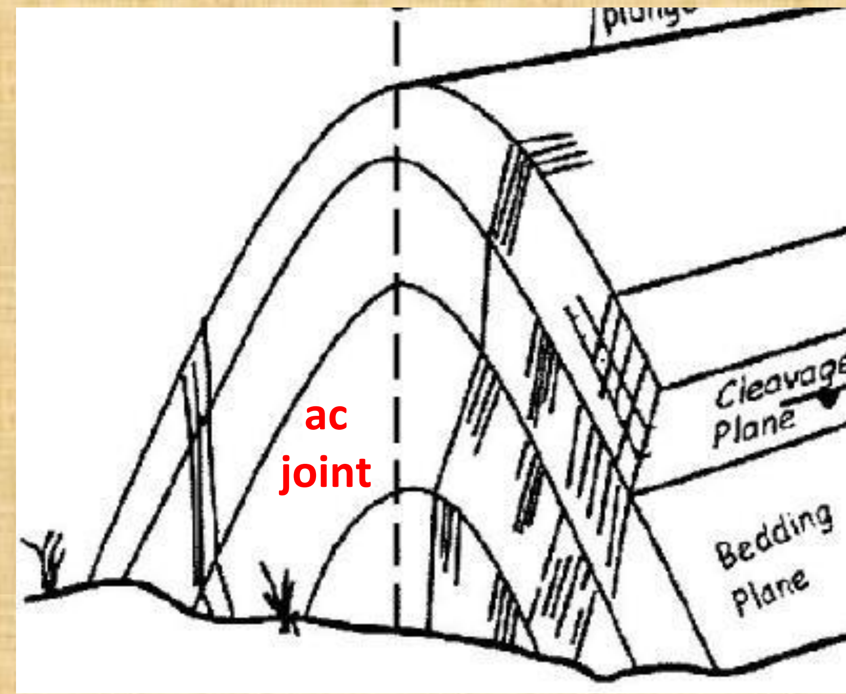


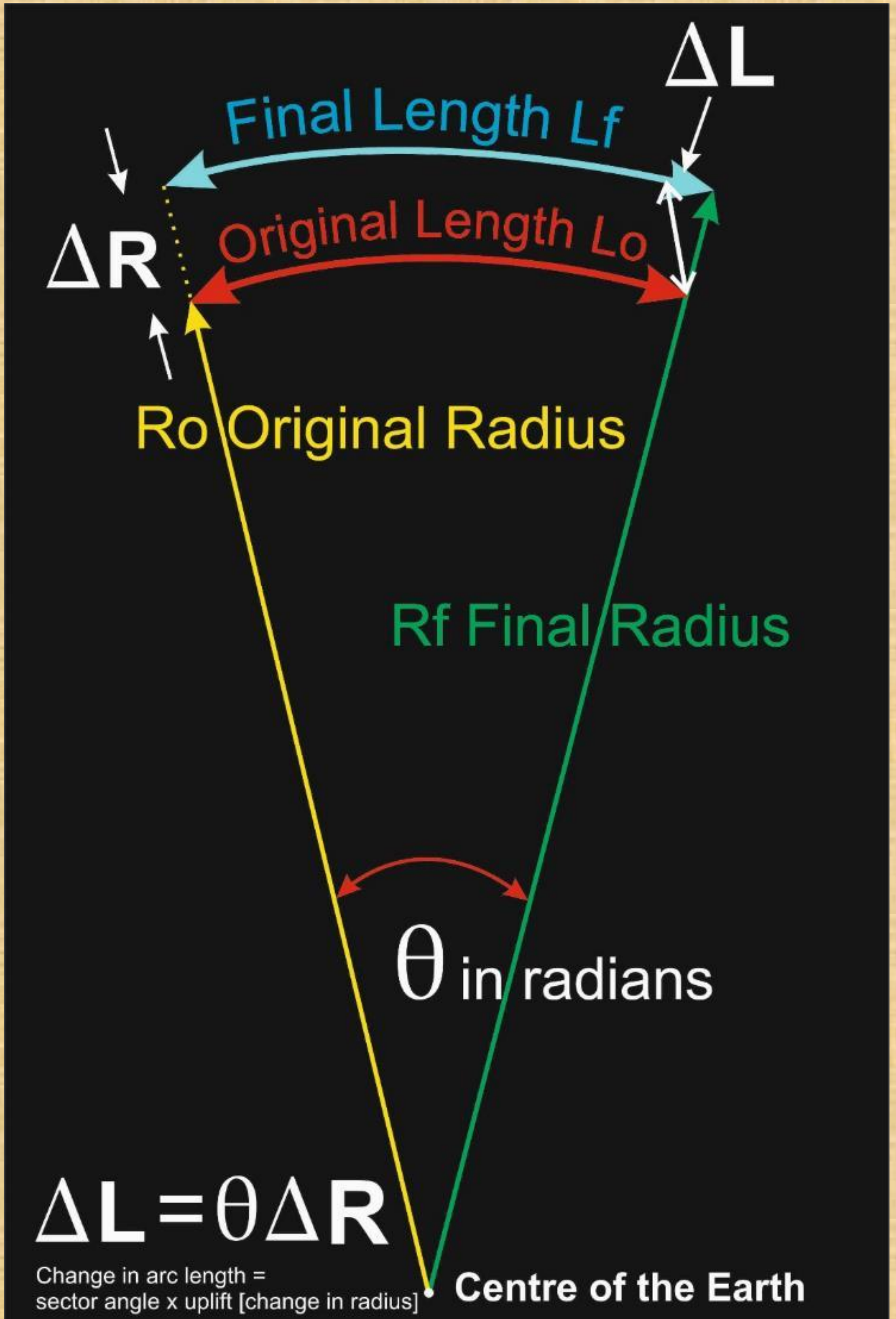
Diagram from: P Thomas 2002 The Winster Valley: aspects of the WGS mapping project. Proceedings of the Westmorland Geological Society, pp. 46-50.

Almost every rock exposure is fractured. In almost every case this fracturing is an inevitable consequence of exposing the rock because to create a rock almost always involves taking it to depth and bringing it back again. Perhaps too many "almosts" but there are always exceptions such as beach rock formed at the surface and it is very hard. Mentioning fractured rock typically conjures up thoughts of faults which are fractures with relative movement either side of the fracture. Joints have no visible offset associated with them. In folded rocks the fold shape is typically well displayed in profile because of jointing. Before scientific study of geology began it was thought that the rocks had been put in place much as a brick house is built, hence the derivation of the word joint. Quarry working normally will take advantage of the joint pattern but, in a quarry for ornamental rock, too many joints will lead to closure.

Joints relieve stress built up in rock masses and, when the rocks can no longer sustain the forces, joints form at supersonic speeds creating micro-earthquakes. Changes in stress orientation from fracture initiation to growth produces a variety of joint surface features such as ribs, hackles, and plumose structures. Microscopic fracture splays create much of the joint surface irregularity.

JOINT SURFACE STRUCTURES

When you see these features you know that you are looking at a fracture surface rather than something like a saw or wire cut. Plumose structures are very common on joints and look like the imprint of a feather defining the joint propagation direction.



ORIGIN of most JOINTS

Apart from cooling joints in igneous rocks [and ignimbrite], the vast majority of joints can be explained by the process of uplifting a segment of the crust. A block of rocks at some depth will have an arc length that is related to its distance from the centre of the knobbly sphere we live on. Once uplifted and brought to the surface, that arc length will be longer. The stresses built up by this extra length will be relieved by joint formation, as shown in the diagram to the left.

Adapted from: Price, N.J. 1966 Fault and joint development in brittle and semi-brittle rock. Pergamon Press, Oxford.

JOINT/BEDDING SURFACE COATINGS

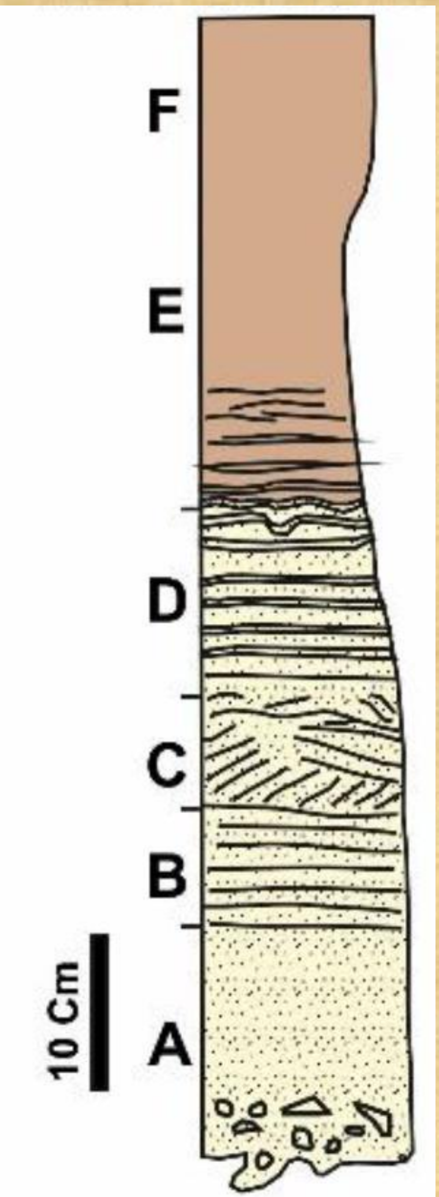
A striking example from Grasmere of reddening along joint faces; the oxidising iron-rich fluids probably got into the Borrowdale volcanics in the Middle Triassic, about 240 million years ago, when the Cumbrian haematite deposits were forming.

Pyrite coated joint [?bedding?].

Oxidised iron on joint face.

Processes, along the lines of those shown here, give rise to variegated exteriors to some buildings in places like Ambleside and Grasmere; much more interesting than the Auld Grey Town!

Turbidite Units - deposits from turbidity currents.



Pelagite/Hemipelagite

Turbidite mud

Turbidite silt-fine sand

Parallel-laminated

Cross-laminated/climbing ripples

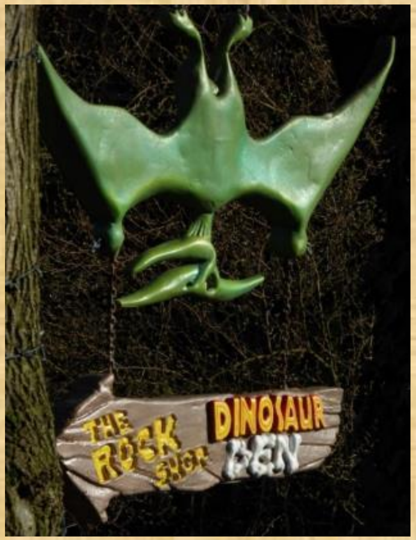
Parallel-laminated

Massive to fining upwards

Sole structures/load & flame

Turbidity currents are turbulent mixtures of sediment and water that are denser than the ambient fluid hence flow down slope under the influence of gravity. Several of the volcanic lakes in the Borrowdale volcanics were very large and much of their sedimentary infill was transported to their final resting place by turbidity currents. Many of these deposits have internal structures, in full or in part, as shown in the diagram. Ta, Tb, Tc, Td, Te, is a shorthand nomenclature for these divisions. Despite grain modification during slaty cleavage formation, many Lake District slates display the original sedimentary structures in fine detail particularly on the cleavage plane.

Diagram: Classic Bouma model for medium grained sandstones. Adapted from: Distinguishing between Deep-Water Sediment Facies: Turbidites, Contourites and Hemipelagites. Dorrik Stow and Zeinab Smillie, 2020, Geosciences, 10, 68; doi:10.3390/geosciences10020068.

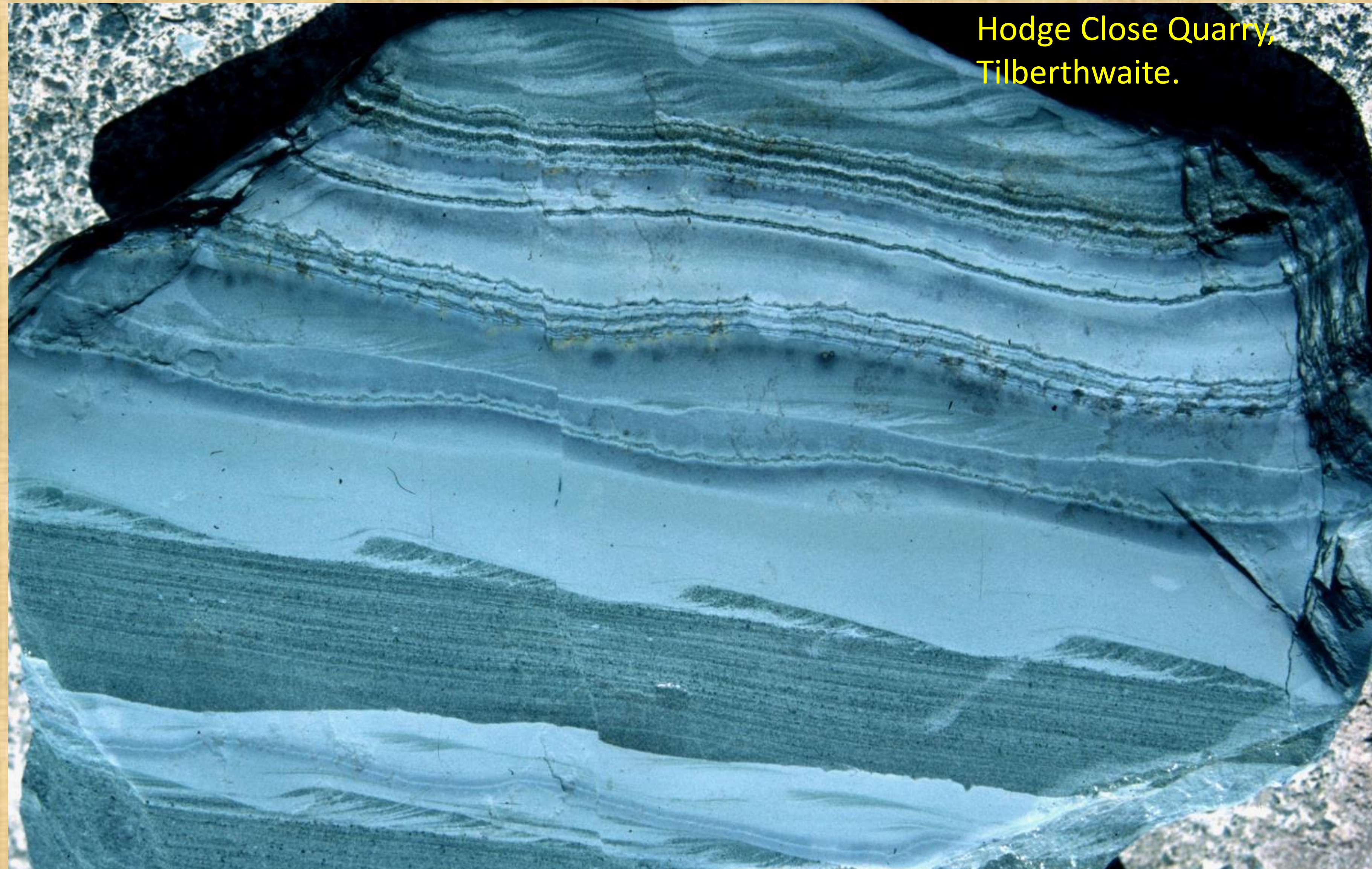


The Rock Shop, Ambleside.

Outside the Rock Shop, North Road, is a particularly fine example of turbidites displayed on a slab that has been split along the cleavage plane. Ta, Tb, Tc, divisions are labelled on the oldest turbidite. When the C horizon had been deposited it created ripples on the lake floor and mud from the turbidity current settled out and draped the ripples. The next turbidity current deposited a very thin layer of sand in the topography left after the draping event. A smooth lake floor was not re-established until the next turbidity current event.

Details of the ripples in the C horizon of the Rock Shop turbidite.

Note the truncated layers; they are older than the white layer.



Wonderful preservation of fine detail in a rock shortened by around 60%. The C [rippled] horizons of the most prominent layer formed isolated [starved] ripples on the lake floor.

Soft-sedimentary Deformation.

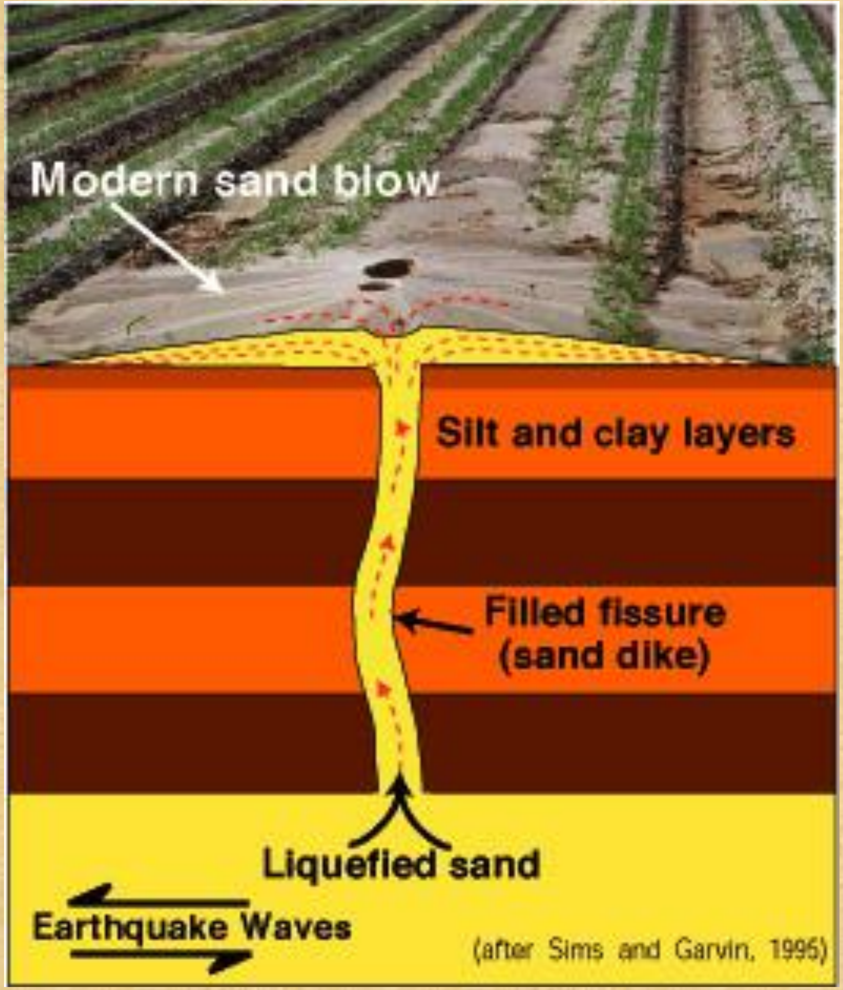
"Christchurch quake, 2011-02-22" by Tim - Christchurch quake, 2011-02-22. Licensed under CC BY-SA 2.0 via Wikimedia Commons http://commons.wikimedia.org/wiki/File:Christchurch_quake,_2011-02-22.jpg#mediaviewer/File:Christchurch_quake,_2011-02-22.jpg

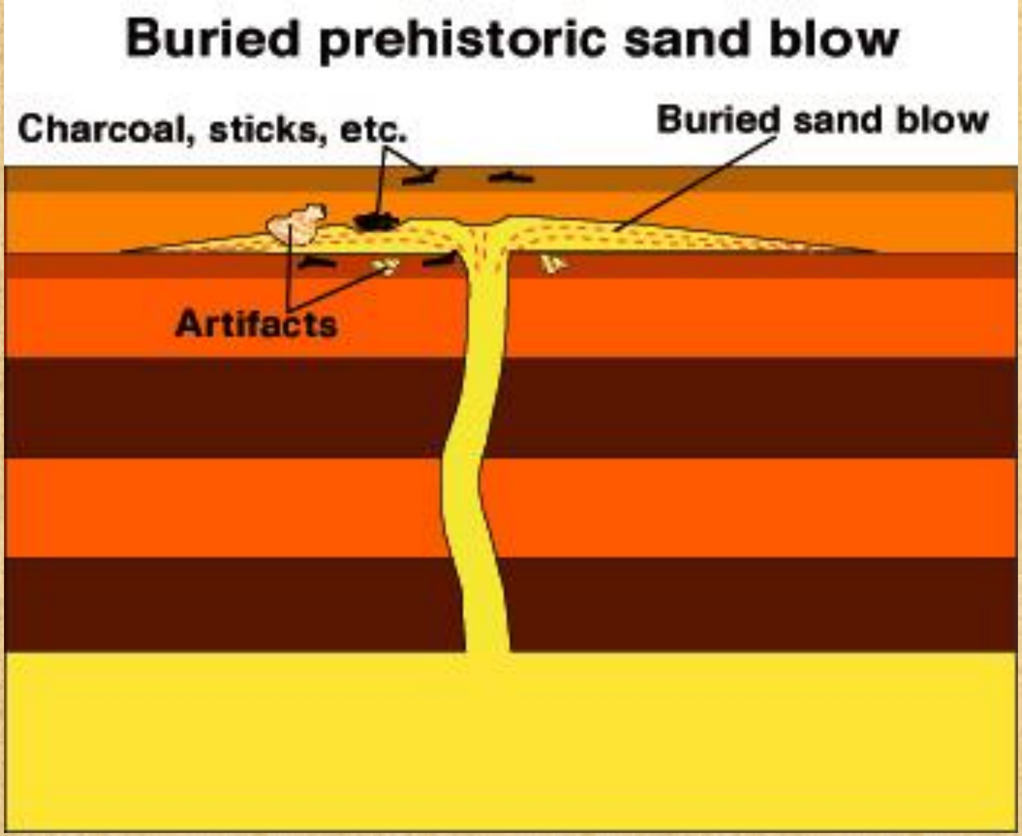
If a sedimentary deposit is disturbed soon after deposition, the structures created during its deposition can be modified in shape. The key to understanding what happens is the fluid between the sedimentary grains. It is also important to appreciate that initially there are no chemical precipitates binding the grains together so they can move independently. Earthquakes, or sediment piled on top of a layer, can increase the pressure on the fluid between the grains until the grains are forced apart, allowing them to become mobile.

In this example pore-fluid pressure exceeded the weight of the grains in the sediment layers resulting in liquefaction; the slurry of pore fluid and grains found [or created] weaknesses in the sediment leading to an eruption of slurry at the surface. The volcano-like forms are very susceptible to erosion and their preservation potential is very low.

http://www.showme.net/~fkeller/quake/liquefaction.htm

Mechanism of Sand Volcano Formation

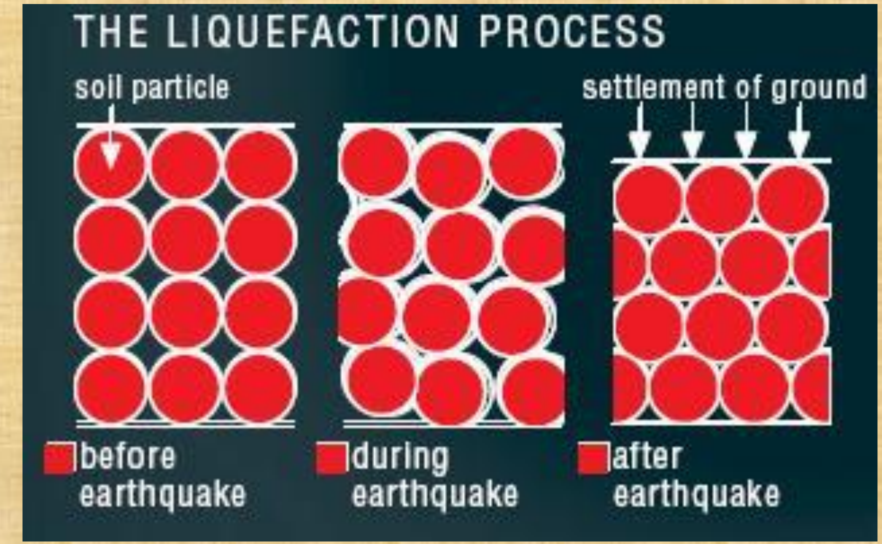


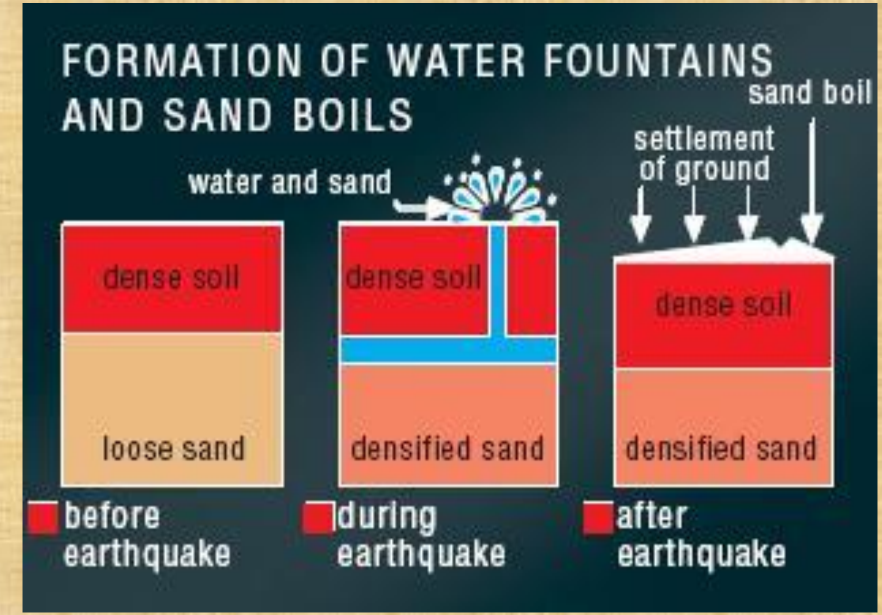


http://pubs.usgs.gov/fs/fs-131-02/fs-131-02-p3.html

Shaken not Stirred:

grain-scale processes during liquefaction.

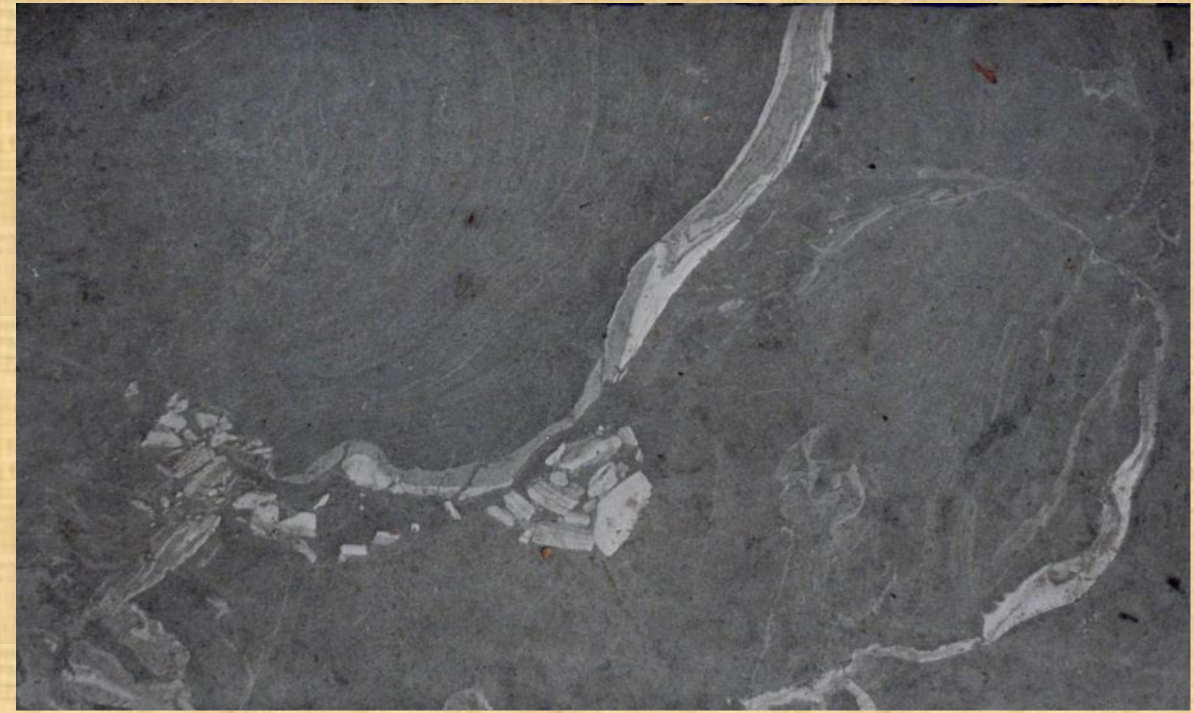




http://img.scoop.co.nz/media/pdfs/1009/Ecan_Brochure_Title__The_Q_files___the_solid_facts_on_Christchurch_liquefaction.PDF

The Borrowdale volcanic succession has many lake deposits mainly filling calderas. Seismic events may have shocked these volcaniclastic sands and muds to deform them in a soft-state but similar results can be caused by the sudden arrival of a large mass of sediment. This table-top example has intricate soft-sediment folds and essentially coherent blocks of mudrock in slurried sand.

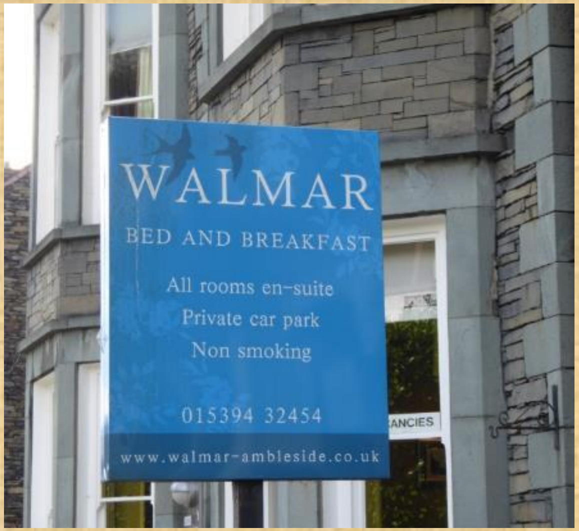
Ambleside Examples of Soft-Sedimentary Deformation.



Doorstep: J F Martin & Co.

During liquefaction, sand typically becomes cohesionless but mud behaves very differently. It is very hard to push apart mud grains because of the van der Waals forces on their highly charged surfaces. The mud is more likely to break hence the angular mud flakes in many of the examples shown here.

Pavement outside RUSH.



A classic example of soft-sedimentary deformation at Walmar B&B; the sandy layers became mobilised whilst the muddy layers were brittle and fractured. Once mobilised the sandy layers intruded into the fractured muds. This behaviour is the reverse of what happens during orogeny when the muddy rocks flow and the sandy rocks rotate and/or break under low-grade metamorphic conditions.

An undoubted example of soft-sedimentary deformation which slurried the granular material and fractured the muddy sediment. The slurry can wear away at the mud clasts and round their edges.

A less clear-cut example. The mud flakes could have been created by soft-sediment deformation but there are several other possible mechanisms and in isolation this slab remains equivocal.

Load & Flame Structures: a type of soft-sedimentary deformation.

When deposited, mud may be 70% pore space which is filled with fluid. Load & Flame structures form when either the mud, or both the sand and mud, lose strength [become fluidised] and the sand sinks down into the mud at the same time as the mud is squeezed upwards in flame-like structures.

A loose block of slate from near Allan Bank, Grasmere, to show that some flames are very flame like.

Lithification: The Process of Changing a Sediment into a Rock.

Concretions allow us to track some of the conversion process [diagenesis] that takes unconsolidated collections of sedimentary particles and turns them into hard rocks. Concretions grow during this process and arrest the compaction [vertical squeezing] that is generated by the weight of sediment being piled up in a sedimentary basin. Compaction is important in driving pore fluid out of the sediments thus taking fluids from one part of the sedimentary pile to another which in turn is responsible for many chemical changes. Precipitated chemicals bind the grains together making hard rocks.

The concretion shown [mainly an iron carbonate] is from the Windermere Supergroup and, fittingly, it now resides outside Musgraves in Windermere. Trace the layer near the centre of the concretion towards its margin and note how the layer thickness decreases so much that it is barely identifiable on the outside. The deflection of other layers at the concretion margin also shows that the growth took place early in the lithification process. Distortions associated with the slaty cleavage complicate the story a little but much of the early diagenetic history of the rock is found in the concretion.

Concretions can be found in various building stones around Ambleside.

Lava Flows & Magmas That Nearly Made It to the Surface

Kerb stone, North Road by Central Buildings, Ambleside. The block is amygdaloidal andesite with a mainly carbonate infill of the vesicles. The block is in a debris flow deposit that probably was formed when a peperitic intrusion became eruptive.

Vesicles are preserved bubbles and they confirm that you are looking at something that was once a magma; whether or not it escaped to the surface to form a lava flow is another matter. The bubbles form when the pressure on the magma can no longer keep gasses dissolved, something which happens as the magma is brought close to the Earth's surface. Many factors influence the preservation of vesicles including their rate of growth, the cooling rate of the magma, magma viscosity, the gas composition, temperature, and pressure.

A garden wall in Ambleside; Nota bene, no cleavage.

Quartz and chlorite amygdales in an andesite from Honister. This is magma that never made it to the surface; it is from a peperite.

Within a few years of a vesiculated magma crystallising, the bubbles can be filled by chemical precipitates; quartz and carbonate are the most common but chlorite is seen in a lot of Lake District volcanics. Less metamorphosed regions have zeolites. An infilled vesicle is an amygdale. Weathering can remove an amygdale's filling removing part of the history of the rock.

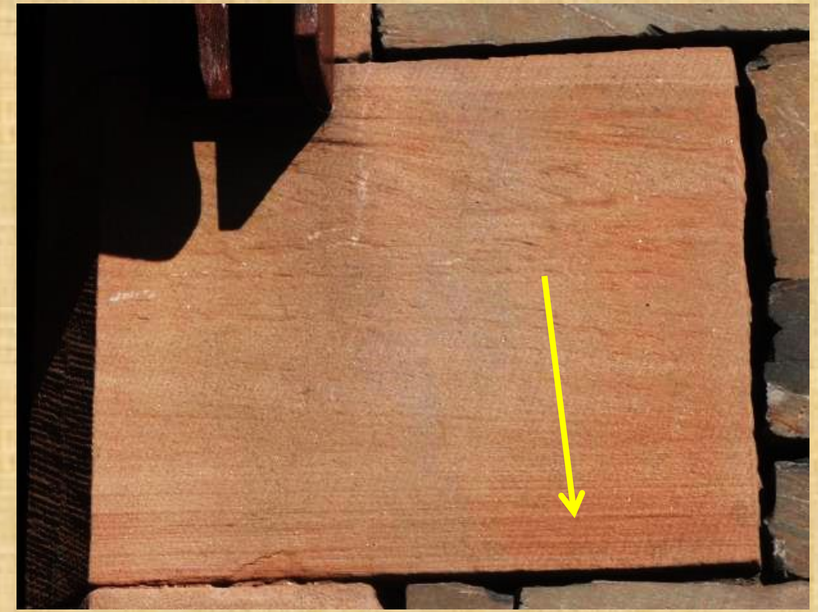
Kerbstones

- Slate
- Plutonic Igneous
- Limestone
- Sandstone

Borrowdales volcaniclastic sedimentary kerbstone – cleavage vertical

Shap Granite as kerbstone near Mint Dental.

Walnut Fish Bar, Ambleside. The source of the red beds is not known but they very likely came from the Permo-Triassic deposits in the Cumbrian Ring.

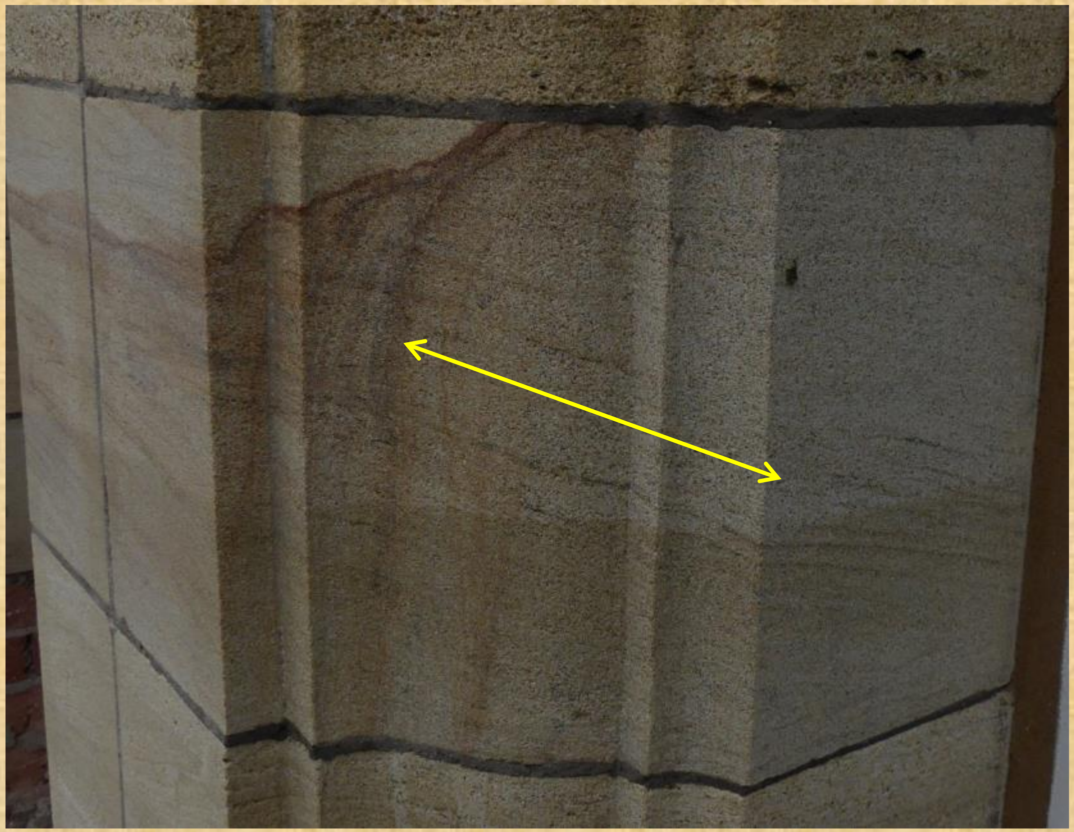


Truncated cross-bedding shows this block is upside down.

Individual blocks "Photoshoped" to enhance the sedimentary structures. The Old Bank House Chocolate Shop has similar features that are a little more etched by weathering.

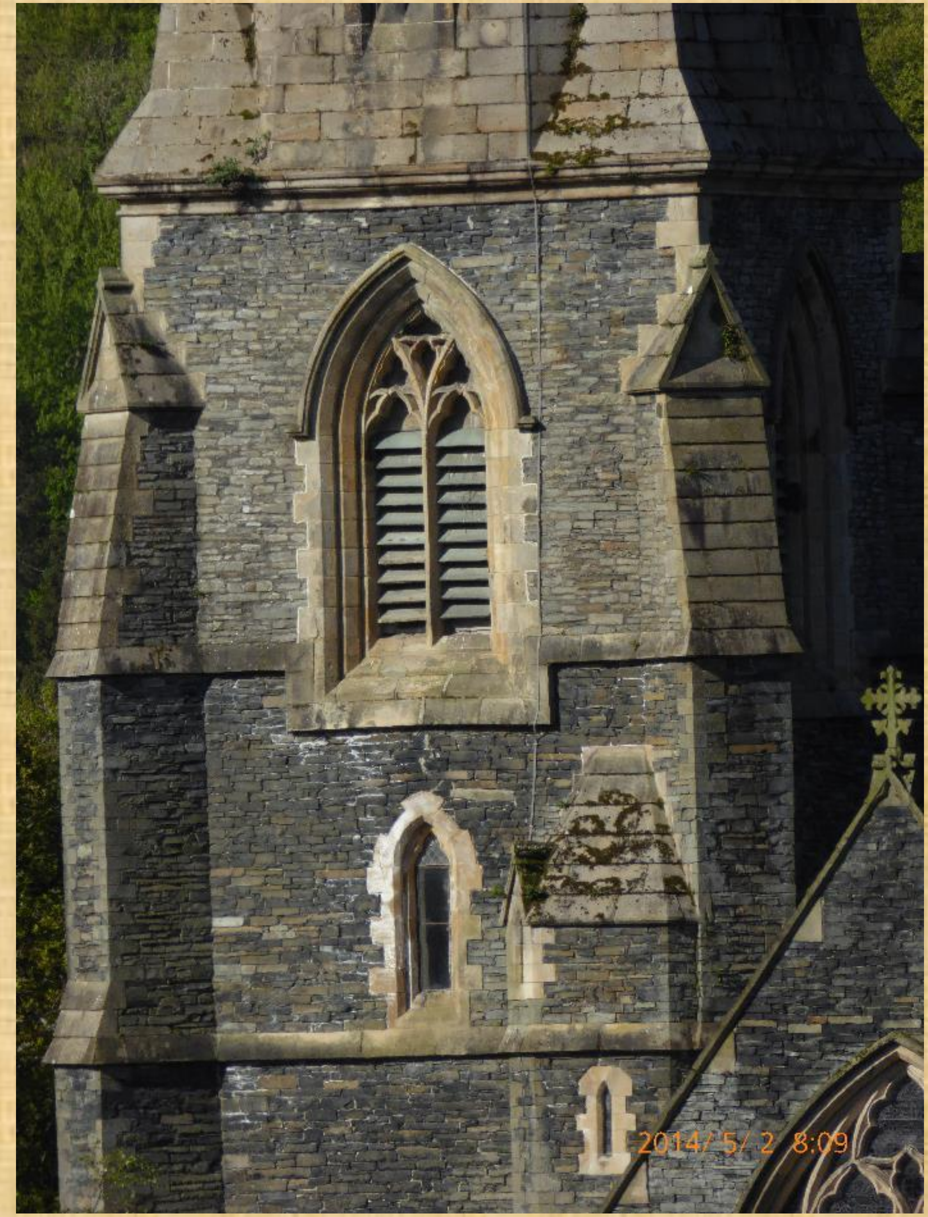
Liesegang Rings/Banding

The frontage of the old HSBC in Ambleside has been modified. The ATMs have been cut out and the windows enlarged; the clean new portions display examples of liesegang banding.



Detail of the Ex-HSBC frontage; the yellow line highlights the original depositional layering, liesegang banding in brown iron oxy-hydroxides.

Liesegang bands are formed in the near-surface as rocks are exhumed during uplift. Oxidising fluids access the rock mass by way of the joints formed during uplift and if porosity is favourable they penetrate the rocks leading to patterns controlled by geometry of the joints. The variation in chemistry of the bands is minimal [fractions of a percent] and probably is diffusion related.



St Mary's Church: extensive use of Brathay slates some of which show a deformation of the slaty cleavage. These are kink bands where there is a sharp deflection of the cleavage and then it returns to its original orientation in another sharp bend. Kinks are know as wrinkles in slate quarry and they prevent the rock from being split into slates.

Miscellany

Quartz vein blocks: King Street.

Limestone-pavement pieces as decoration: Central Buildings.

Kinked slate in Brathay Formation: Biketreks, Rydal Road.