Origin of Scottish slates

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> **From: Richey, J.E. and Anderson, J.G.C. 1944. Scottish slates. Wartime pamphlet No. 40. London : Geological Survey of Great Britain.**

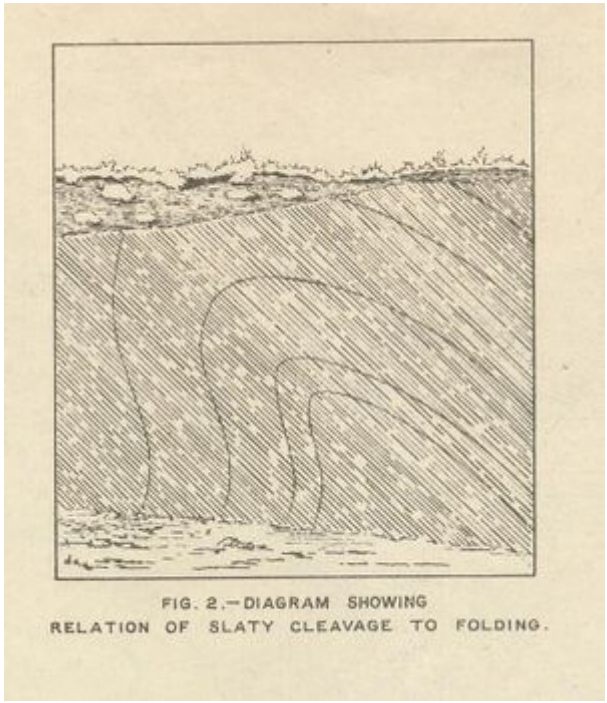


Diagram showing relation of slaty cleavage to folding. P519814.

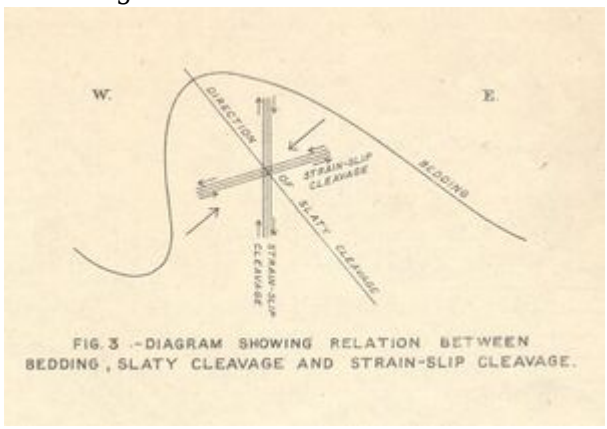
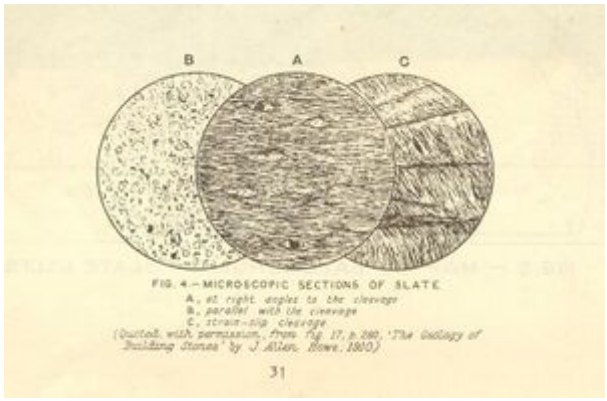
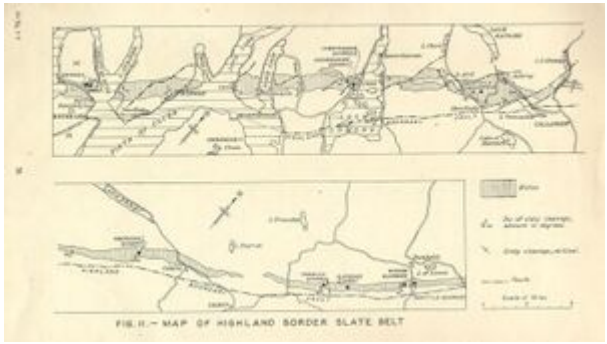


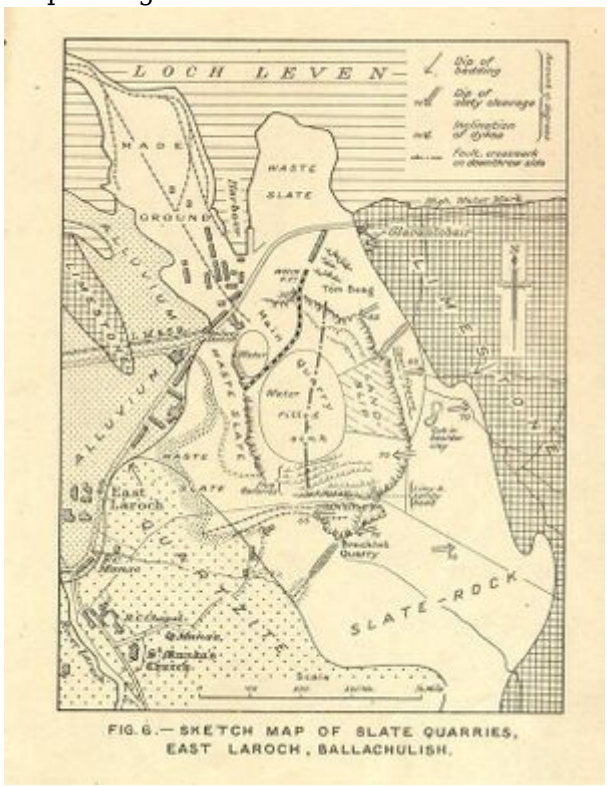
Diagram showing relation between bedding, slaty clavage and strain-slip cleavage. P519815.



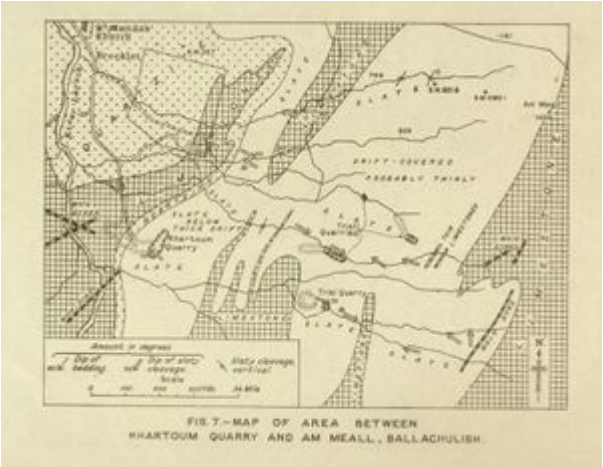
Microscopic sections of slate. A. at right angles to the cleavage. B. parallel with the cleavage, C. strain-slip cleavage (Quoted with permission from fig. 17 p.280 ‘The geology of building stones’ by J. Allen Howe, 1910. P519816.



Map of Highland Border slate belt. P519823.



Sketch map of slate quarries, East Laroch, Ballachulish. P519818.



Map of the area between Khartoum Quarry and Am Meall, Ballachulish. P519819.

The slates of the Scottish Highlands have been formed from accumulations of finely divided sediment which originally existed as horizontal layers (beds) of clay and silt. These sediments were laid down upon the floor of the sea or of some extensive river-estuary or great inland lake of past geological times. In such an accumulation, beds at various levels tend to differ more or less from one another in physical properties (e.g. grain size) and in chemical composition (e.g. relative percentages of silica, alumina, iron, etc). The differences are reflected in the quality and appearance of the slate-rock into which the clays and silts have been transformed. In addition to such local variations, affecting the quality of the slates in different parts of a quarry. Sediments that were laid down in different areas or at different geological epochs show variations by which one series of beds may be distinguished from another. Partly for this reason the Ballachulish slates, for example, differ from those of the Highland Border region.

In course of time, owing to their own weight and the pressure exerted by overlying, later-formed sediments, the beds of clay and silt become compressed and consolidated, and so form the rock called shale. Shales, like slates, can be readily split into thin layers, but the fissility in their case is entirely due to the close-set nature of the original bedding planes. As already stated, they have been quarried extensively for roofing materials in some districts, for example, in various parts of the Southern Uplands. As compared with true slates, however, they are much less strong, thickness for thickness, and therefore have to be split into relatively thick slabs.

The next stage in the formation of slate is the subjection of the beds of shale to intense pressure directed in a more or less horizontal direction and brought about by lateral movements which, at certain geological periods, take place in the earth’s crust and lead to the making of mountain chains. Such pressure bends the beds into folds, comparable in form though not in size to the crumples in a cloth that has slid over the surface of a table. As long as the pressure is not too intense, the beds of shale, although bent and inclined, retain their original characteristics and split readily only along the bedding planes. If, however, the folds become closely packed and the pressure is maintained, profound physical changes take place in the shales. A new set of planes is formed, termed cleavage planes, along which the rock splits very readily, and at the same time the degree of compactness and the strength of the rock is greatly increased. The shale has, in fact, been transformed into a true slate, the fissility of which depends entirely upon the presence of the cleavage planes; the latter may coincide with the original bedding, but usually cross the bedding at an angle which varies up to 90º.

The cleavage planes in slate are, in general, at right angles or at a high angle to the direction of the pressure which has led to their formation. The reason for the ready fissility of slates parallel to the cleavage and for their great resistance to forces applied at right angles to the cleavage, is apparent when thin sections of the rock are examined under the microscope (P519816) . It is seen in the case

of the Ballachulish and Easdale slates that minerals such as quartz occur as little plates with their flat faces all lying in a particular direction, parallel to which certain dark-coloured flaky minerals (mica and some chlorite) are also developed in abundance (P519816) A. Parallel to this direction the rock splits very readily; at right angles to it, the rock possesses great strength owing to the overlapping effect of the tiny plates of quartz and films of mica, which may be compared to the bonding of bricks in a wall. In the case of the Aberfoyle slates, the quartz grains are not usually flattened, and the fossility of the rock is largely due to the development of flaky minerals, mainly mica.

A number of theories have been advanced as to the exact nature of the changes which brings about the parallel orientation of minerals in slate. The subject however, is too complicated to discuss in the present connection, and we may pass on to consider the relationship of the slaty cleavage to the folding.

The rock-folds extend to some unknown depth in the earth, and superficially their tops have been cut across by prolonged erosion which has gone on for vast periods of time. In size, the rock-folds that affected the Highland slates are often extensive. In some cases the rocks forming one side of a fold may occupy an entire quarry. In others, a complete fold, showing both side, or limbs as they are termed, and the turn-over between the two limbs, may be visible on a rock-face, presenting the appearance shown in (P519814) . The slaty cleavage, however, is the most conspicuous structural feature in a slate quarry, and it is usually only by close examination that the ‘ribboning’ or ‘stripping’ which marks the run of the bedding can be distinguished.

The direction (i.e. strike) of the cleavage follows approximately the same direction as the general strike of the strata forming the surrounding country, and also of the bedding of the slate-rock itself. The cleavage-dip, on the other hand, is liable to vary in amount and sometimes in direction. In the case of the Highland Border belt, the direction of the cleavage-dip is away from the Highlands (i.e. south-south-east) along the south-western half of the belt, and towards the Highlands along the north-eastern half (P519823) . The place where the change-over in the direction occurs, and where the cleavage is vertical, lies to east-north-east of Loch Lomond, between Luss and Aberfoyle. At Ballachulish, on the other hand, the direction of cleavage-dip is prone to vary across a belt, so as to converge downwards or upwards (P519818) and (P519819) .

The diagrammatic sketch (P519814) illustrates the relationship between cleavage and folding. An upfold (anticline) only is shown. The diagram, however, if viewed upside down will also serve as an illustration of a down-fold or syncline. The axial plane of a fold is a term which requires explanation. It is an imaginary plane by which a fold may be divided into halves. In the case of a symmetrical fold, that is, one having two exactly similar limbs so that one limb is a mirror image of the other, the axial plane is vertical. In an asymmetrical fold of the type found in the Highland slate belts, the axial plane is inclined. On a quarry-face running with the cleavage-dip, where a fold is to be seen in a sectional view, the trace of the axial plane is a line drawn so as to connect the successive points where beds are seen to turn over at the top of an anticline or the bottom of a syncline.

In the case of the asymmetrical folds of the Highland slate belts, one limb of a fold is inclined at a much lower angle than the other, which is often vertical, or even overturned, that is, inclined in the same direction as the adjoining limb though at a much steeper angle. The cleavage planes are parallel to the axial plane of a fold, and so they cut across the bedding at angles of varying amounts (P519814) . The angle between cleavage and bedding is different in different limbs of a fold, and also at the turn-over. At the turn-over, the cleavage is almost at right angles to the bedding. Along the more steeply inclined or vertical limb the cleavage is strongly oblique to the bedding, or the two may coincide. These are matters well known to the quarrymen, especially when they are dealing with a good, though somewhat thin, seam of slate-rock. In such a case, large slates are to be had perhaps

only along the gently inclined limb where cleavage and bedding almost coincide. Along the steeply inclined or vertical limb, the slates that can be got out may be too small, while at the turn-over it is seldom that good slates are available.

In the Easdale district, the quarrymen have given Gaelic names to the various parts of a fold. A working along a gently inclined limb, where cleavage and bedding nearly coincide, is said to be on the sgriob (pronounced nearly the same as it if were spelt streep). Along a highly inclined limb, the beds are said to be on the beul (pronounced nearly as byel). At the turn-over, the beds are said to be on the bonn (pronounced nearly as bown). The cleavage is called sgoltadh (pronounced nearly as skoltje).

It may be mentioned that, in some places, a cleavage-plane, in passing from one bed to another, is bent, and follows a slightly different direction in the other bed. Where this happens in a series of thin beds of slate-rock, the size of slates which can be obtained may be too small, or the cleavage may be curved.

In addition to true cleavage, an aberrant kind of cleavage called strain-slip cleave is very prevalent. This consists of very closely spaced fracture planes, like miniature faults (P519816) c. It crosses the true cleavage at a wide angle, following two directions relatively to the cleavage (P519815) and tends to be developed especially along the axial plane of a fold. In other words, it is a feature of the bonn or turn-over of a fold. Partly for this reason, it is not usual to get slates along the bonn. But strain-slip cleavage is fortuitous in its occurrence and, in the Easdale belt, perhaps more good slate-rock is spoilt by it than through any other single cause.

One more point in regard to folding should be mentioned. It will be evidence from what has already been said that a quarry face extending across the dip of the cleavage, that is, along the strike, provides a longitudinal section of a fold, since the strike of the cleavage is either parallel, or nearly parallel, to the strike of the bedding, and the strike of the bedding is the direction in which the fold extends. Now rock-folds do not continue endlessly, any more than do folds in a table-cloth. A fold in a crumpled table-cloth will come to an end, and another which takes on just beyond will perhaps not be exactly in line with the first. In fact, the folds tend to be slightly staggered. The same thing happens when rocks are folded. For this reason, a good bed of slate-rock when traced along the strike of the cleavage may come to an end, corresponding to the end of a fold, and its continuation may be found to have been displaced a short distance one way or the other along the comparable limb of a succeeding fold. Thus, a quarry following a particular seam of slate-rock along the gently inclined limb of a fold, that is, along the ‘sgriob’, may have been abandoned owing to the seam coming to an end, as far as its usefulness as a source of marketable slates is concerned; and the next quarry may have got the seam a little out of line with the first quarry. This may be the explanation of a slight staggering of the quarries at Cullipool in the Easdale belt (see under III 4).

Another feature, due to the shape of the folds along their length, that is to say as seen on a quarry-face parallel to the strike of the cleavage, is that a particular seam of slate may extend obliquely across the quarry-face and disappear either into the air or farther below ground than operations can be profitably taken. If the quarry-face has been cut into the other direction, that is, with the dip of the cleavage, the seam, if worked on the limb of a fold, will certainly extend obliquely across the quarry face, and the face may be extended below ground in the direction in which the seam is dipping until the seam turns over on to the other limb (P519814) . From what has been said it will be evident that it is often important for the quarryman to be able to recognise and understand the ways in which the bedding of the rocks is running, and the reasons for the difficulties he may encounter.

- Building Stones
- Grampian Highlands

Navigation menu

Personal tools

- Not logged in
- Talk
- Contributions
- Log in
- Request account

Namespaces

- Page
- Discussion

□

Variants

Views

- Read
- Edit
- View history
- PDF Export

□

More

Search

Search Go

Navigation

- Main page
- Recent changes
- Random page
- Help about MediaWiki

Tools

- What links here

- Related changes
- Special pages
- Permanent link
- Page information
- Cite this page
- Browse properties

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- Privacy policy
- About Earthwise
- Disclaimers
-
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