Structure, Midland Valley of Scotland

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Jump to navigation Jump to search

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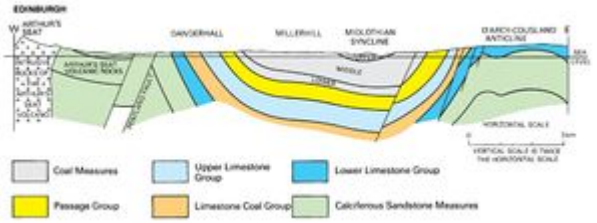
Contents

Structure

Priniciple faults and folds in the Midland Valley. P915547.



Cross-section of the Midlothian syncline. P915548.

The Midland Valley is in structural terms a graben, and is approximately 80 km wide, bounded in the north by the Highland Boundary Fault and in the south by the Southern Upland Fault. The graben

structure developed as such in the Devonian, but its location and dimensions were determined by crustal events which happened in the Lower Palaeozoic.

The Grampian Highlands are the result of intense deformation and metamorphism in early Ordovician times of a thick pile of Dalradian sediments. The Dalradian sediments accumulated on the southern part of a northern continent which included North America, Greenland and Scandinavia. The Iapetus or Proto-Atlantic ocean lay to the south of this northern continent.

The Southern Uplands rocks are thought to have accumulated as a result of subduction of oceanic crust beneath the North American–North European continent. Lower Palaeozoic sequences of basalt, chert and thick greywackes accumulated on the floor of the Iapetus Ocean and were progressively scraped off as the oceanic plate moved north-westwards into the subduction zone. The sediments accumulated and were deformed as successively younger slices were thrust under each other to form an imbricate accretionary prism. The accretionary prism became emergent in the northern part of the Southern Uplands and shed detritus into the southern part of the Midland Valley in Silurian times.

The final closure of the Iapetus Ocean and the cessation of subduction is assumed to have occurred in the late Silurian or Devonian. Several plate-tectonic models for the Caledonian orogeny have been proposed.

The deep structure of the Midland Valley is poorly known and the evidence is fragmentary, but it appears to be fundamentally different from the Grampians to the north and the Southern Uplands to the south. It is separated from these two areas by major crustal lineaments which date from the Lower Palaeozoic and which more or less pre-determined the location of the lines of weakness which define the graben.

The positions of the major faults and folds in the region are shown on P915547.

Faulting

Highland Boundary Fault

The Highland Boundary Fault extends from Stonehaven in the north-east to near Helensburgh on the Firth of Clyde. It separates the little-deformed rocks of the Midland Valley from the intensely deformed rocks of the Highlands.

The fault is only one of a number of parallel fractures which form a zone usually consisting of two or three major and several minor fractures, with the Highland Boundary Fault itself as the most south-easterly of the major faults.

The inclination of the major faults, as seen in exposure, is steep towards the north-west between Stonehaven and Aberfoyle, but from Loch Lomond to the Clyde coast its hade is steep towards the south-east. The apparently straightforward south-easterly downthrow between Stonehaven and Aberfoyle is complicated by later movements affecting younger sediments in the Loch Lomond to Firth of Clyde area. The fault bifurcates south-west of Loch Lomond into a northern branch which passes north-west of Helensburgh and crosses the Rosneath Peninsula, Toward Point and the Island of Bute. The southern branch passes south-east of Helensburgh and its course is obscured south of the Clyde by the cover of Carboniferous rocks.

The line of the fault is marked in places by fault slices of a variety of rocks of the Highland Border Complex, which is thought to be of Lower Ordovician age. The rocks include serpentinite, cherts,

spilites and limestone.

The main displacement on the fault occurred prior to deposition of the Upper Devonian and probably occurred both during and after deposition of Lower Devonian. The amount of downthrow to the south-east has been estimated to be of the order of 2500 to 3000 m in the Crieff and Tayside area. Evidence of downthrow to the north-west, after deposition of the Upper Devonian and basal Carboniferous sediments, is preserved in the Loch Lomond to Firth of Clyde area. Gravity measurements suggest that the Upper Devonian north-west of the fault is underlain by several hundred metres of Lower Devonian sediments.

The possibility that transcurrent movement has taken place on the fault has been discussed by Anderson (1947) and it is inferred to have occurred in the Ordovician according to the plate-tectonic model of Lambert and McKerrow (1976). Bluck (1980) also suggested lateral movement on the fault during Devonian times, but in a sinistral sense, opposite to that of Lambert and McKerrow. No such movement has yet been proved, although sinistral displacement is known to have occurred on faults with NNE trends in the Highlands and these faults trail into the Highland Boundary Fault.

The north-westerly hade of the fault, in exposure, is supported by interpretation of the gravity measurements which suggest that the hade is between 10° and 20° to the north-west, at least as far as the base of the Lower Devonian. This evidence suggests that the fault is a high angle reverse fault. This is likely to be too simple a description, but stratigraphic evidence enabling a more detailed analysis is lacking.

Southern Upland Fault

The Southern Upland Fault runs from Glen App in the south-west to Leadburn in Midlothian where the fault apparently is buried by the cover of Carboniferous sediments. It is perhaps continued en echelon by either the Lammermuir Fault which runs from south of Leadburn to the coast near Dunbar or the Pentland Fault which separates the Pentland Hills from the Midlothian basin.

The Southern Upland Fault and the Lammermuir Fault separate the steeply dipping, folded and faulted rocks of the Southern Uplands from the more gently deformed strata in the Midland Valley. In the south-west, in the Glen App area, the fault lies within the outcrop of the Lower Palaeozoic rocks and the line of separation between the Southern Uplands and the Midland Valley, in terms of the sediments and their deformation, is that section of the Straiton Fault which lies between Girvan and Dailly.

The Southern Upland Fault is accompanied by a group of associated faults subparallel to the main fault, including the Straiton Fault, the Kerse Loch Fault, the Carmichael Fault and the Pentland Fault among others.

Displacement began at least as early as mid Devonian and was renewed, in some instances with the throw reversed, during the Carboniferous and later. The main displacement was probably in the Lower and Middle Devonian with a net downthrow to, the north-west across the zone, and it occurred along the whole length of the fault. Later movements, during the Carboniferous, were more local in their effect. Differential subsidence across the lines of faulting resulted in abrupt changes of thickness in the Carboniferous of Ayrshire and south Lanarkshire, but similar variations in thickness in relation to faulting are absent in the Lothians.

In several instances later movements on a fault in the zone are in an opposite sense to the earlier displacement. The relationships of the rocks on either side of the Straiton Fault indicate that downthrow to the south-east occurred prior to deposition of the Upper Devonian, but the direction of

displacement was reversed later causing Carboniferous and Upper Devonian rocks, resting unconformably on Silurian rocks, to be downfaulted against Lower Devonian rocks to the south-east. The Southern Upland Fault between New Cumnock and Sanquhar is a double fault with a narrow strip of Ordovician rocks in faulted relationship to Lower Devonian rocks in the north-west and Coal Measures sediments to the south-east. The displacement on the northern fault occurred before Carboniferous deposition and that on the southern fault is post-Carboniferous. The pre-Carboniferous throw has been estimated to be about 900 m. A similar reversal of throw occurs on the Pentland Fault.

The net displacement on the fault zone is unknown. The several components of the displacement on each fault vary in amount and in direction from place to place. Only locally can a component of the throw be measured where it affects Carboniferous rocks.

The Southern Upland Fault is assumed to be primarily a normal fault, but transcurrent movement has been suggested to explain the variability of the downthrow.

The Pentland Fault, in its post-Carboniferous displacement, is a reverse fault. The hade has been measured at 22° to the north-west by drilling and the north-west limb of the Midlothian syncline is locally overturned. The fault can be traced offshore in the Firth of Forth and it passes between the east Fife coast and the Isle of May.

Other faults

Other faults with a trend more or less parallel to the marginal faults include the Dusk Water Fault and the Paisley Ruck. Both faults were active during Carboniferous deposition and the latter has a downthrow to the north-west of up to 500 m.

In the north-east of the region the North Tay, South Tay and Dura Den faults all trend approximately north-east. The North Tay and South Tay faults form a graben structure on the crest of the Sidlaw Anticline and have throws of more than 500 m and about 1 km respectively. Upper Devonian and Carboniferous sediments are preserved in the graben. The Dura Den Fault has a downthrow to the south of not less than 300 m.

The Ochil, Campsie and the Inchgotrick faults are major fractures, oblique to the marginal faults. The Ochil Fault, like the others, is a normal fault and has a maximum downthrow of about 3000 m near Alva. Most of the throw is post-Carboniferous, but there may have been movement during Carboniferous sedimentation.

Two important NNE-trending fold-fault structures occur in the Firth of Clyde area. The Cumbrae Ruck traverses the Great Cumbrae and geophysical evidence suggests that it causes a sinistral displacement of the Highland Boundary Fault off Cloch Point, near Gourock. A parallel structure crosses the Hunterston peninsula and runs north-north-east into the Renfrewshire Hills behind Largs. Downthrow is on the eastern side of the faults except in Cumbrae where Lower Carboniferous strata are downthrown on the west side.

The pattern of faulting revealed by mining information in the coalfields shows two predominant trends of normal faulting. A W–E trend appears to be earlier since the other, NW–SE trend, terminates against or trails into the W–E trend (Anderson, 1951). Faults with a W–E trend are particularly numerous and include several with a considerable downthrow. In West Lothian there are three important W–E faults. The Ochiltree Fault has a downthrow of about 360 m on the south side. The Middleton Hall Fault and the Murieston Fault both throw down on the north side, with a displacement on the former of about 470m and on the latter of about 550m. Faults trending W–E are

particularly numerous in a zone between the Clyde and the Forth.

Three sub-parallel NW-trending faults are known from geophysical evidence in the Firth of Clyde. The Ardrossan Fault and the Sound of Bute Fault both throw down to the south-west and limit the North-East Arran Trough on its north-east side. The south-west side of the trough is bounded by the Brodick Bay Fault.

Folding

The Lower Palaeozoic rocks of the Straiton area and the Pentland Hills show evidence of folding prior to deposition of the Lower Devonian. The rocks are steeply inclined or vertical with a NE strike and are unconformably overlain by Lower Devonian strata. However, in the Lesmahagow and Hagshaw Hills inliers, and at Stonehaven, Lower Devonian rocks follow Silurian rocks with apparent conformity.

The Lower Devonian rocks are folded about NE-trending axes and the folds are tightest, with locally overturned limbs, in zones adjacent to the marginal faults. Away from the north and south margins the folds are more open, but of considerable amplitude. In the north-east of the area the NW limb of the Strathmore syncline is locally overturned in the vicinity of the Highland Boundary Fault, but the Sidlaw anticline is a broad open structure.

The main structures in the Carboniferous in the western part of the Midland Valley differ in style and axial trend from those in the eastern part. In the west there are broad regional warps with a north-westerly or westerly trend and locally north-easterly trending folds associated with faults, but in the east the main axes run a few degrees east of north.

In the west the Mauchline basin has a broad synclinal structure with a north-westerly orientation. The SW limb of the syncline appears to culminate in the Kirkoswald area. To the north of the Mauchline basin the axis of maximum thickness of the Clyde Plateau lavas, which runs from Greenock to Strathaven, is the primary control on the outcrop and the broad W–E syncline in the Kilmarnock and Irvine area is truncated on the south side by the Inchgotrick Fault.

Folds with a north-easterly trend are associated with faults of the same orientation and occur on the downthrown side. These folds are in part contemporaneous with Carboniferous sedimentation and are exemplified by the Dailly, Littlemill and Douglas synclines.

In the east the main structures are the synclines which contain the Central and Stirling and Clackmannan coalfields and the Midlothian Coalfield. These structures trend a few degrees east of north. The axis of the Clackmannan Syncline, in the Stirling and Clackmannan Coalfield is more or less coincident with the Kincardine basin. The syncline was forming during deposition of the Upper Carboniferous and possibly also in Lower Carboniferous times. The formation of the syncline is thought to have been complete by the end of the Carboniferous.

The main structure affecting the Carboniferous rocks in Midlothian and Fife is comparable to the Clackmannan syncline, but the relationships are obscured by later displacement on the Pentland Fault. The basin is parallel to the Clackmannan syncline and isopachytes in the Carboniferous of Midlothian indicate thickening of Dinantian and Namurian sediments towards the axis of the structure from the eastern side. The western half of the depositional basin in Midlothian is cut out by post-Carboniferous displacement on the Pentland Fault.

The syncline in Midlothian is markedly asymmetrical (P915548). The NW limb is highly inclined and has in places subsidiary anticlines. The strata have dips in the range 60° to 80° and locally they are

overturned. The syncline is flanked on the east side by the D'Arcy–Cousland anticline which brings to outcrop a core of Dinantian rocks flanked by Namurian. Both syncline and anticline close to the south-south-west.

Bibliography

Allan, D. A. 1928. The geology of the Highland Border from Tayside to Noranside. Trans. R. Soc. Edinburgh, Vol. 56, pp. 57–88.

Allan, D. A. 1940. The geology of the Highland Border from Glen Almond to Glen Artney. Trans. R. Soc. Edinburgh, Vol. 60, pp. 171–193.

Anderson, E. M. 1951. The dynamics of faulting and dyke formation with application to Britain. (2nd edition). (Edinburgh: Oliver and Boyd.)

Anderson, J. G. C. 1947. The geology of the Highland Border, Stonehaven to Arran. Trans. R. Soc. Edinburgh, Vol. 61, pp. 479–515.

Bamford, D. 1979. Seismic constraints on the deep geology of the Caledonides of northern Britain. In Harris, A. L., Holland, C. H. and Leake, B. E. (editors). 1979. The Caledonides of the British Isles — reviewed. Spec. Publ. Geol. Soc. London, No. 8.

Bluck, B. J. 1978. Sedimentation in a late orogenic basin: the Old Red Sandstone of the Midland Valley of Scotland. In Bowes, D. R. and Leake, B. E. (editors). 1978. Crustal evolution in northwestern Britain and adjacent regions. Spec. Issue Geol. J., No. 10.

Bluck, B. J. 1980. Evolution of a strike-slip fault-controlled basin, Upper Old Red Sandstone, Scotland. In Sedimentation in oblique slip mobile zones, pp. 63–78. Reading, H. G. and Ballance, P. F. (editors). Spec. Publ. Int. Assoc. Sedimentol., No. 4.

Bluck, B. J. 1983. Role of the Midland Valley of Scotland in the Caledonian orogeny. Trans. R. Soc. Edinburgh: Earth Sci., Vol. 74, pp. 119–136.

Dewey, J. F. 1971. A model for the Lower Palaeozoic evolution of the southern margin of the early Caledonides of Scotland and Ireland. Scott. J. Geol., Vol. 7, pp. 219–240.

George, T. N. 1960. The stratigraphical evolution of the Midland Valley. Trans. Geol. Soc. Glasgow, Vol. 24, pp. 32–107.

Hall, J. 1974. A seismic reflection survey of the Clyde Plateau lavas in north Ayrshire and Renfrewshire. Scott. J. Geol., Vol. 9, pp. 253–279.

Kennedy, W. Q. 1958. Tectonic evolution of the Midland Valley of Scotland. Trans. Geol. Soc. Glasgow, Vol. 23, pp. 107–133.

Lambert, R. St. J. and Mckerrow, W. S. 1976. The Grampian orogeny. Scott.J. Geol., Vol. 12, pp. 271–292.

Leeder, M. R. 1982. Upper Palaeozoic basins of the British Isles — Caledonide inheritance versus Hercynian plate margin processes. J. Geol. Soc. London, Vol. 139, pp. 479–491.

Mckerrow, W. S., Leggett, J. K. and Eales, M. H. 1977. Imbricate thrust model of the Southern Uplands of Scotland. Nature, London, Vol. 267, 237–239.

McLean, A. C. 1966. A gravity survey in Ayrshire and its geological interpretation. Trans. R. Soc. Edinburgh, Vol. 66, pp. 239–265.

McLean, A. C. and Deegan, C. E. 1976. A synthesis of the solid geology of the Firth of Clyde region In McLean, A. C. and Deegan, C. E. (editors). The solid geology of the Clyde sheet (55°N/6°W). Rep. Inst. Geol. Sci., No. 78/9.

Paterson, E. M. 1954. Notes on the tectonics of the Greenock–Largs Uplands and the Cumbraes. Trans. Geol. Soc. Glasgow, Vol. 21, pp. 430–435.

McLean, A. C. Phillips, W. E. A., Stillman, C. J. and Murphy, T. 1976. A Caledonian plate tectonic model. J. Geol. Soc. London, Vol. 132, pp. 579–609.

Russell, M. J. and Smyth, D. K. 1983. Origin of the Oslo Graben in relation to the Hercynian–Alleghenian Orogeny and lithospheric rifting in the North. Atlantic. Tectonophysics, Vol. 94, pp. 457–472.

Thomson, M. E. 1978. IGS Studies of the geology of the Firth of Forth and its approaches. Rep. Inst. Geol. Sci., No. 77/17.

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More

Search

Search Go

Navigation

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

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

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