Moffat Shale Group, Ordovician–Silurian, Southern Uplands

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Moffat Shale Group

Frontispiece Dob’s Linn, Moffatdale. The waterfall cascades down the slightly overturned base of a thick turbidite sandstone bed at the base of the Queensberry Formation (Gala Group, Silurian). P220190.
Ordovician graptolites from the south of Scotland. P912316.

Silurian (Llandovery) graptolites from the south of Scotland. P912317.

Thin, pale-coloured layers of volcanic ash (metabentonite) interbedded with mudstone of the Moffat Shale Group at Dob's Linn, Moffatdale. P220194.

Representative structural-stratigraphical profiles across the Ordovician–Silurian Southern Uplands terrane. P912326.
The classical black mudstone succession of the Moffat Shale Group was first examined in detail by Charles Lapworth as a part of the extensive and far-sighted stratigraphical work that he undertook around Moffatdale during the early 1870s. Graptolites provide a basis for the biostratigraphical subdivision of the sequence and the faunal biozones established by Lapworth remain the foundation of the modern scheme. Lapworth’s Glenkiln, Lower and Upper Hartfell and Birkhill Shale divisions are retained as formations in modern terminology, with the first three being entirely Ordovician in age. Although previously regarded as wholly Silurian, the basal part of the Birkhill Shale is now referred to the Ordovician following the assignment of the *Glyptograptus persculptus* Biozone to that system. The Birkhill Shale therefore spans the Ordovician – Silurian system boundary and indeed includes, at Dob’s Linn (NT 196 158), 15 km north-east of Moffat, the Global Stratotype Section and Point (GSSP) for the base of the Silurian ([P220190](#)). A selection of the characteristic graptolites that help define the stratigraphy is shown in [P912316](#) (Ordovician examples) and [P912317](#) (Silurian examples).

The Moffat Shale Group is best developed in its type area of Moffatdale where it spans the Upper Ordovician and Lower Silurian beneath the overlying Llandovery sandstones. Traced towards the north-west, the Moffat Shales are replaced by the wacke sandstone turbidites at progressively lower stratigraphical levels in successive fault-bounded tracts ([P912326](#) and [P912327](#)). In the most northerly tract, occupied by the Llanvirn to Caradoc Tappins Group, no true Moffat Shale is seen, the lithofacies being represented instead by black laminae within a turbidite sandstone succession that rests directly on red chert and lava, likely correlatives of the Kirkton Formation.

The Glenkiln Shale Formation (about 25 m) is the oldest and least well-known formation of the Moffat Shale Group and consists of at least two units of cherty, black graptolitic mudstone, separated and succeeded by grey mudstones and siltstones. The graptolites establish the lower Caradoc, *apiculatus-zic Zac* Subzone, the lower subzone of the *bicornis* Biozone. Though originally named after exposures in the Glenkiln Burn (NY 007 898), near Ae, a type section for the base of the
Glenkiln Shale Formation has recently been proposed to the north of the Leadhills area where a stratigraphical contact with underlying grey chert (Kirkton Formation) is exposed in Gripps Cleuch (NS 883 171); the chert contains conodonts indicative of a late Llanvirn to early Caradoc age.

The overlying Lower Hartfell Shale Formation (22 m) consists of dark grey and black pelagic mudstone with an abundant graptolite fauna. As with the Glenkiln Shale, and for the same reasons of limited exposure, more than one section is required to illustrate the different parts of the formation. At Hartfell, soft black mudstone with grey cherty ribs is referred to the wilsoni Sub-zone, the upper subzone of the bicornis Biozone, and is overlain by black siliceous mudstone of the clingani and linearis biozones. The younger part of the Lower Hartfell Shale Formation is also well preserved at Dob’s Linn where mudstone from the upper part of the clingani Biozone is overlain by softer black mudstones containing linearis Biozone graptolites. White beds of metabentonite, representing devitrified volcanic ash, first appear at Hartfell as thin beds and laminae (< 2 cm) in the clingani Biozone of the Lower Hartfell Shale, but become thicker and more numerous in the succeeding Upper Hartfell Shales and Birkhill Shales (P220194).

In contrast to the dark and richly fossiliferous beds of the Lower Hartfell Shale Formation, the mudstones of the Upper Hartfell Shale Formation (28 m) are pale grey and virtually unfossiliferous apart from a few isolated black bands, from 1-50 mm thick, containing graptolites. Its type section at Dob’s Linn ranges from the complanatus Biozone up to the extraordinarius Biozone (P912326 and P912327). Although metabentonite layers are present at Dob’s Linn in the complanatus Biozone, they only start to become common in the succeeding anceps Biozone where at least 18 have been recorded (P912329). They range up to 20 cm, form 4 per cent of the total thickness and originated as fine-grained volcanic ash, composed of glass shards, fragmented crystals and lithic clasts (up to 0.7 mm), altered in contact with seawater prior to low grade metamorphism. Zircon crystals from one of the anceps Biozone bentonites at Dob’s Linn have given a U-Pb radiometric age of 445.7 ± 2.4 Ma.

An unusual feature is seen in the Upper Hartfell Shale Formation in its outcrop at Ettrickbridge (NT 390 243), where one of the southernmost inliers of Moffat Shale Group strata in the Central Belt underlies Ettrick Group (Kirkhope Formation) strata. There, about 55 m of coarse, wacke sandstone are interbedded within the mudstone sequence at about the level of the anceps Biozone. This sandstone unit is now referred to the Ettrickbridge Formation (P912326). As a sandstone turbidite unit, the Ettrickbridge Formation has obvious links with the Leadhills Supergroup and it has generally been included within that division. Alternatively, but less commonly, it is regarded as a local arenaceous member of the Upper Hartfell Shale and so forms part of the Moffat Shale Group. The sandstone is texturally a wacke and though quartz-rich it also contains numerous grains of lava, metamorphic rocks and feldspar, but no ferromagnesian minerals. The most unusual feature of the sandstones is that many of the larger quartz grains (those > 0.3 mm) are well rounded, some even being spherical, in marked contrast to the irregular angular quartz grains seen in every other formation in the Leadhills Supergroup. In comparison with the latter, the Ettrickbridge quartz grains have obviously been through at least one additional cycle of mechanical abrasion/erosion. Curiously, it is only the larger quartz grains that are well rounded, all other clasts, including the smaller quartz grains, being quite angular.

Only the basal 1.6 m of the Birkhill Shale Formation (40 m), that part lying within the persculptus Biozone, is of Ordovician age. At Dob’s Linn these beds are black pyritous mudstones with several white bentonite interbeds and a thin development of grey green mudstone at the base. Above this, the Silurian part of the Birkhill Shale Formation is composed predominantly of grey to black, variably laminated mudstone that yields graptolites representative of every Silurian biozone from acuminatus to halli. In the more southerly outcrops the mudstone passes up into a few metres of grey siltstone that is unfossiliferous at Dob’s Linn, but farther south includes black mudstone.
laminae that yield graptolite faunas of the *guerichi* Biozone. Pale metabentonite layers are conspicuous throughout the succession, generally as laminae to thin beds but with a few reaching 50 cm in thickness. They typically comprise 5–10 per cent of the total succession, but this proportion rises to 20 per cent in the convolutus to sedgwickii biozones (P912329). Zircon crystals from one of the *revolutus* Biozone bentonites at Dob's Linn have given a U-Pb radiometric age of 438.7 ± 2.0 Ma. The geochemistry of the bentonites shows a range of ash types, from subalkaline to peralkaline, that were generated in an ensialic volcanic-arc and, possibly, in a backarc setting.

Sandstone interbeds are rare in the Birkhill Shale Formation but occur at a few localities and at various levels, for example: in Wigtownshire, at Culroy (NX 255 540) a few metres of succession at the local top of the Moffat Shale Group (where it underlies the Gala 4 tract — see P912327) spans the *acuminatus*, *atus* and *acinaces* biozones and part of the *revolutus* Biozone, and is composed of sandstone with mudstone interbeds; at Dob's Linn, thin sandstone beds occur interbedded with the *revolutus* and convolutus Biozone mudstones (in the succession underlying the southernmost Queensberry Formation tract — see P912326). These sandstone beds, and the Ettrickbridge Formation described above, probably originated when distal turbidite deposition extended unusually far out across the oceanic sequence.

**Bibliography**


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