Excursion 1 Langholm And Canonbie: the evolution of a sedimentary basin

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OS 1:50 000 sheets 79 Hawick & Eskdale, 85 Carlisle & The Solway Firth

1:63 360 sheets 10 E Ecclefechan, 11 Langholm

Main points of interest Silurian turbidite sedimentology, Caledonian folding, the Permo-Carboniferous stratigraphy and evolution of the Northumberland Trough, Carboniferous lavas.

Logistics This excursion will look at geological outcrops over a relatively wide area so is best done in a full day by car, working upwards through the geological succession. Localities 1 and 2 are right by the road, but the rest include stream or river sections where wellington boots will be needed if the sections are to be examined closely.

Introduction

Langholm lies on the north margin of a Permo-Carboniferous sedimentary basin, the Northumberland Trough. The objective of this excursion is to look at the rocks filling the basin, to determine their characteristics and the environment in which they formed, and to piece these observations together into a model for the evolution of the northern margin of the Northumberland Trough through time. The Northumberland Trough contains rocks which range in age from early Carboniferous to Permian (Table 1) and (Table 2); they were deposited under changing environmental conditions which started as a shallow tropical sea and ended as a desert. The trough itself resulted from the stretching and down-faulting of sedimentary rocks of Silurian age, which had already been extensively folded and faulted during the Caledonian Orogeny. The range of rocks of differing lithology, and age makes Langholm an exciting area in which to investigate how a sedimentary basin starts, how it evolves and how sediments fill it through time. The area is described in detail by Lumsden et al. (1967).

1 Peden's View Quarry: Hawick Group greywackes

From Langholm turn NW off the A7 and follow the B709 up the valley of the River Esk. Peden's View Quarry [NY 345 862] is 5 km from Langholm on the right.

The rocks here belong to the Hawick Group (Carghidown Formation) of Wen-lock age and form part of the old basement of the Northumberland Trough. Beds of greywacke are dominant, a poorly sorted and immature sandstone, interbedded with shales. They were deposited by turbidity currents which flowed across the sea bed, mostly from the NE along the axis of the Silurian sedimentary basin. Each bed of greywacke represents an event when a turbidity current, charged with sediment, deposited its load. The base of the greywacke bed is generally coarse grained but as the current slackened progressively finer sediment was deposited (see (Figure 6)) to produce graded bedding. The effects of a turbidity current on the soft, fine-grained sediment deposited during a previous flow can be seen in the erosional sedimentary structures. In Peden's View Quarry large bedding planes are exposed along which groove casts are seen to have bifurcated, and grooves within grooves have developed. These features give a real impression of the direction of flow of the turbidity current and some idea of its erosive power. Prod marks can also be seen. These result when debris carried in the current scores the underlying unconsolidated mud before being plucked back into the current. Load casts can also be seen where the denser greywacke, once deposited, has sunk into the soft mud below. Ripple marks are less common but may also be seen here.

These sedimentary structures are useful in determining the environment of deposition but they can also tell which way up the strata are resting. From the steeply inclined orientation of the bedding planes it is clear that the strata have been compressed and folded, but to determine the nature of the folding in terms of anticlines or synclines it is necessary to know the way up of the strata. Groove casts, prod marks and load casts are features only found on the *bottom* of a greywacke bed. Using this knowledge it can be seen that the beds here are upside down, with the beds getting younger downwards. This conclusion may be tested by looking for other sedimentary structures: graded bedding and ripple marking should confirm it.

The rocks have been folded and the orientation of the bedding here can be determined by measuring the dip and strike of the bedding planes. However, other planar surfaces are also present in these rocks. The process of folding has produced new platy minerals which have grown with the plates perpendicular to the principal direction of stress. These planes are cleavage planes and they are often orientated approximately parallel to the axial plane of the folds. Measuring the orientation (dip and strike) of the cleavage plane thus allows you also to determine the orientation of the axial plane of the folds. The next locality will develop this concept further.

2 White Birren Quarry: folding in Hawick Group greywacke

Continue NW on the B709 through Bent-path. About 3.5 km beyond Bentpath the B709 turns abruptly right to cross the River Esk. Immediately before the bridge, a minor road continues straight on towards Lockerbie. Follow this for a short distance; White Birren Quarry [NY 274 918] is a small disused quarry by the roadside on the left. Fine-grained greywackes are interbedded with thin beds of red mudstone. The strata are part of the Hawick Group (Carghidown Formation) as at Locality 1, but here show tight folds with subhorizontal hinges. The orientation of these hinge lines and that of the axial planes of the folds, particularly the smaller ones, can be measured using a compass clinometer. Slaty cleavage has formed by the growth of new platy minerals parallel to the axial plane of the folds. The orientation of the cleavage planes can again be measured and these data compared with the orientations of the axial planes of the folds. Both the axial planes and the cleavage surfaces dip steeply to the SE. In the SE of the quarry (left as you view the rock face) the folds are fairly open but on the NW side become tight to isoclinal. Sedimentary structures are abundant and flute casts are particularly well developed on the bases of thicker greywacke beds. They confirm the direction of younging on the fold limbs.

The quarry also shows an example of an igneous intrusion, a dolerite dyke. This is a dark coloured rock, rich in ferromagnesian minerals (usually pyroxene) and appears to be highly altered. The dyke cuts across the folded bedding of the sedimentary strata and is therefore younger than these rocks; it is probably of early Devonian age. The NW side of the dyke is marked by a strike-parallel fault with slickensided surfaces at the dyke margin. The absence of red mudstone interbeds from the strata to the SE of the dyke suggests that movement on the fault was at least several metres. The geological features to be seen in the quarry are summarised in the sketch cross-section, (Figure 11).

3 Skipper's Bridge: Birrenswark lavas

Return to Langholm and head south on the A7 for 3 km. At Skipper's Bridge continue south on to the B6318 immediately before the A7 turns right on to the bridge. Park on the roadside [NY 371 833]. Access to the rocks is by a gate on the west side of the bridge. The section can be examined for about 1.5 km downstream from the bridge. **Extreme care should be taken if the river is in flood.**

The Birrenswark lavas can be seen on the riverside at Skipper's Bridge. The main lava lithology is olivine-rich microporphyritic basalt, with olivines or pyroxenes less than 2 mm in size. The lavas are rarely fresh and often the olivine or pyroxene is replaced by reddish brown iron oxides. The upper parts of individual lava flows are commonly amygdaloidal, with former gas bubbles in the lava now filled by secondary minerals, usually calcite. The thickness of lavas here is at least 50 m. At Skipper's Pool [NY 3703 8328], sedimentary rocks can be seen interbedded with the basaltic lavas. These are iron-rich, water-laid deposits formed by reworking the weathered rubbly tops of the lavas. Angular blocks of basalt, probably locally derived, can also be seen in these strata.

This volcanic episode marks a period of crustal extension and the initiation of the Northumberland Trough. Extension of this sort produces rifting, where normal faults, principally at the basin margins, move to form a graben structure. Crustal thinning associated with these processes results in increased heat flow and the generation of basaltic magmas.

4 Liddel Water: Upper Liddesdale Group, Penton Anticline

From Skipper's Bridge, continue on the B6318 south for 18 km until the Liddel Water is reached at Penton Bridge [NY 433 775]. Cars can be parked in the small car park by the bridge and access to the downstream section is by a footpath along the northern bank of the river. The section in Liddel Water at Penton Linns demonstrates a sequence of changing environments in the Upper Liddesdale Group of Carboniferous (Brigantian) age. The sequence and the structure are both best examined in thesection downstream from Penton Bridge. The oldest rocks occur in the core of the prominent Penton Anticline.

On the east limb of the anticline a succession can be followed upwards from the Penton Limestone, found in the core of the anticline, to the Bridge Limestone, found close to the foundations of Penton Bridge. The sequence of lithologies on the west limb of the fold is shown in graphical form in (Figure 12), and a brief description of the sequence is given below.

The graphic log shows a sequence of marine limestones interbedded with clastic strata which commonly coarsen upwards from mudstone to sandstone, with seatearth and coal at the top. The pattern is repeated many times, each unit being termed a cyclothem. The graphic log also shows that the change from mudstone to sandstone is not always steady; there are oscillations between mudstone, siltstone and sandstone but the overall upward-coarsening pattern is maintained. The lithological variation in this sequence can be interpreted in terms of cycles of changing depositional environment.

The limestones were deposited in a shallow- marine environment and are made up of organic fragments, some large and recognisable and others broken down to fine-grained carbonate sediment. Large productoid brachiopods, Gigantoproductus sp., and large solitary corals are common in the Penton Limestone. Near the top of this bed occur algal patches, *Girvanella,* and a trace fossil, *Zoophycos caudagalli.* The Bridge Limestone is only sparsely fossiliferous but near the top *Zoophycos caudagalli* occurs together with large crinoid stems and the colonial coral *Siphonodendron pauciradiale.* The Linns Limestone is sandy at its base and has the characteristic ochreous colour of a dolomitic limestone. The top of the Linns Limestone is red, iron-rich and knobbly. The Tombstone Limestone is poorly fossiliferous but the mudstone immediately above contains a diverse marine fauna including corals, brachiopods, gastropods, bivalves and goniatites. In the Gastropod Limestone at Loup Pool (NY 430 774) crinoid columnals, brachiopods, gastropods, bivalves and trilobite fragments can be found. The Harelawhill Limestone crops out on the prominent tree-covered island. This limestone is sparsely fossiliferous but crinoid columnals and corals including *Siphonodendron junceum* are present; near the top are several beds of nodular chert.

The faunas in the limestones and overlying mudstones indicate that the depositional environment of these strata was a warm, shallow sea, probably close to a shoreline supplying fine-grained detritus. The presence of corals is a good indicator of shallow-water conditions, as these organisms require sunlight to survive.

In many cyclothems a coal seam rests on the sandstone. Examination of the top of the sandstone units commonly reveals the presence of roots, either as the thicker root stalk, *Stigmaria,* or as fine hair roots. Prominent black roots are present in the sandstones at the top of the clastic sequence above the Linns Limestone. Here the internal structure of the sandstone has been destroyed and a hard massive rock, a ganister, has been formed. Roots are present beneath all the coals and, where these penetrate into fine-grained strata, the original bedding is obliterated, alteration of the minerals takes place and seatclay is formed. These rooty beds are the fossilised remnants of the soil on which the coal-forming plants grew and, together with the coal, indicate a terrestrial swamp environment.

The pattern of coarsening-upwards sedimentation shows how the change from marine conditions with deposition of limestone, to terrestrial conditions with accumulation of coal, took place. Broadly speaking, the mudstones were deposited in front of an advancing delta where the water was still mostly marine, the lower siltstones and sandstones were deposited on the delta front as it prograded into the marine environment, and the higher ones were deposited with coals and seatclays in the fluvial and swamp environments of the delta top. A return to a marine environment and the deposition of limestone comes about by a combination of delta switching, basin subsidence, and worldwide changes in sea level. This cyclical pattern is typical of sedimentation in the Lower Carboniferous over much of northern Britain.

On the western limb of the anticline, the sequence of strata stops abruptly downstream against a fault downthrowing to the south and bringing the younger Catsbit Limestone (earliest Namurian) to outcrop ill the bed of the river. The fault trend is approximately east–west, at right angles to the trend of the fold axis, and the strata south of the fault dip gently to the SW. If the sense of movement on the fault were vertical then the axial plane of the Penton Anticline should still be discernable on the south side of the fault. As it is not, it must be assumed that there is an element of lateral displacement in addition to down-throw to the south.

5 Gilnockie Bridge: mid-Carboniferous unconformity

Return north from Penton Bridge on the B6318 for 2 km, turn left on to the B6357 and continue to the village of Canonbie. Through Canonbie turn right on to the A7 heading north; note that this is a new bypass replacing the former A7 on the east side of the River Esk. About 4 km north of Canonbie turn right on to the old A7 (now closed) and park at Gilnockie Bridge [NY 385 781]. The section can be best viewed from the south side of the bridge but direct access is via the north bank through the Mill.

At Gilnockie Bridge, Lower Coal Measures strata can be seen resting unconformably on beds of Namurian age (formerly called Millstone Grit Series, now named Stainmore Group). The central pillar of the bridge rests on coarse gritty sandstone beds, gently inclined towards the SE. These are rocks of the Lower Coal Measures. Beneath these strata are medium-grained sandstones of the Stainmore Group dipping at 30° NW. The plane of unconformity which separates the two sequences dips at about 10° to the east and can be traced for about 50 m along the north bank of the river. The unconformity displayed here has also been identified in boreholes in the area. The difference in dip between the beds above and below the unconformity suggests that it represents a period of compression, uplift and erosion during mid-Carboniferous time.

The closure of the old A7 in the area south of Gilnockie Bridge is due to the collapse of old workings in the Lower Coal Measures. Adits into these workings are recorded downstream at Byreburnfoot.

6 Canonbie: Permian to Triassic

From Gilnockie Bridge, return to Canonbie via the new bypass and at its junction with the old A7, turn left, heading north. Continue through the village and, immediately after crossing the bridge over the River Esk, turn right and park at the churchyard [NY 395 763]. Access to the riverbank is by a public footpath.

Walking along the eastern bank of the River Esk affords views of the red sandstones, thought to be of Permian to Triassic age, on the opposite bank between Dead Neuk [NY 3923 7621] and Prior Linn [NY 3927 7615]. Large-scale dune cross-bedding can be seen with individual foresets in the order of 3 m high. Note that the tops of the foresets are truncated by bounding surfaces and each group of foresets represents the migration of an individual sand dune. The nature and significance of these bounding surfaces and the detailed sedimentary structures and grain characteristics of wind-blown sedimentary rocks in general, are described in Excursion 9. For a closer examination of these rocks at Canonbie, the opposite river bank must be accessed at Prior Linn on the A7 at the south edge of the village [NY 394 759]. Like those at Locharbriggs (Excursion 9, locality 1), the sandstones at Canonbie are coarse grained and well sorted with well-rounded 'millet-seed' grains. These characteristics are typical of wind-transported sands.

The red sandstones are the last evidence for the filling of the Northumberland Trough which had become completely terrestrial, with desert conditions prevailing. However, these Permian strata were deposited in basins, like the Dumfries Basin and the Vale of Eden, which are elongated NNW–SSE and opened up in response to a new extensional regime. There is some evidence that this transition was preceded by a tectonic inversion, probably towards the end of the Carboniferous, when compression of the strata of the Northumberland Trough took place prior to the extension which established the new Permian basins.

References

Age		Langholm (after Lumsden et al., 1967)	Kirkbean Glen (after Craig, 1956; BGS, 1993)	Southerness–Borron Point–Hogus Point (after Craig, 1956; BGS, 1993)	Castlehill Point–Gutcher's Isle (after BGS, 1993)
Dinantian (Lower Carboniferous)	Brigantian	Upper Liddesdale Group		? Arbigland Limestone Formation	? Rascarrel Formation
	Asbian	Lower Liddesdale Group Upper Border Group Glencartholm Volcanic Beds			
	Holkerian	Middle Border Group		Thirlstane Sandstone Member Powillimount Sandstone Formation	
	Arundian	Harden Beds		Gillfoot Sandstone Formation Southerness Limestone Formation Syringothyris Limestone	
	Chadian	Lower Border Group	? Kirkbean Cementstone Formation	?	
	Courceyan	Birrenswark Volcanic Formation			
Late Devonian		Upper Old Red Sandstone			
Silurian		Riccarton Group	Hawick Group		Hawick Group

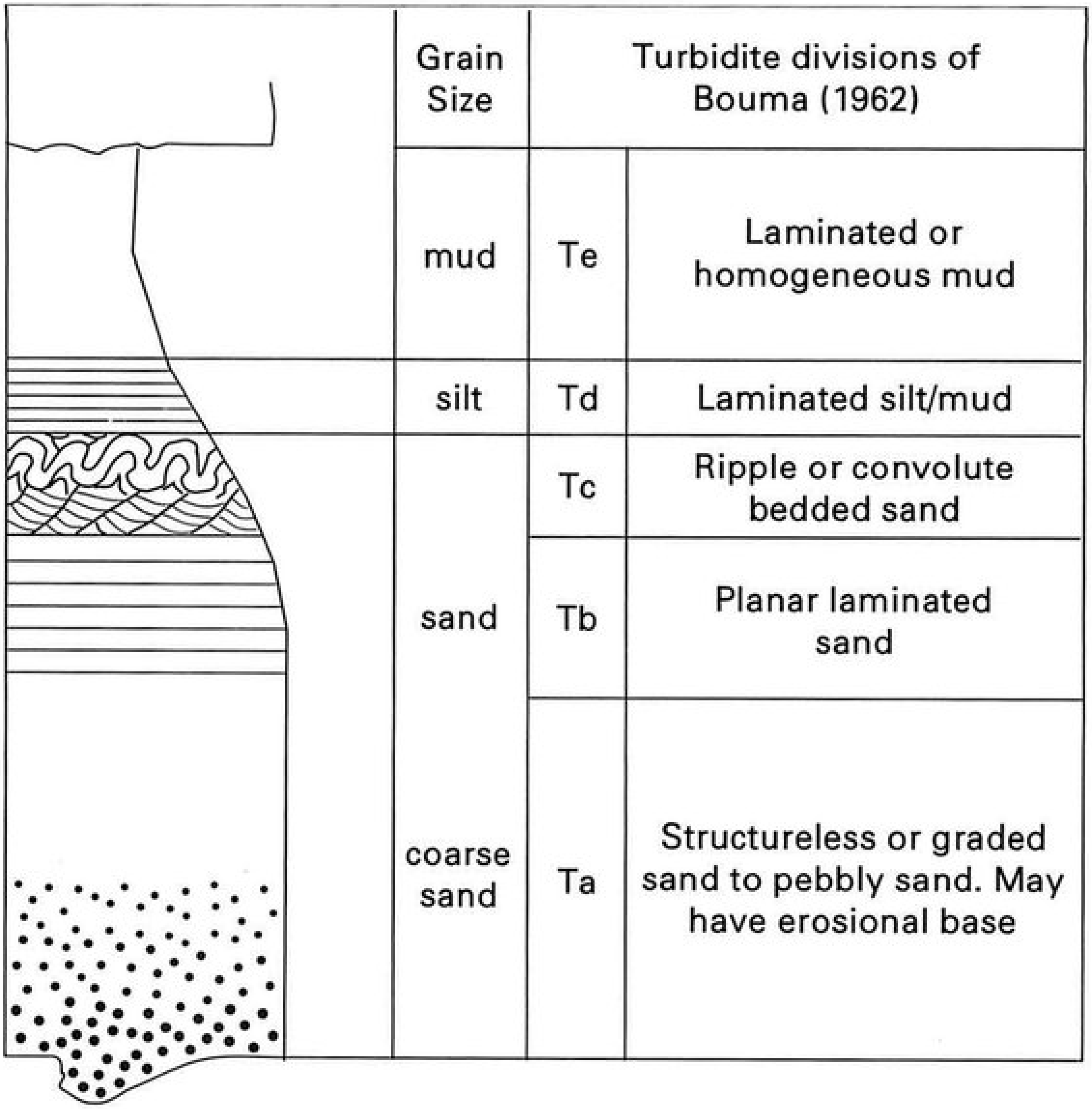
This table does not show relative thickness of different groups, formations and members.

(Table 1) Lower Carboniferous stratigraphy correlated along the northern margin of the Solway Basin.

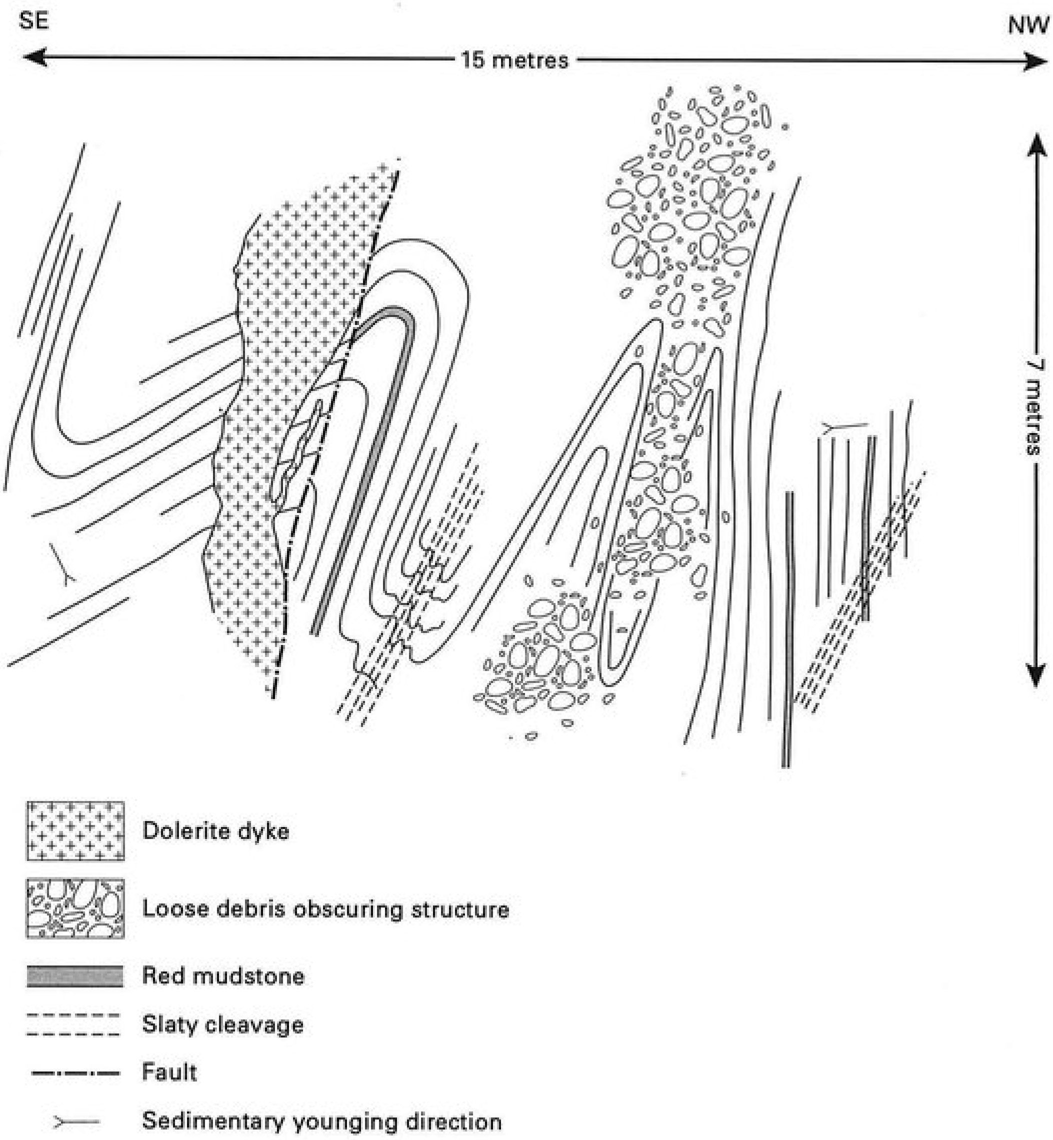
Age		Thornhill Basin (Permian after Brookfield, 1978)	Langholm (after Lumsden et al., 1967)	Dumfries Basin (after Brookfield, 1978)	Ballantrae & Loch Ryan (after Stone, 1988)
Early Permian		Thornhill Sandstone Durisdeer and Locherben breccias Carron Basalt	'New Red Sandstone' strata (Permian to Triassic)	Locharbriggs Sandstone Doweel Breccia	Corseclays Sandstone Park End and Loch Ryan breccias
Silesian (Late Carboniferous)	Westphalian	Upper Coal Measures Middle Coal Measures Lower Coal Measures		strata not proven	Upper Carboniferous rocks with interbedded basalt at Loch Ryan
	Namurian	Passage Formation	Stainmore Group		

This table does not show relative thickness of different groups, formations and members.

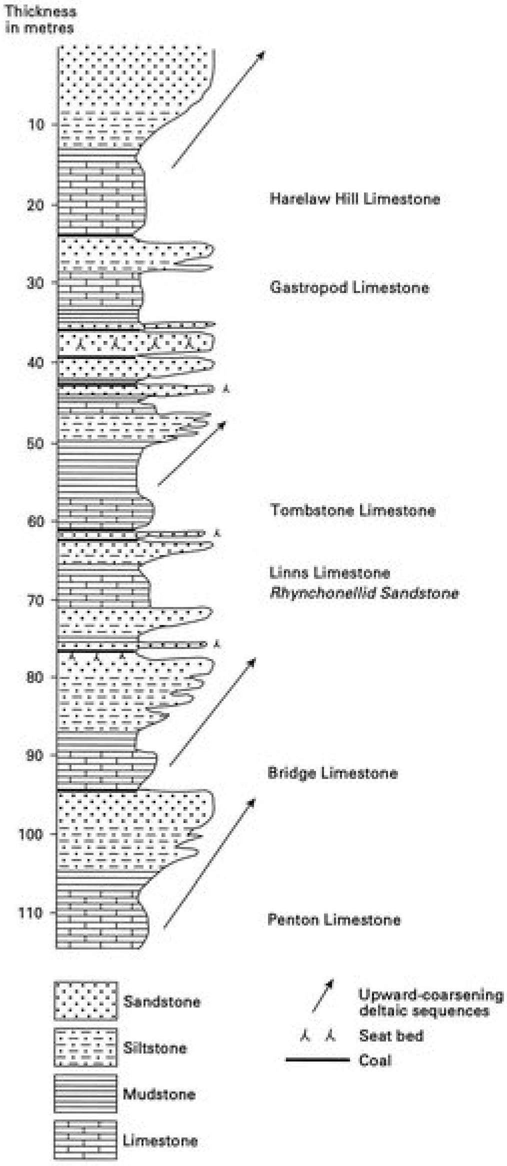
(Table 2) Upper Carboniferous and Permian suatigraphy in south-west Scotland.



(Figure 6) Divisions within an idealised turbidite bed after Bouma (1962) and Pickering et al. (1989).



(Figure 11) Tight, gently plunging folds exposed in the SW face of White Birren Quarry (Locality 2). After Gallagher et al. (1983).



(Figure 12) The Carboniferous section in the Liddel Water at Penton Linns.