Penwhapple Burn

[NX 2327 9769]–[NX 2262 9892]

Introduction

Penwhapple Burn lies within an outcrop of Silurian rocks to the south of the Girvan Valley, separated from the Craighead Inlier on the north side by a strip of Old Red Sandstone and Carboniferous rocks. This region, termed 'the Main Outcrop' by Cocks and Toghill (1973) in their description of the Silurian strata of the Girvan area (Figure 3.82), displays a succession of formations striking nearly east–west, with the dips nearly all vertical or overturned, so that the rocks dip southwards but young northwards. Along the burn, there are exposures through the complete local Silurian succession (Figure 3.75).

The succession was not fully elucidated until publication of the classic paper on the Girvan area by Lapworth (1882). Lapworth (1882, p. 603) noted that a continuous section through strata of late Ordovician and early Silurian age was exposed in the gorge of the Penwhapple Burn, extending for nearly 5 km; this provides a major reference section for the area. Peach and Horne (1899) also reported the exposures in the burn, mostly drawing from Lapworth's descriptions. In their reinvestigation of the geology of the Silurian rocks of the Girvan area, Cocks and Toghill (1973) recognized the lithostratigraphical succession determined by Lapworth (1882), but renamed several of the rock units to accord with modern nomenclatural practice. The sequence of formations used by Cocks and Toghill (1973) is shown in (Figure 3.75).

Penwhapple Burn provides an excellent, almost complete, representative section through the Llandovery succession of the Girvan Main Outcrop. Several formations contain abundant graptolites, allowing accurate local and international correlation of the sequence.

Description

A full description of the succession in and around the bum was given by Cocks and Toghill (1973), whose observations are summarized here. The basal Silurian unit, the Tralorg Formation (the *modestus* Shales of Lapworth), lies unconformably on the Shalloch Formation (the Barren Flagstones of Lapworth), with a gentle overstep westerly onto successively lower levels within this upper Ordovician unit. The contact is exposed in Penwhapple Burn [NX 2327 9769], 360 m north-west of Penwhapple Bridge; the junction here is inverted, with the basal Silurian strata dipping 50° SSE. The lowest beds of the Tralorg Formation consist of 1.5 m of concretionary mudstones with echinoderm fragments and rare brachiopods, identified as *Leangella scissa* and *Clorinda* sp.. The entire thickness of the formation is about 180 m, although estimates are complicated by small faults and folds. Above the basal beds are black pyritic mudstones and thin grey mudstones, which grade up into banded grey and green shales with thin sandstone beds. Graptolites are common in the black mudstones and occur occasionally in the shales of the upper part of the formation. The lower black mudstones have yielded a diverse fauna, including *Atavograptus atavus, A. strachani, Coronograptus cyphus, Monograptus revolutus, Rhaphidograptus toernquisti, Climacograptus rectangularis, C. normalis* and *C. medius,* with *C. cyphus* and *M. revolutus* persisting into the higher shales. Both of these faunas are indicative of the uppermost Rhuddanian *cyphus* Biozone.

The Tralorg Formation is succeeded abruptly and conformably by the Saugh Hill Grits, which are 180 m thick in Penwhapple Burn. The formation comprises thick greywackes with thin shales and occasional conglomerates. In the middle of the unit is a conspicuous 30 m shale sequence, which contains a few unidentifiable fragments of graptolites.

The Pencleuch Shale (the *M. Sedgwickii* Mudstones of Lapworth) is well exposed in the burn, but is extremely contorted so that bedding is not evident; the estimated thickness is 60 m. Cocks and Toghill (1973) distinguished a lower grey shale subdivision from an upper unit of black shales with large calcareous nodules. The higher unit contains abundant graptolites, sometimes well preserved. The very diverse fauna includes *Coronograptus gregarius, Monograptus* cf. *convolutus, M. triangulatus, M. clingani, Stimulograptus* cf. *sedgwickii, Pristiograptus jaculum, Petalolithus palmeus,*

Petalolithus folium, Rastrites peregrinus,

Pseudoclimacograptus hughesi and *Climacograptus scalaris.* These graptolites suggest that the Penleuch Shale spans a graptolite biozonal range from within the *gregarius* Biozone perhaps to the base of the *sedgwickii* Biozone and is dominantly assignable to the *convolutus* Biozone. It is thus of Aeronian age.

The junction between the Pencleuch Shale and the Lower Camregan Grits is marked by an important strike fault, the Camregan Fault. The grits here are 36.3 m thick and comprise fine- to medium-grained sandstones in beds 0.1 to 0.6 m thick (Figure 3.76). Transported brachiopod shells occur at the bases of some of the beds, and include rhynchonellids and *Eocoelia* sp., suggesting derivation from an *Eocoelia* benthic community.

Stratigraphically overlying the Lower Camregan Grits are vertical beds of the Wood Burn Formation (equivalent to the Upper *Pentamerus* Limestone and Camregan Limestone of Lapworth), comprising an estimated 19.6 m of siltstones and sandstones grading upwards into siltstones and shales (Figure 3.76). The lower part of the formation has yielded a brachiopod fauna that includes *Pentamerus oblongus* and *Steptalasma* sp., assignable to a *Pentamerus* benthic community. Towards the top, a much more diverse assemblage occurs, constituting a *Clorinda* benthic association, and including the brachiopods *Eoplectodonta penkillensis, Atrypa reticularis, Coolinia pecten, Clorinda undata* and *Skenidioides lewisii.* Graptolites from the nearby Penkill Burn show that the formation belongs to the upper part of the *sedgwickii* Biozone, of uppermost Aeronian age.

The Wood Burn Formation is succeeded abruptly by purple mudstones (the *Rastrites maximus* Mudstones of Lapworth) termed the Maxwellston Mudstones. The formation is 13 m thick, with a 0.3 m bed of dark grey graptolitic mudstone apparent 3.8 m above the base (Figure 3.76). The graptolite fauna includes numerous *Spirograptus turriculatus,* together with *Streptograptus barrandei, Torquigraptus planus, Stimulograptus halli, Pristiograptus nudus, P. regularis, Rastrites linnaei, R.* cf. *maximus* and *Petalolithus altissimus.* This fauna is characteristic of the lowermost *turriculatus* Biozone (*maximus* Sub-biozone), of earliest Telychian age.

Pale greenish-brown greywackes that abruptly follow the Maxwellston Mudstones are referred to the Upper Camregan Grits. These are 33 m thick in Penwhapple Burn, where they have not yielded fossils, but a small quarry in the formation at Camregan Wood (NIX 2256 9813) has provided a *turriculatus* Biozone fauna.

Above the Upper Camregan Grits is the 210 m thick Penkill Formation, which is equivalent to Lapworth's *Crossopodia* or Purple Shales and his Penkill Flags. The lower part of the formation comprises purple shales and thin grey-green shales (Figure 3.77), with sandstones becoming interbedded in the upper part. Graptolitic horizons occur sporadically, all with faunas of the *turriculatus* Biozone. The highest recorded fauna, 15 m below the top of the formation contains *Oktavites* aff. *spiralis, Streptograptus barrandei, Monograptus marri* and *Monoclimacis galaensis.* Meandering trace fossils also occur.

Only the lower 90 m of the 165 m thick Protovirgularia Grits are exposed in Penwhapple Burn, where the formation consists of greywacke units in which shale is subordinate. The trace fossil *Protovirgularia* occurs in the shales. Graptolites are not known from the sequence in the burn, but higher beds elsewhere have yielded faunas assigned to the *crispus* and *griestoniensis* biozones.

The Lachlan Formation (the *Cyrtograptus grayi* Mudstones of Lapworth) reaches a thickness of about 50 m in Penwhapple Burn, although the lowermost beds are not exposed. The unit comprises red and purple flaggy shales and thin sandstones. A dark grey mudstone 9 m below the top of the formation contains a few brachiopods and numerous graptolites, especially abundant *Monograptus priodon* which occurs along with *M. parapriodon, M. knockensis, M. marri, Torquigraptus dextrorsus, Lapworthograptus grayi, Barrandeograptus* sp. and *Retiolites geinitzianus angustidens.* The fauna indicates a Telychian age, in the *griestoniensis* Biozone.

The highest Silurian beds in the Main Outcrop were referred by Cocks and Toghill (1973) to the Drumyork Flags, although Lapworth (1882) had three divisions at this level in some areas. This is a thick formation, reaching 610 m, but only the lower part is exposed in Penwhapple Burn, where the succession is truncated by the Bargany Fault (Figure 3.75). At the base of the formation there are massive grey-green greywackes, but above this exposures become

sporadic, mostly showing vertical greywacke units. Cocks and Toghill (1973) recorded the recovery of one specimen of the graptolite *Cyrtograptus? lapworthi;* graptolite faunas elsewhere in the main outcrop show that the strata still belong in the *griestoniensis* Biozone.

Interpretation

Much of the sequence at Girvan was considered by Cocks and Toghill (1973) to have been deposited in relatively deep water, characterized by graptolitic shales or by turbidites. Cave (in Bassett *et al.,* 1992), however, suggested that the sea may not have been particularly deep and that the greywackes may represent sub-littoral, storm-generated sands rather than turbidites. A few horizons with shelly fossils certainly indicate a shelf environment, although mostly in the mid and offshore shelf areas.

Lapworth (1882) considered the junction between the Ordovician and Silurian strata in the Main Outcrop to be a fault, but Cocks and Toghill (1973) showed it to be an unconformity both here and in the coastal exposures (see description of the GCR site at Woodland Point). In the Main Outcrop there are no equivalents of the shallow water Craigskelly Conglomerate of the coast sections, nor of the Lady Burn Formation and Mulloch Hill Formation of the Craighead Inlier, so the unconformity incorporates a greater portion of the Rhuddanian in this region. By combining the thickness of the succession in the Craighead Inlier up to the top of the Saugh Hill Grits (1323 m) with that of the Main Outcrop from the Pencleuch Shale to the top of the succession (1514 m), Cocks and Toghill (1973) arrived at a total of 2837 m, nearly three times the figure estimated by Lapworth (1882).

The biostratigraphical data accumulated by Cocks and Toghill (1973) allowed a refinement of the correlations between the outcrops in the Girvan area, and a revision of some of Lapworth's conclusions. Cocks and Toghill's (1973) correlations are shown in (Figure 3.78). The recovery of graptolite faunas throughout the succession in the Main Outcrop has demonstrated that the whole sequence is of Llandovery age, in contrast to the suggestion of Walton (1965) that, on lithological grounds, all the formations above the Maxwellston Mudstones might be of Wenlock age. Cocks and Toghill (1973) also postulated a stratigraphical break at the base of the Lower Camregan Grits, equivalent to much of the *sedgwickii* Biozone; their evidence for this comes from the abrupt replacement of euxinic black graptolitic shales of the Pencleuch Shale by shallow-water sandstones with an *Eocoelia* benthic community.

Many of the lithological characteristics of the Girvan sequence were undoubtedly strongly influenced by local factors, particularly at the base and near the top of the succession. However, the effects of more widespread or global changes may also be evident. The very diverse *convolutus* Biozone graptolite fauna of the Pencleuch Shale correlates with a widely recognized episode of diversification in planktonic communities, termed the Jong Primo Episode by Aldridge *et al.* (1993a). The abrupt change to the shelly fauna of the Lower Camregan Grit could, therefore, be attributed to the Sandvika Event, which terminated this episode, or to the onset of the Malmoykalven Secundo Episode. The return of diverse graptolites in the *turriculatus* Biozone would then relate to the beginning of the Snipklint Primo Episode, which persisted for the rest of the Telychian. The oxygenation of deep bottom waters that is characteristic of primo episodes (Jeppsson, 1990) is recognizable in the common development of trace fossils, indicative of a healthy substrate.

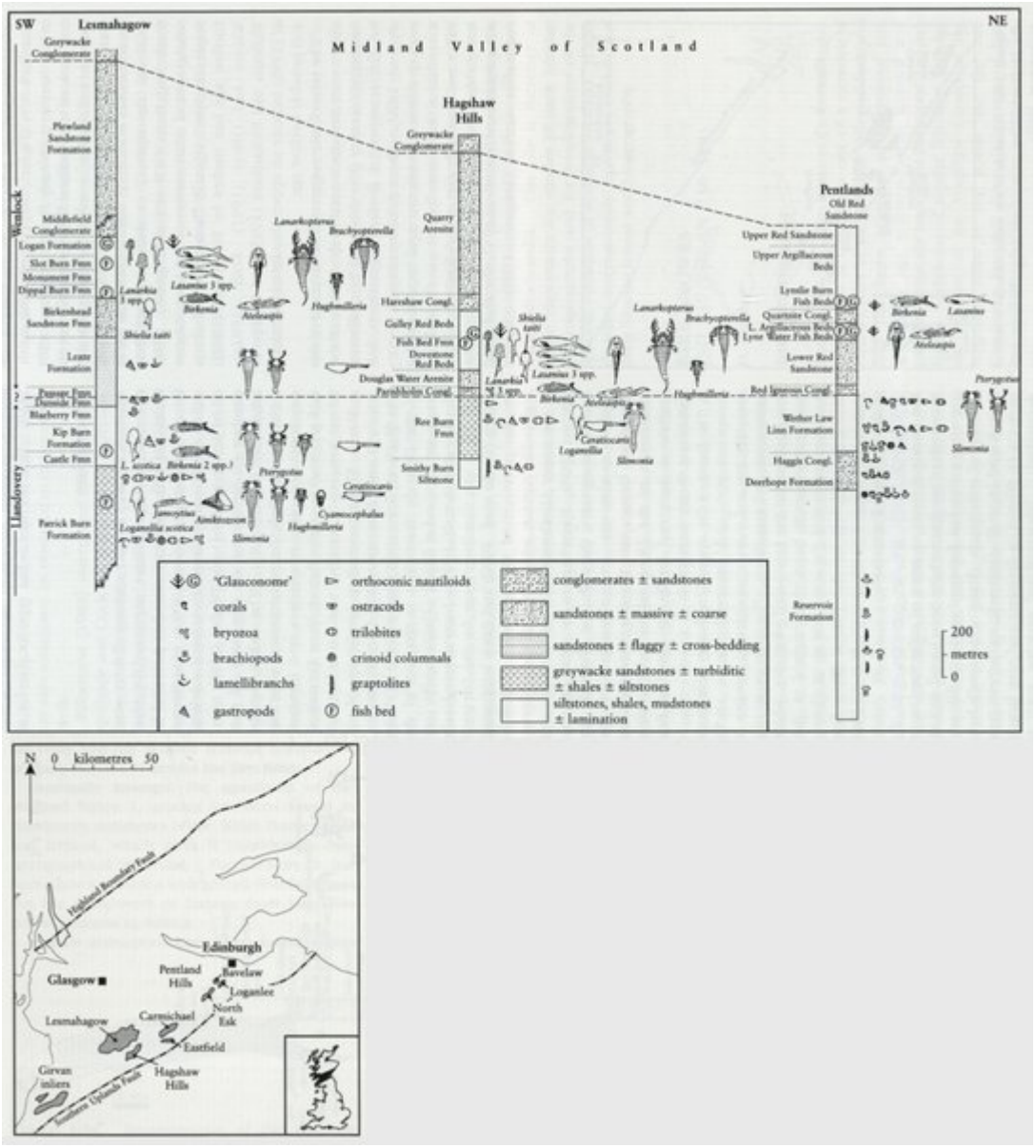
The site at Penwhapple Burn combines with those at Woodland Point, Roughneck Quarry and Blair Farm to provide a representative coverage of the early Silurian stratigraphy and palaeoenvironments of the Girvan area. Further sites in the Midland Valley (Birk Knowes, Gutterford Burn) illustrate the wider palaeoenvironmental setting.

Conclusions

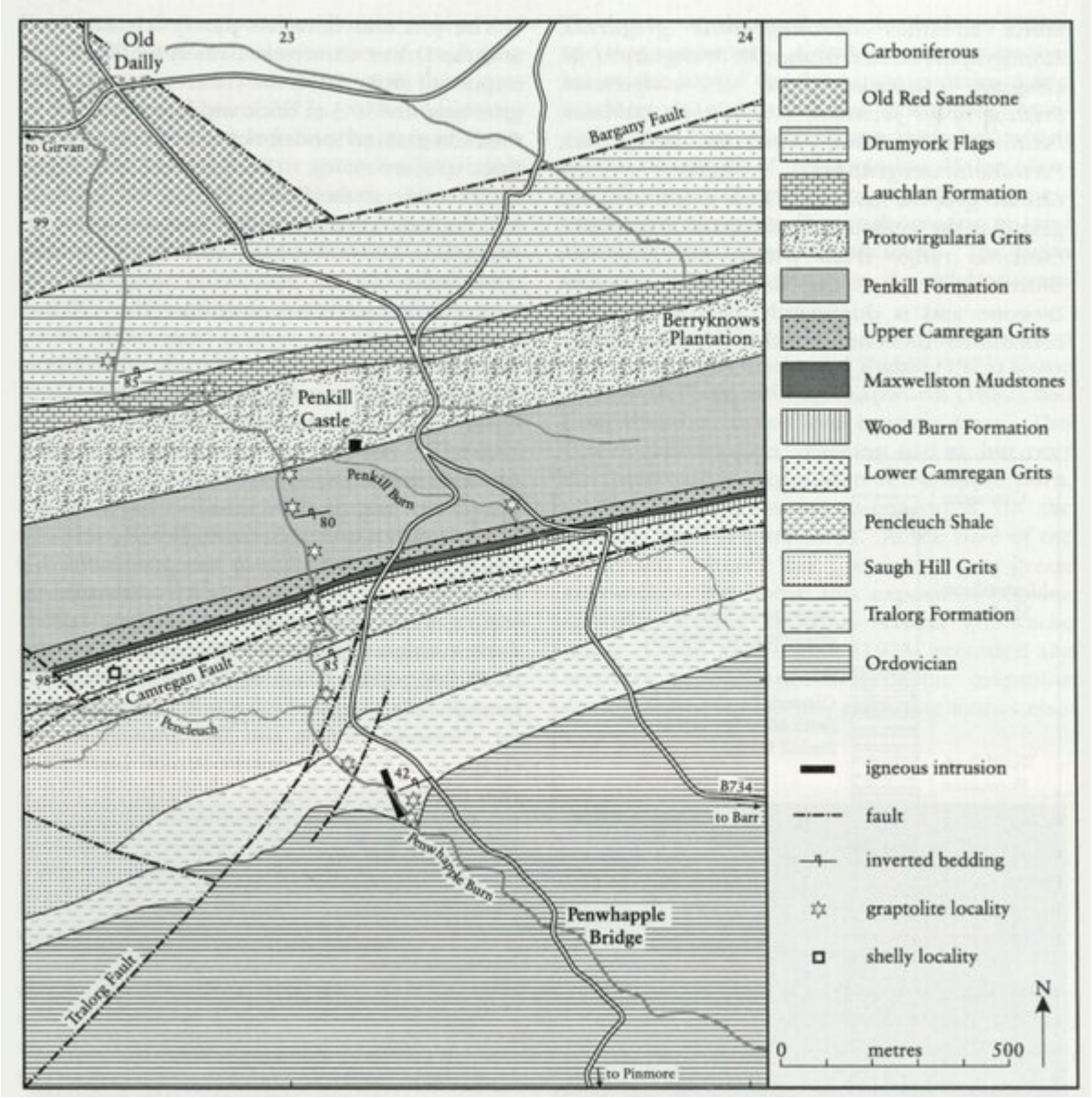
In Penwhapple Burn there is an almost complete section through the Llandovery succession of the Main Outcrop in the Girvan area, and this provides an important reference sequence for the whole region. There are numerous graptolitic horizons through the succession, containing abundant specimens, which are often well preserved. This has allowed accurate dating of the sequence, which ranges from the *typhus* Biozone to the *griestoniensis* Biozone. The graptolites also enable accurate international correlation of the Girvan succession, and provide a basis for recognizing global influences on the local depositional environment. This is, therefore, a site of considerable significance for local, regional

and international studies of stratigraphy, palaeontology and palaeoecology.

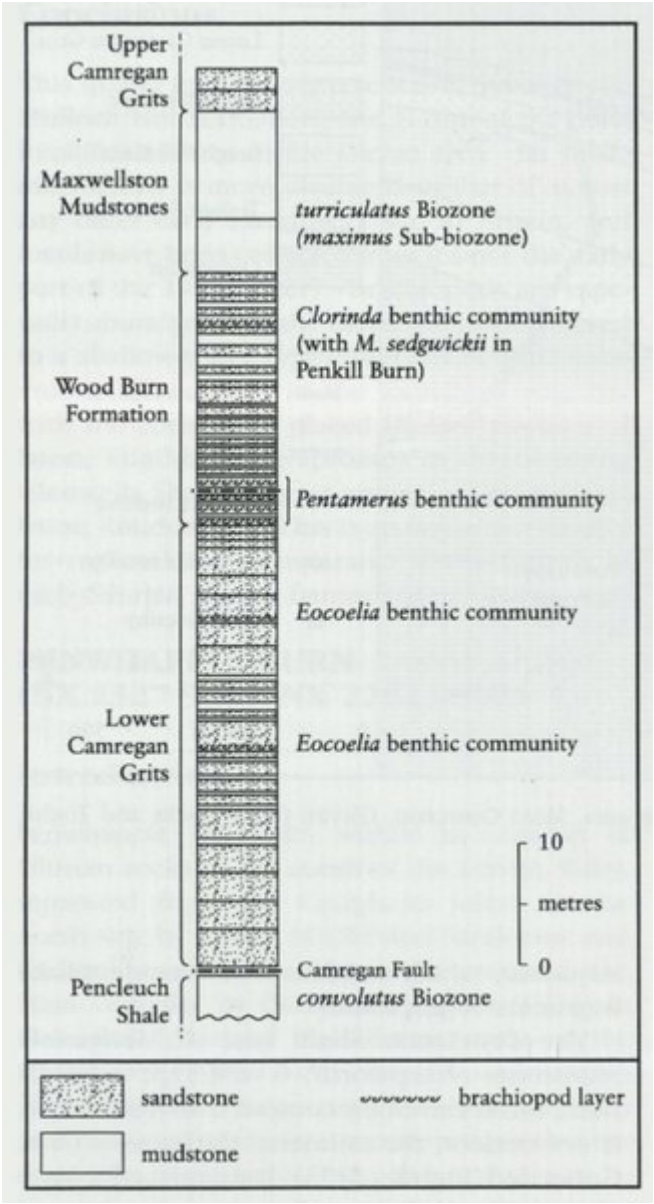
References



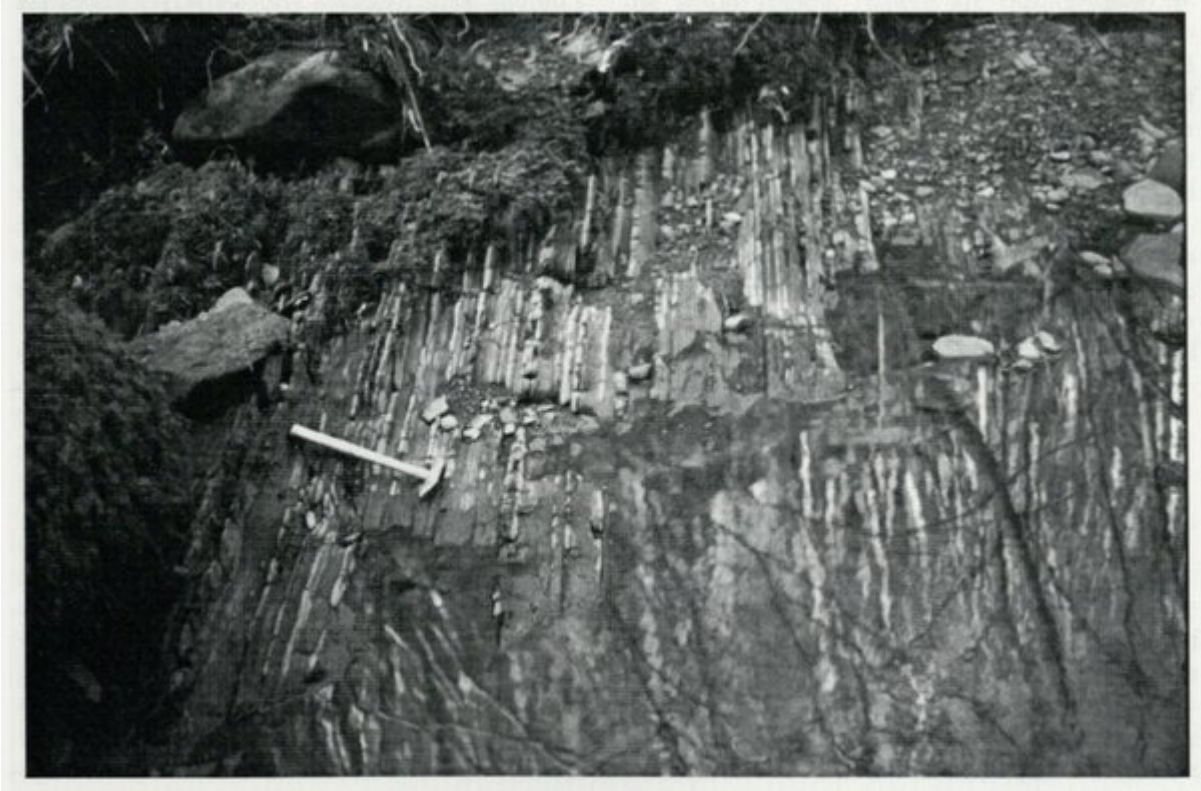
(Figure 3.82) Location of the main Silurian inliers of the Midland Valley of Scotland (after Wellman and Richardson, 1993).



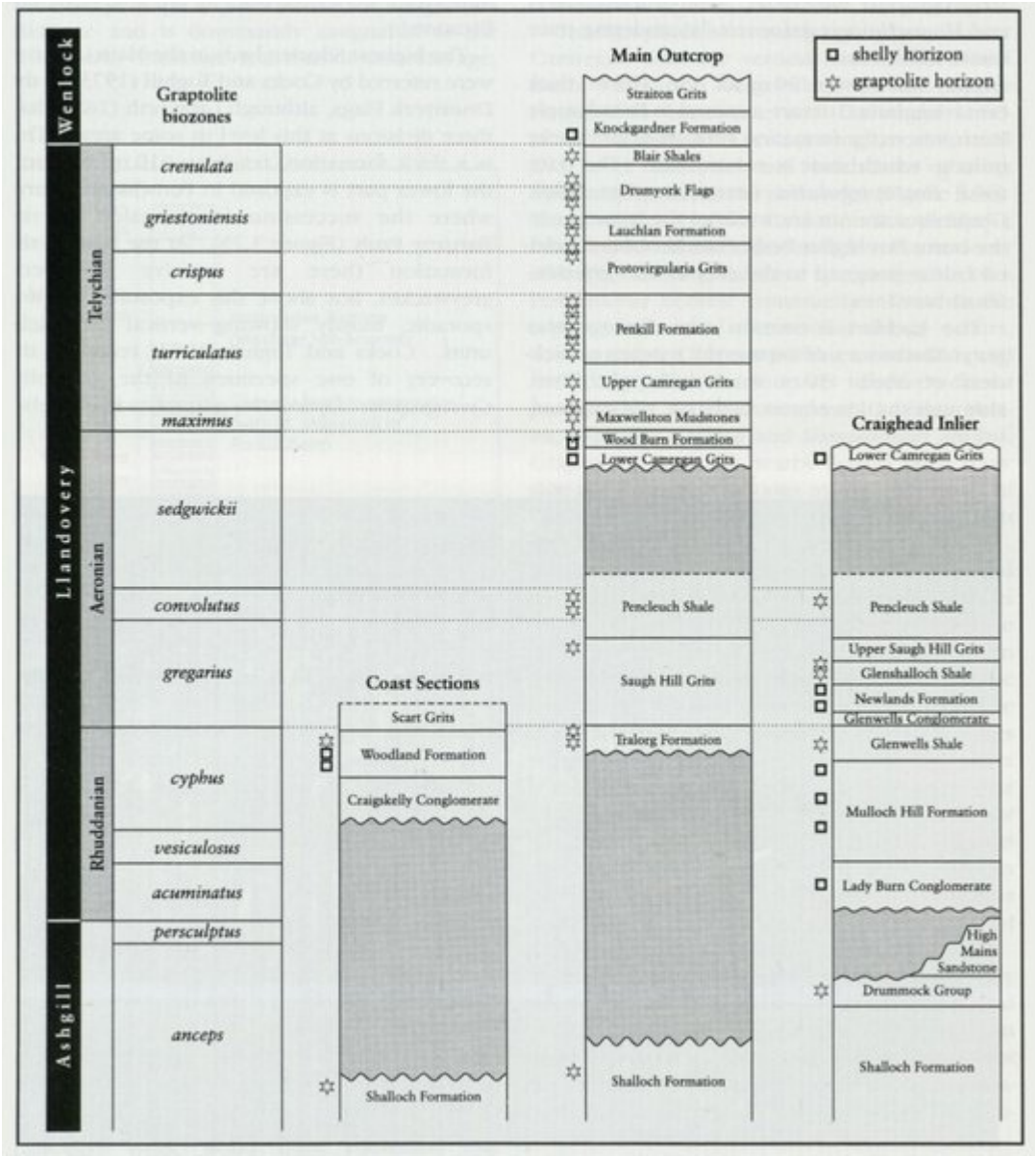
(Figure 3.75) Geological map of the Penwhapple Burn area, Main Outrcrop, Girvan (after Cocks and Toghill, 1973).



(Figure 3.76) Sedimentary log through the Lower Camregan Grits, Wood Burn Formation and Maxwellston Mudstones in Penwhapple Burn (after Cocks and Toghill, 1973).



(Figure 3.77) Purple mudstones of the Penkill Formation, Penwhapple Burn. (Photo: TS1493, reproduced by kind permission of the Director, British Geological Survey, © NERC.)



(Figure 3.78) Correlation of the Llandovery successions within the various outcrops in the Girvan area (modified after Cocks and Toghill, 1973).