Paduff Burn, North Ayrshire

[NS 291 562]–[NS 307 545]

Introduction

Some 3 km west of Kilbirnie and 6 km north of Dairy, the Paduff Burn drains south-east off the Clyde Plateau lavas of the Renfrewshire Hills onto sedimentary sequences at the northern margin of the North Ayrshire (Dairy) Basin. Within its valley [NS 291 562]–[NS 307 545] is exposed a vital reference section of strata in the Kirkwood Formation and Lawmuir Formation (Strathclyde Group, Brigantian), Lower Limestone Formation (Clackmannan Group, Brigantian) and parts of the Limestone Coal Formation (Clackmannan Group, Pendleian). An early description of features at the site was made by Craig (1869), and fuller descriptions have been given by Macnair (1915), Carruthers and Richey (1915), Richey (1925) and Richey *et al.* (1925, 1930). Further important details of the section have also been described by Richey (1946) and Monro (1999).

Description

A simplified log of the succession is presented in (Figure 2.33). The oldest beds are exposed at the upstream end of the section in a fault-bounded exposure. Here limestones and thin calcareous shales of the Broadstone Limestone (5 m) occur above at least 2 m of volcanic detritus (Kirkwood Formation). The limestones contain colonial rugose corals and are replete with large gigantoproductids (*Gigantoproductus giganteus*), many of which are preserved in life position. Orange-coloured marls and shales (2 m) have been recorded overlying the Broadstone Limestone (Richey *et al.,* 1930), but are not currently well exposed. The top of the limestone is penetrated by rootlets and is slightly bleached.

A gap in exposures is followed by outcrops of shales and the overlying Dockra Limestone. The limestone (9 m) is a bedded fossiliferous limestone with thin shale partings and is grey or dark-grey coloured in its lower parts. The uppermost bed of the limestone (1–1.5 m), referred to as the 'White Post', is in contrast a white or creamy-coloured limestone with, in places, a brecciated appearance. It is cut by irregular veins of calcite and penetrated by rootlets, which pipe down some of the overlying green fireclay into the limestone (0.25 m). Richey (1946) noted that these rootlets are often associated with localized dolomitization of the limestone, and red-weathering patches of siderite also occur on the upper surface of the White Post. The top of the Dockra Limestone and the characters of the White Post are beautifully displayed in an extensive series of exposures down the Paduff Burn and have been thoroughly documented by Richey (Richey *et al.,* 1930; Richey, 1946). Richey (in Richey *et al.,* 1930) recognized that the base of the White Post could be slightly transgressive to the underlying beds. He also noted remarkable downward extensions of the base of the White Post (Figure 2.34) which appear as spaced linear features (2–3 m apart) with a wedge or 'V'-shaped cross-section (up to 0.3 m deep) that have the effect of distorting the underlying dark beds into a series of broad flat anticlines and narrow sharp synclines (Richey *et al.,* 1930; Richey, 1946). The amplitude of the folds diminishes downwards and they flatten out and disappear within 2 m.

A shale-dominated succession overlying the Dockra Limestone is also beautifully exposed in repeated exposures down the Paduff Burn. It includes four thin limestones, which are collectively known as the 'Hosie Limestones' and which are individually designated in ascending sequence with the letters A to D. The lowest limestone, Hosie Limestone A, is a thin crinoidal band (15 cm) separated from the Dockra Limestone and green fireclay by 2.4 m of dark shale. At the base these shales are very fissile and contain fish remains and siderite nodules, but at the top they become more calcareous and contain a shelly fauna. Shales with a shelly fauna (0.23 m) also lie above Hosie Limestone A, but pass up into more fissile dark shales (2.7 m) from which *Lingula* and goniatites have been recorded (Carruthers and Richey, 1915; Richey *et al.,* 1930). The crinoidal Hosie Limestone B (0.6 m) lies on these, and above this, a coarsening-upward succession (3 m), with shales (containing a marine fauna) grading into sandstone, is capped by the Hosie Fireclay (1.5 m). Hosie Limestone C, which is a crinoidal limestone (0.9 m), is separated from the Hosie Fireclay by a thin sideritic band with fish remains and ostracodes and from Hosie Limestone D by 1.5 m of calcareous shales with marine fossils.

The latter limestone is a shelly argillaceous limestone, 0.25 m thick. The shales immediately above Hosie Limestone D contain abundant *Lingula* and *Posidonia corrugata* and, while the correlation of lower beds is the subject of some debate, the top of this limestone is generally agreed to mark the top of the Lower Limestone Formation.

The lowest beds of the Limestone Coal Formation are a relatively monotonous, shale-dominated succession (20 m) in which *Lingula* is present. They do, however, include two notable horizons. The first of these, 12 m above the base, is a siderite band (0.3 m), the Dairy Clayband Ironstone; a prominent development in the North Ayrshire sequence. The second, at the top of the section, is a marine unit (1.8 m) with *Sanguinolites costellatus* and rare small productoids in the lower part, and *Lingula* and *Phestia attenuata* in the upper part (Carruthers and Richey, 1915). Beds above the marine band are not well exposed but shales and three ironstones have been recorded (Macgregor *et al.,* 1920) about 10 m above the marine band at the downstream end of the section.

Interpretation

The Paduff Burn succession is an important reference section for the North Ayrshire Basin and a vital section for consideration of the correlation between North Ayrshire and the Central Coalfield. Macnair (1915) regarded the Broadstone Limestone and Dockra Limestone as equivalent respectively to the Hollybush Limestone and Blackbyre Limestone of the Paisley area, while the Ayrshire Hosie Limestones were regarded as equivalent to beds from the Hurlet Limestone to the Top Hosie Limestone (Figure 2.4). Carruthers and Richey (1915) used the Paduff Burn sequence as a standard succession for North Ayrshire and developed a different correlation, which was used in subsequent memoirs (Richey *et al.,* 1925, 1930) and was, for a long time, the generally accepted correlation between the two basins. In this the Broadstone Limestone and Dockra Limestone were correlated with the Blackbyre Limestone and Hurlet Limestone (Carruthers and Richey, 1915). In addition, Hosie Limestone A was correlated with the Blackhall Limestone, and Hosie Limestone B to Hosie Limestone D with the Main Hosie Limestone, Mid Hosie Limestone, Second Hosie Limestone and Top Hosie Limestone of the Central Coalfield. More recently, Wilson (1979) suggested, with some supporting evidence, that the four units of the Ayrshire Hosie Limestones were the equivalents of the four units of the Hosie Limestones of the Central Coalfield and that the Dockra Limestone and Broadstone Limestone were correlatives of the Blackhall Limestone and Hurlet Limestone (Figure 2.4). Whyte (1981) accepted the equivalence of the two groups of Hosie Limestones, as suggested by Wilson (1979), but supported Carruthers and Richey's (1915) correlation of the lower horizons. He further suggested that the absence of the Blackhall Limestone in North Ayrshire was related to the effects of the supra-Dockra Disconformity (Whyte, 1981). This surface is also responsible for the features of the White Post of the Dockra Limestone, which are seen particularly well at a number of localities including Paduff Burn (Richey, 1946; Whyte, 1981).

The Lawmuir Formation comprises the strata between the Kirkwood Formation and the base of the local equivalent of the Hurlet Limestone. Whether the Broadstone Limestone (Wilson, 1979) or the Dockra Limestone (Carruthers and Richey, 1915; Whyte, 1981) is correlated with the Hurlet Limestone, it is clear that the thickness of the Lawmuir Formation at Paduff Burn is not great. In the Paisley to Howwood area and in the centre of the North Ayrshire Basin, much thicker and fuller successions have been proved (Macgregor *et al.,* 1925; Richey *et al.,* 1930; Whyte, 1981; Paterson *et al.,* 1990). Thus the Paduff Burn outcrops provide clear evidence of a prolonged period of erosion and of gradual overlap of the lavas of the Clyde Plateau Volcanic Formation (Richey, 1925; Richey *et al.,* 1930; Whyte, 1981). The thickness of the Kirkwood Formation, in which the weathered products of the lavas have been re-distributed, also seems to be relatively thin in the vicinity of Paduff Burn.

The Broadstone Limestone is found only at one other outcrop in the Kilbirnie part of the northern margin of the North Ayrshire Basin. Its occurrence at Paduff Burn thus provides valuable information about the palaeogeography of this horizon and about the topography of the adjacent lava landmass (Richey, 1925; Richey *et al.,* 1930; Whyte, 1981). The extension of roots into the leached top of the limestone is indicative of a disconformity at this horizon (Whyte, 1981, 1983).

The lower parts of the Dockra Limestone, with their dark colour and bedded character, show well the 'Lugton Fades' of the Dockra Limestone, recognized and described by Richey (1946; Richey *et al.,* 1930) and which contrasts with the lighter coloured and more massive 'Trearne Fades'. The general characters of the White Post were clearly recognized by

Richey (1946; Richey *et al,* 1930) as the product of soil-forming processes and leaching by roots, and as an indication of the presence of a disconformity in the sequence. The characters and extent of the disconformity surface and its significance in correlation have been discussed by Whyte (1981, 1983). However, the genesis of the unique linear wedge structures at the base of the White Post (Figure 2.34) is problematical.

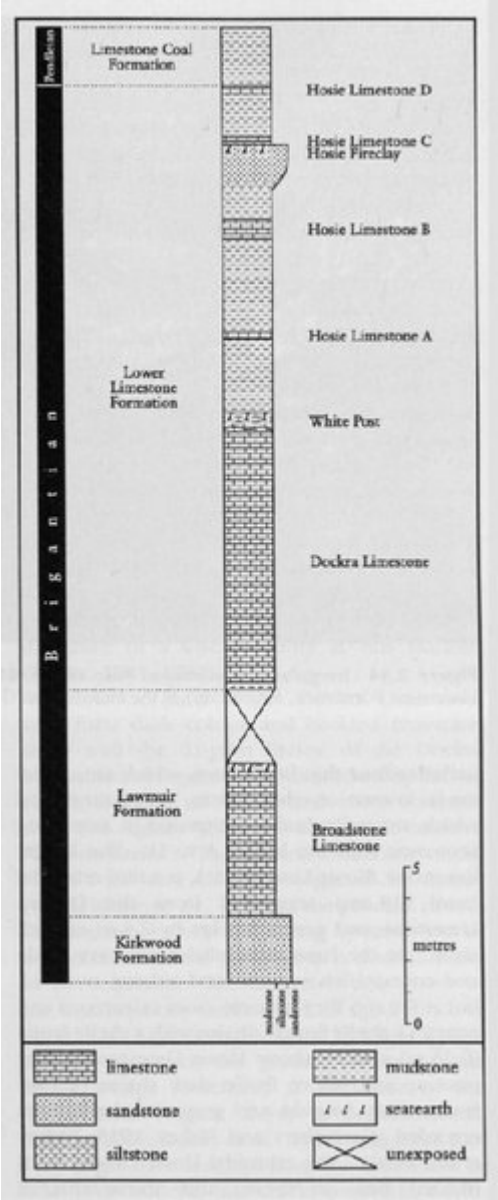
Richey (1946; Richey *et al.,* 1930) suggested that they might have resulted from the movement of White Post material into cracks created by down-slope stretching and movement of beds. An alternative explanation is that they might be tepee-like pedogenic structures caused by expansion of the White Post due to the growth of an early diagenetic calcite cement. The unusual inverted nature of the tepees or wedges might be the result of the upper part of the White Post having developed a very strong hard-pan layer, which forced downward expansion of the base. This implies that during pedogenesis the top of the White Post changed from a bed soft enough to allow root penetration to one strong enough to prevent buckling.

The characters of the upper part of the Lower Limestone Formation contrast markedly with the underlying beds in which thick marine beds alternate with fireclays. The Hosie Limestone sequence is dominated by dark and often fissile shales with thin limestones. These reflect an increased overstep oC and decreased influence from, the lava landmasses (Richey, 1925; Richey *et al.,* 1930; Whyte, 1981). The Hosie Limestones fall into two composite marine bands separated by the Hosie Fireclay, which correlates with the Lillie's Shale Coal and Lillie's Sandstone in the Central Coalfield and which may represent another disconformity surface (Whyte, 1981). Paduff Burn is one of the localities examined by Snook (1999) in his study of faunal and facies associations in the Hosie Limestones. The presence of *Posidonia corrugata* in association with Hosie Limestone D supports the correlation of this limestone with the Top Hosie Limestone of Paisley (Carruthers and Richey, 1915; Macnair, 1915; Wilson, 1979; Whyte, 1981). Support for this correlation also comes from the overlying sequence of the Limestone Coal Formation, which has two distinctive horizons. The lower of these, the Dairy Clayband Ironstone, can be correlated with the Johnstone Clayband Ironstone of the southwestern Central Coalfield (Macgregor *et al.,* 1925; Richey *et al.,* 1930). The upper horizon, a marine shale, represents the Johnstone Shell Bed, which is the lower and better developed of two marine horizons within the Limestone Coal Formation (Macgregor *et al.,* 1925; Richey *et al.,* 1930). The siderite bands at the top of the section are the Logan's Claybands (Macgregor *et al.,* 1920) and, like the Dairy Clayband Ironstone, these have in the past been exploited in the North Ayrshire area as a source of iron. These beds, with the exception of the marine strata of the Johnstone Shell Bed, were deposited in a brackish or estuarine environment, which contrasts with the more marine strata below.

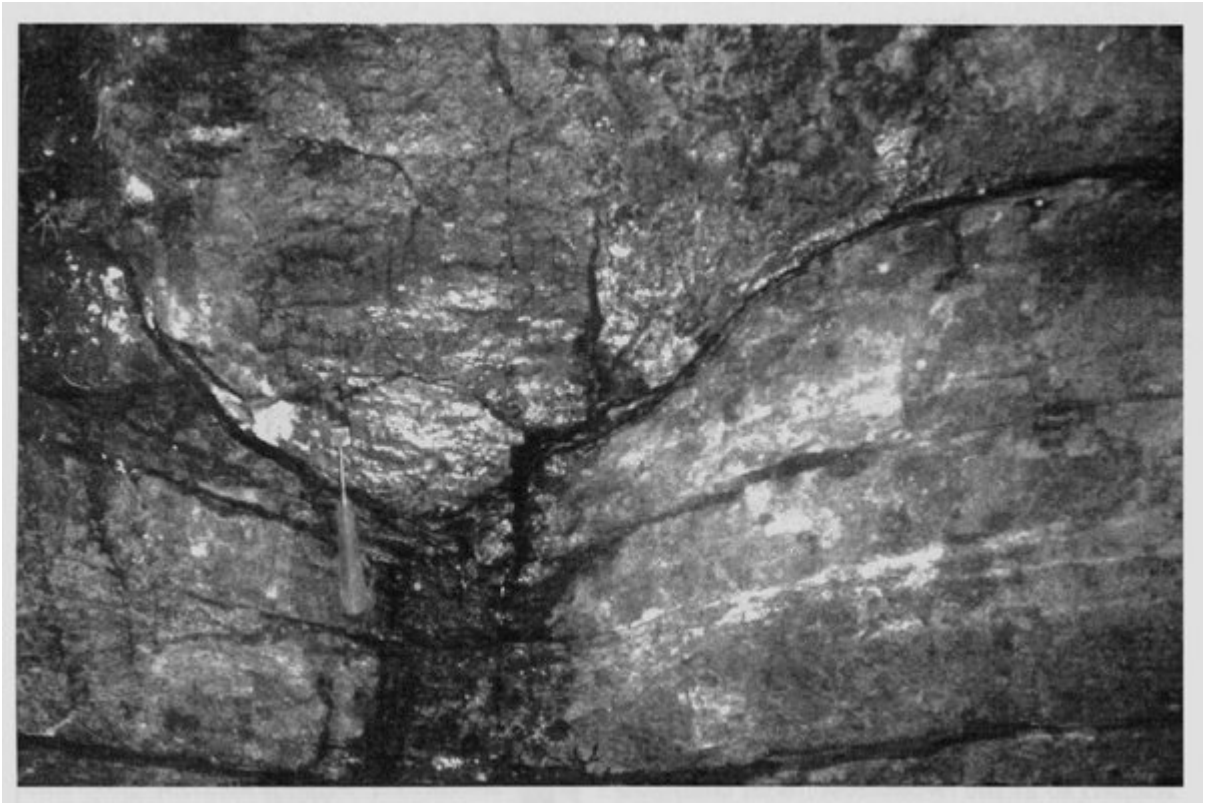
Conclusions

The natural exposures of the Paduff Burn are the best representative sections of the Lower Carboniferous rocks of the North Ayrshire Basin and show clearly the relationships between the Kirkwood Formation and Lawmuir Formation of the Strathclyde Group (Brigantian) and the Lower Limestone Formation and the lower parts of the Limestone Coal Formation (Clad/maim-Ian Group, Brigantian to Pendleian). Together they constitute a vital section for the correlation of successions between North Ayrshire and the Central Coalfield. The development of unique pedogenic structures in the Dockra Limestone make this an excellent site for future sedimentological research.

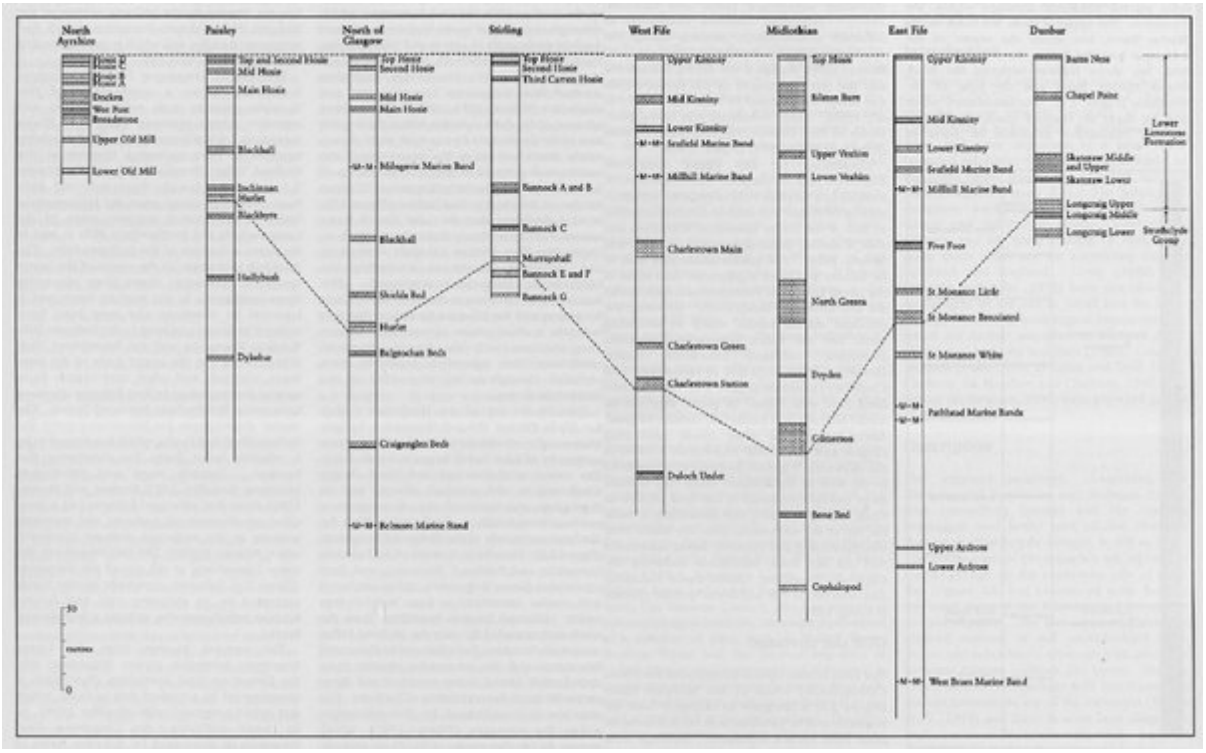
References



(Figure 2.33) Simplified stratigraphy of the Strathclyde Group and Clackmannan Group succession at Paduff Burn. Based on various sources.



(Figure 2.34) Irregular wedge-shaped base of the White Post at the top of the Dockra Limestone (Lower Limestone Formation, Brigantian) at the Paduff Bum GCR site. (Photo: C. MacFadyen.)



(Figure 2.4) Correlation of the principal marine horizons in the Brigantian Lower Limestone Formation and uppermost part of the Strathclyde Group in the Midland Valley from North Ayrshire to Dunbar. Note that most of the named units figured here are, unless otherwise stated, limestones (names abbreviated). Based on various sources and including information from George et al. (1976), Cameron and Stephenson (1985), Wilson (1989) and Francis (1991).