Avon Gorge, Bristol, Avon

[ST 554 748]–[ST 566 727]

Introduction

The Avon Gorge site lies 3 km west of Bristol city centre. The GCR site includes exposures on both banks of the river and in the surrounding cliffs and old quarries from near Sneyd Park [ST 554 748] to Clifton [ST 566 727]. Here almost all of the Dinantian succession of the region is exposed. This classic stratigraphical site assumed national and international significance as a result of the pioneering work undertaken by Vaughan (1905), who established the first biostratigraphical zonation scheme for the Carboniferous Limestone based on the distribution of coral–brachiopod faunas taken largely from the Avon Gorge section. This work, with various subsequent modifications, proved to be the standard for the correlation of Lower Carboniferous shelf limestone successions in Britain for the next 70 years. Its significance has recently been evaluated by Riley (1993). Aspects of the succession were also considered by Vaughan (1906) and Reynolds (1920, 1921, 1926, 1936). One of the more critical of these contributions was by Reynolds (1921) in which the lithological succession in the gorge was first defined. The most informative recent account is by Kellaway and Welch (1993) who record all the significant changes at the site since Vaughan's work was published and who also provide an abundance of modern and high-quality annotated outcrop illustrations. Conodont faunas from the section were described by Rhodes *et al.* (1969).

Description

Kellaway and Welch (1993) summarize the changes that have affected the Avon Gorge section since the work of Arthur Vaughan. Overall there has been some deterioration in the section, with parts becoming overgrown and inaccessible. The nature of the exposure also changed when a railway line along the right bank was closed and a road (the Portway) opened. The uppermost part of the succession has always been poorly exposed and the Ashton Park Borehole (Kellaway, 1967) was drilled to examine that part of the succession. The construction of new deep tunnels has also added to our knowledge of the stratigraphy of the area. The account here is based on the work of Kellaway and Welch (1993) and a summary stratigraphical column based on their work is illustrated in (Figure 9.37). Strata dip southeastwards at an average of 25°–35°, although there are considerable structural complications especially in the more southerly part of the section, some of which were not recognized by earlier workers. A map of the gorge illustrating the distribution of lithostratigraphical units is presented in (Figure 9.38).

In the Bristol area the non-marine beds of the Upper Old Red Sandstone 'pass imperceptibly upwards into the wholly marine sequences of the Carboniferous Limestone' (Kellaway and Welch, 1993). The Shirehampton Beds, which record this passage, are said to possess a mixed Devonian–Carboniferous fauna. For convenience, the base of the Carboniferous Limestone Series is taken at a pebbly sandstone containing fish remains, known as the 'Sneyd Park Fish Bed', at the base of the Shirehampton Beds. The Shirehampton Beds consist of a heterolithic assemblage of impure limestones, mudstones and sandstones. Much of this part of the succession on the right bank of the river is now obscured, but the upper part of the unit, consisting of shale and sandstone overlain by a red crinoidal and bryozoan limestone, known as the 'Bryozoa Bed', can be seen [ST 558 747]. This part of the section was placed in the *Modiola* Zone by Vaughan (1905) and is recognized as a shallow-water phase at the base of the Carboniferous succession. In his zonal scheme, Vaughan (1905) recognized discrete intervals in which the zonal indices of two contiguous zones could be found. Vaughan designated these with a Greek letter, the Bryozoa Bed becoming Horizon a. On the left bank of the river, some 25 m of shale, sandstone and limestone, succeeded by the Bryozoa Bed, overlie a conglomerate thought to mark the top of the Old Red Sandstone (Kellaway and Welch, 1993). The palynology of the Shirehampton Beds was described by Utting and Neves (1970). Their evidence confirms that the Devonian–Carboniferous boundary lies close to the Sneyd Park Fish Bed.

The Lower Limestone Shale is now poorly exposed in the gorge. On the left bank, about 15 m of thinly bedded mudstones and fine-grained limestones can be seen overlying the Bryozoa Bed [ST 556 746]. The lowest bed, resting on an eroded surface of the Bryozoa Bed, is a thin conglomeratic and phosphatic unit containing *Lingula* and fish remains. This was called the 'Palate Bed' by Stoddart (1876). *Vaughania vetus* has been recovered from the upper part of this succession (Kellaway and Welch, 1993). Conodonts from this level were reported by Butler (1973), who also recorded caliche development in the Bryozoa Bed. On the right bank of the river, thinly bedded bioclastic limestones attributed to the top of the Lower Limestone Shale can be seen immediately beneath the more massive limestones (Black Rock Limestone) at the base of the overlying Black Rock Group [ST 559 747].

The succeeding limestone-dominated units are better exposed than the muddy facies below. The Black Rock Limestone has been extensively quarried on both sides of the river. It forms the main cliff at Sea Walls on the right bank [ST 560 746] and is exposed in workings known as quarries 1 [ST 557 745] and 2 [ST 558 744] (Vaughan, 1905) on the left bank (Figure 9.38). The lowest beds were referred by Vaughan (1905) to his Horizon 8, the zone of overlap between his K and Z zones. Horizon y between the Z and C zones, identified by *Zaphrentis* and *Caninia* occurring together in abundance, lies at the top of the Black Rock limestone in the Avon Gorge. The Black Rock Limestone is crinoidal with a fine-grained dark-coloured matrix. The overlying Black Rock Dolomite (Laminosa Dolomite) is a hard purplish-grey dolomite about 30 m thick (Kellaway and Welch, 1993). A re-assessment of the faunas of the Black Rock Group, including an updating of nomenclature, was undertaken by Mitchell (1981, 1993), using evidence from the Portway Tunnel.

The Gully Oolite, called the 'Caninia Oolite' by Vaughan (1905), is the lowest unit in the Clifton Down Group. It consists of massive white-weathering, cross-stratified oolite, the base of which is obscured by dolomitization, such that a fossiliferous unit at the base elsewhere in the Bristol area — the 'Sub-Oolite Bed' — cannot be recognized (Kellaway and Welch, 1993). The Clifton Down Mudstone consists of well-bedded or lenticular, pale-grey carbonate mudstones and stromatolites with very few fossils. The upper part contains three beds of more massive, cross-stratified, oolitic and crinoidal limestone, correlated with the Goblin Combe Oolite found to the south of Bristol (Figure 9.2) and (Figure 9.3)b. These are succeeded by 15 m of hard grey limestones with brachiopods including productoids, spiriferoids and rhynchonelloids, as well as the gastropod *Bellerophon* (Kellaway and Welch, 1993). The occurrence of the latter led to Vaughan (1905) naming this part of the succession the 'Bellerophon Beds', although he did not recognize this unit in the Avon Gorge. The Bellerophon Beds can be seen in a crag between quarries 3 and 4 on the left bank [ST 560 742] (Kellaway and Welch, 1993).

The Clifton Down Limestone is seen particularly well in sections at Great Quarry [ST 563 740] and is repeated by faulting farther south under Brunel's suspension bridge (Figure 9.39). The base of the Clifton Down Limestone is a bed of sandy limestone correlated with the Lower Cromhall Sandstone seen to the north of Bristol (Kellaway and Welch, 1955, 1993). This is overlain by more thinly bedded, sometimes stromatolitic, fine-grained limestones and dolomites with few fossils. These give way to fossiliferous limestones containing colonies of *Siphonodendron martini* together with bands containing *Composita ficoidea* and *Linoprotonia.* A number of named fossil bands described by Reynolds (1921) occur in this part of the succession. At the north end of Great Quarry the Lithostrotion Band of Vaughan (1906), now known as the 'Diphyphyllum Band', occurs (Kellaway and Welch, 1993). Some 30 m above stratigraphically, and in close succession, come the Lithostrotion basaltiforme Band, the Trilobite Bed containing complete specimens of *Linguaphillipsia holwellensis* (N. Riley, pers. comm., 2002), the Fluorite Bed and the Caninia bristolensis (now classified as *Caninophyllum archiaci* var. *bristolensis*)Bed. Kellaway and Welch (1993) remark that these beds are not laterally persistent and are of little value in correlation. This part of the succession is repeated by a thrust, unrecognized by earlier workers (Loupekine, 1953).

The higher part of the Clifton Down Limestone is described by Reynolds (1921). He recognized two developments of 'oolitic' limestone, the Seminula Pisolite and the Seminula Oolite, separated by a vuggy dolomite 1.5 m thick. Chert bands and silicified fossils are prominent in the Seminula Pisolite. The Seminula Oolite has a notably sharp base. The oolite grades up into bioclastic limestones and then into fine-grained limestones lacking abundant faunas and resembling those near the base of the group. The uppermost part of the succession, known as the 'Concretionary Beds', comprises stromatolitic limestones interbedded with shales and brecciated limestones. On the left bank of the river, quarries 4 [ST 561 739] and 5 [ST 562 738] show much of the section from the Trilobite Bed to the base of the Hotwells Limestone, although the succession from the Seminula Oolite to the Concretionary Beds is not well exposed (Kellaway and Welch, 1993).

Strata immediately to the north of the suspension bridge are affected by the Avon Thrust (Figure 9.38) and are sheared and distorted. However, to the south of the bridge, from the foot of the Zig-Zag [ST 565 730] to the Colonnade [ST 566 728], the Hotwells Limestone, forming the lower part of Vaughan's *Dibunophyllum* Zone, can be seen. The Hotwells Limestone in the Avon Gorge is about 50 m thick and notably fossiliferous. Gigantoproductid brachiopods and the corals *Dibunophyllum bourtonense, Palaeosmilia murchisoni* and *Siphonodendron martini* are particularly evident (Kellaway and Welch, 1993). This part of the section on the left bank is presently overgrown and the higher part of the Hotwells Group, represented by the Upper Cromhall Sandstone, is not seen at all in the gorge.

Interpretation

The Vaughan zonal scheme for the shelf limestones of the Lower Carboniferous succession, as outlined in his work on the succession of faunas in the Avon Gorge (Vaughan, 1905), became, with some modifications (e.g. Reynolds, 1921), the reference section to which other sections in the British Isles were compared. However, although he set out to produce a workable zonal scheme, Vaughan noted that 'Such a system, deduced from the examination of a single area and founded entirely upon two fossil groups, cannot of course presume to be more than a preliminary attempt to deal with a large and complicated problem; but it may serve as part of the scaffolding, by means of which a system of general application will ultimately be built up' (Vaughan, 1905). Riley (1993), in his review of Dinantian biostratigraphy, pays tribute to the careful observations and descriptions of Vaughan and his awareness of fundamental biostratigraphical concepts that allowed the scheme to have much greater scope than was originally envisaged. Vaughan's zones were not replaced until George *et al.* (1976) set up their regional stages, but even their scheme inherited some boundaries that were originally used by Vaughan.

The need for a replacement of Vaughan's zones became apparent when it was realized that the Avon Gorge succession is not a record of continuous Dinantian sedimentation, but contains a number of non-sequences (see (Figure 9.37)). Ramsbottom (1973) noted four substantial non-sequences in the section, and a fifth has been described from near the base of the section (Butler, 1973), all corresponding with times of sedimentation elsewhere in the British Isles. The first of these non-sequences lies at the top of the Shirehampton Beds, where the Palate Bed rests on an eroded surface of the Bryozoa Bed (Butler, 1973). The second non-sequence occurs at the top of the Black Rock Group and has been discussed by Mitchell (1971, 1972, 1981) who suggested that both the uppermost Tournaisian and the lowermost Viséan successions are not represented. Evidence for the absence of the uppermost Tournaisian succession comes from a comparison of faunas from the Avon Gorge with those of Burrington Combe (see GCR site report, this chapter). Mitchell (1971) inferred that about 130 m of strata seen at the top of the Black Rock Group of Burrington Combe are not represented in the Avon Gorge. The absence of lowest Viséan strata in the Avon Gorge is inferred from a comparison of faunas with those of south Cumbria (Mitchell, 1972). Mitchell concluded that, at least where the Sub-Oolite Bed is missing, the basal Viséan sequence is unrepresented.

The third non-sequence lies at the top of the Gully Oolite where the Clifton Down Mudstone rests on an irregular erosive surface cut in the oolite. George *et al.* (1976) record that much of the lower part of the Arundian Stage is missing, although with the impoverished faunas of the Clifton Down Mudstone the extent of this non-sequence is difficult to establish. Ramsbottom (1973) recorded three faunal horizons of northern England that were absent from the Avon Gorge section at this level. The base of the Holkerian Stage in the Avon Gorge succession is taken at the base of the Seminula Oolite, which has also been interpreted as an erosion surface indicating a stratigraphical break (Kellaway and Welch, 1993) and forms the fourth non-sequence. The fifth non-sequence occurs at the base of the Hotwells Limestone. Although the early Asbian brachiopod *Daviesiella llangollensis* is absent from this unit, the late Asbian form *Davidsonina septosa* is known from the base of the Hotwells Limestone in the Mendips (Kellaway and Welch, 1993).

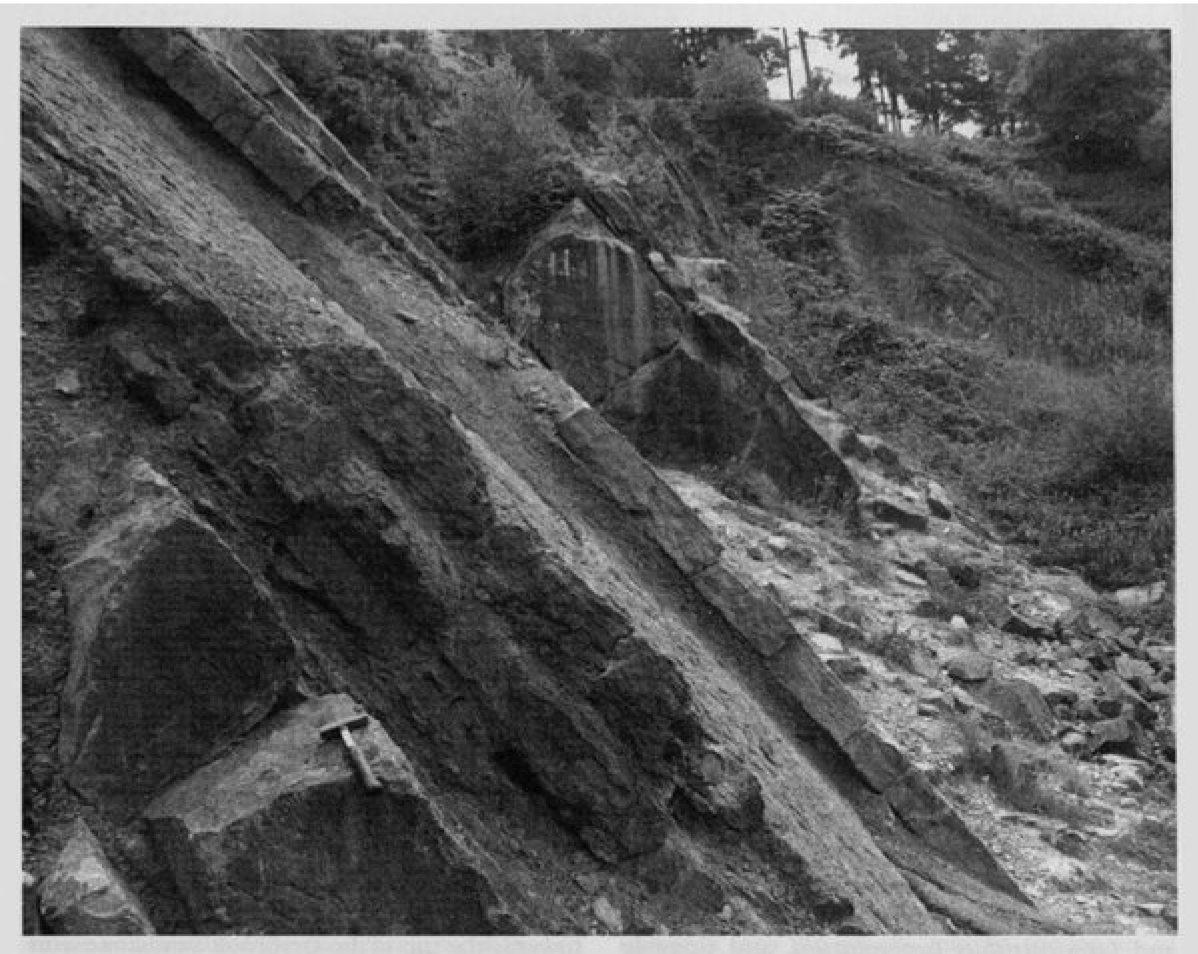
Apart from 200 thin-sections examined by Reynolds (1921) during his work on the lithological succession, there is an absence of detailed petrographical work and facies analysis of the section in the Avon Gorge. However, Kellaway and Welch (1993) provide a summary of the palaeoenvironments represented. The whole succession was deposited on the Mendip Shelf which, at least for the earlier part of Dinantian times, was probably a southerly dipping ramp ((Figure 9.3)b) continuous with that inferred for South Wales (Wright, 1986a). The Avon Gorge was in a fairly proximal position on this ramp, an aspect that accounts for the development of numerous non-sequences here, in contrast to those sections farther south in the Mendips where deposition was more continuous.

The largely terrigenous Shirehampton Beds were deposited in restricted marine or brackish water environments (Kellaway and Welch, 1993). Their accumulation was followed by a period of non-deposition or erosion represented by a non-sequence. The Lower Limestone Shale marked a change to more open marine conditions, but still with a significant supply of fine-grained detrital material. This supply of detritus was reduced during deposition of the overlying Black Rock Group, which contains a diverse fauna in a fine matrix, and probably represents open marine below wave-base environments. The Gully Oolite was deposited in shallower high-energy conditions with shifting, perhaps tidal, sand-bodies providing a habitat inimical to most organisms (Kellaway and Welch, 1993). In contrast, the Clifton Down Mudstone represents low-energy, restricted, sometimes stagnant, lagoonal environments with an Impoverished fauna. This gives way to more open marine conditions again, characterized by bioclastic limestone in the lower part of the Clifton Down Limestone. Shallow, agitated water oolitic deposits (the Seminula Oolite and Pisolite) are succeeded by a return to lagoonal deposits at the top of the Clifton Down Limestone. Following a break in sedimentation, the Hotwells Limestone was deposited in open-shelf conditions of fairly high energy, supporting a diverse and abundant fauna (Kellaway and Welch, 1993).

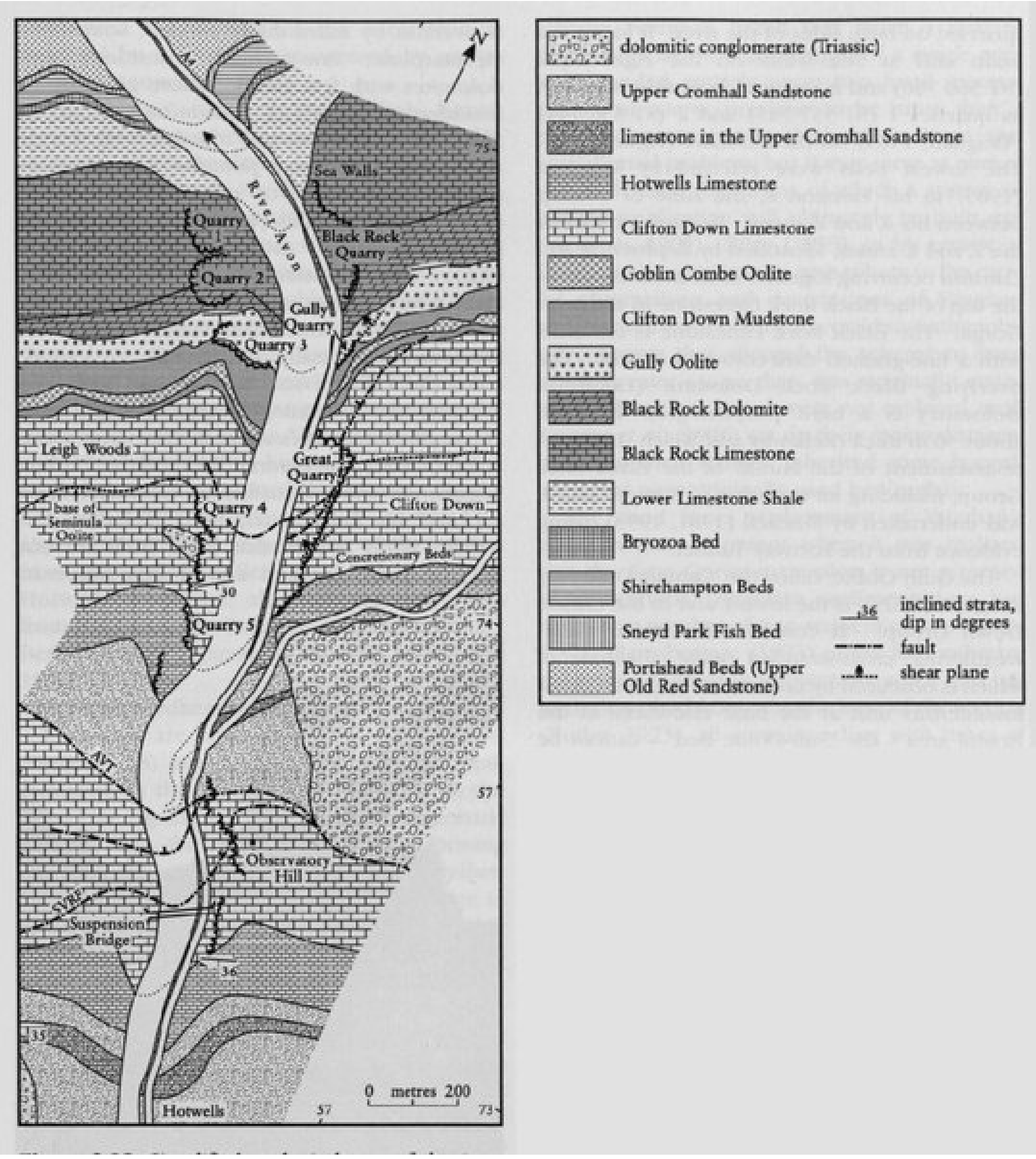
Conclusions

Despite the deterioration In some parts of the succession since the early part of the 20th century, when the classic work of Vaughan and Reynolds was undertaken, the Avon Gorge still provides the best section through much of the Dinantian sequence of the Bristol area. Its importance lies partly in its historical association with one of the most important developments in Carboniferous stratigraphy, but also it continues to provide a valuable resource for research into the stratigraphy and sedimentology of Lower Carboniferous shelf limestones in southern England.

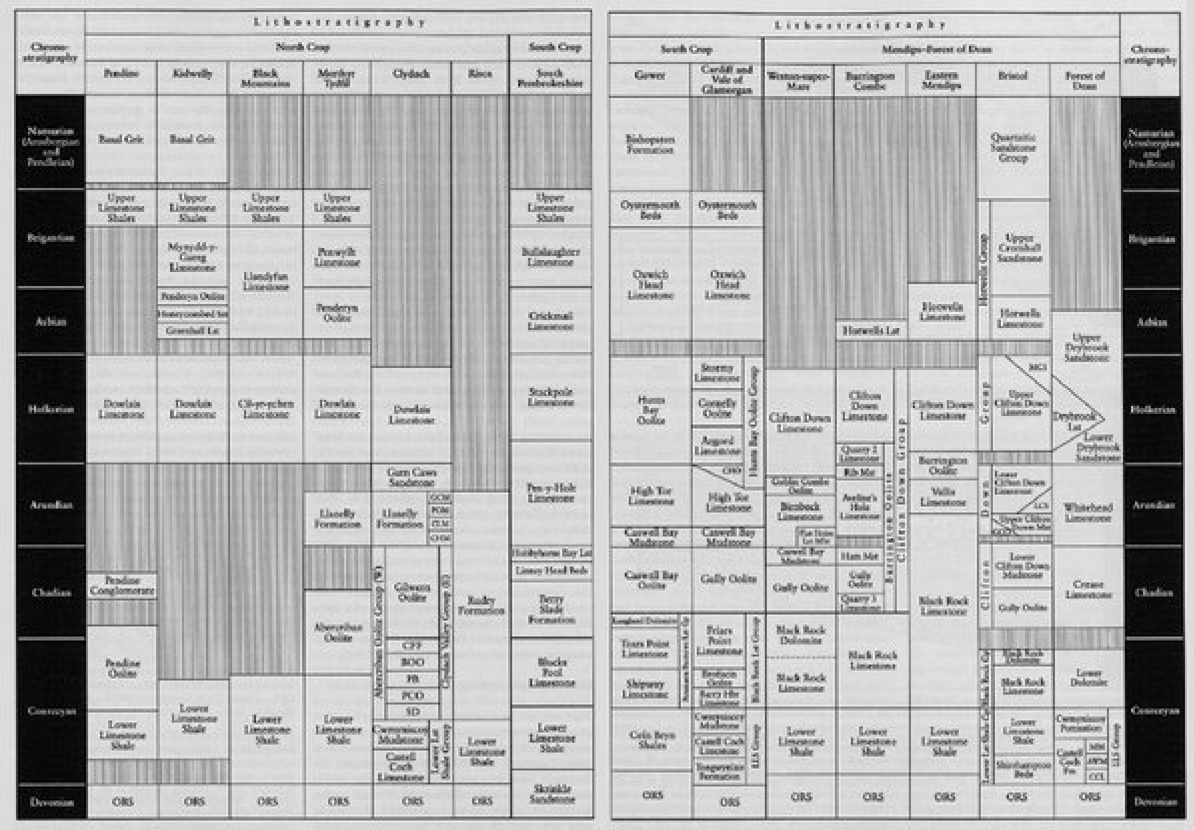
References



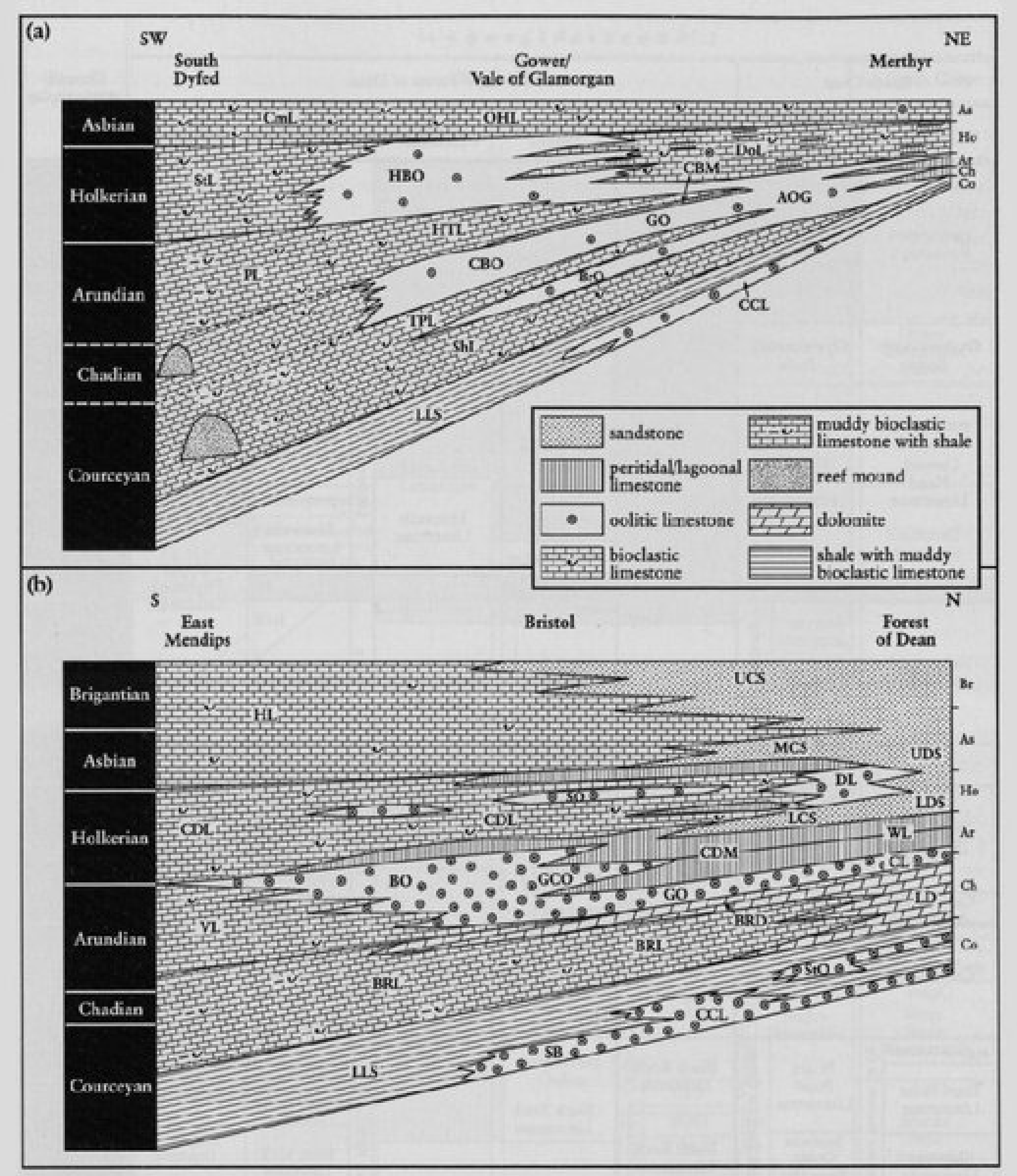
(Figure 9.37) Comparative sections of Dinantian strata exposed at the Avon Gorge and Burrington Combe GCR sites. After Kellaway and Welch (1993) and including non-sequence information from Ramsbottom (1973) and George et al. (1976). Biostratigraphical information is from Vaughan (1905, 1906), Reynolds and Vaughan (1911) and Reynolds (1921). Horizons a, $_R$ and y are based on Vaughan (1905).



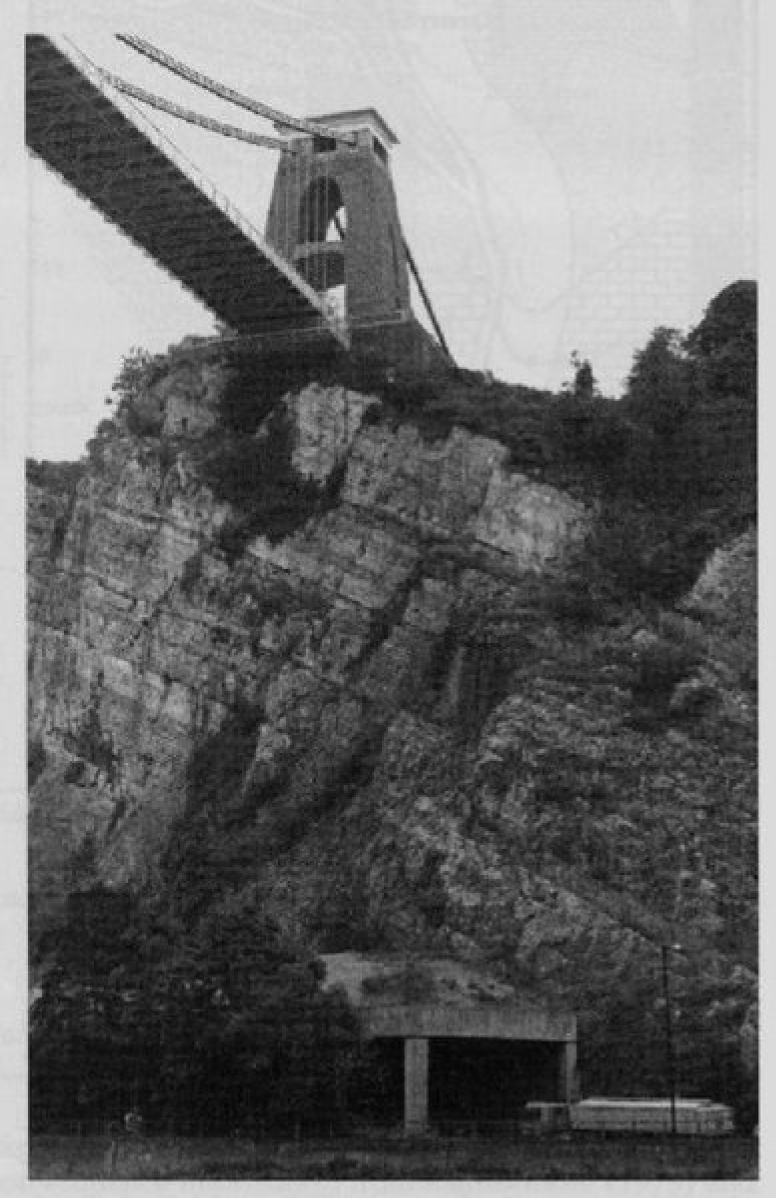
(Figure 9.38) Simplified geological map of the Avon Gorge showing the position of localities referred to in the text. AVI' — Avon Thrust Fault; SVRF — St Vincent's Rocks Fault. After Kellaway and Welch (1993).



(Figure 9.2) Simplified stratigraphical chart illustrating the most widely used lithostratigraphical terms for the Lower Carboniferous sequences in South Wales, the Forest of Dean, Bristol and the Mendips. (SD — Sychnant Dolomite; PCO — Pwil y Cwm Oolite; PB — Pantydarren Beds; BOO — Blaen Onnen Oolite; CFF — Coed Ffyddlwn Formation; CHM — Clydach Halt Member; CLM —Cheltenham Limestone Member; POM — Penllwyn Oolite Member; GCM — Gilwern Clay Member; LIS —Lower Limestone Shale; CHO — Cefnyrhendy Oolite; CCL — Castell Coch Limestone; AWM — Astridge Wood Member; MM — Mitcheldean Member; GCO — Goblin Combe Oolite; LCS — Lower Cromhall Sandstone; MCS — Middle Cromhall Sandstone.) Areas of vertical ruling indicate non-sequences. Not to scale. Based on information from and after Welch and Trotter (1961), Green and Welch (1965), Institute of Geological Sciences (1973, 1977c), George et al. (1976), Wright (1982b), Whittaker and Green (1983), Burchette (1987), Waters and Lawrence (1987), Barclay et al. (1988), Scott (1988), Barclay (1989), Wilson et al. (1990) and Kellaway and Welch (1993).



(Figure 9.3) Simplified stratigraphical sections of Dinantian strata in south-west Britain illustrating the distribution of Dinantian lithofacies. Section (a) based on Wright (1986a) and Burchette et al. (1990); approximate length of section, 100 km. Section (b) based on information from Kellaway and Welch (1955, 1993), Burchette et al. (1990) and Green (1992); approximate length of section, 80 km. (LLS — Lower Limestone Shale; CCL — Castell Coch Limestone; ShL — Shipway Limestone; BrO — Brofiscin Oolite; TPL — Tears Point Limestone; CBO Caswell Bay Oolite; GO — Gully Oolite; AOG — Abercriban Oolite Group; CBM — Caswell Bay Mudstone; PL — Pen-y-Holt Limestone; HTL — High Tor Limestone; StL — Stackpole Limestone; HBO — Hunts Bay Oolite; DoL — Dowlais Limestone; CmL — Crickmail Limestone; OHL — Oxwich Head Limestone; SB — Shirehampton Beds; StO — Stowe Oolite; BRL — Black Rock Limestone; BRD — Black Rock Dolomite; LD — Lower Dolomite; CL — Crease Limestone; VL — Vallis Limestone; BO — Burrington Oolite; GCO — Goblin Combe Oolite; CDM — Clifton Down Mudstone; WL — Whitehead Limestone; CDL — Clifton Down Limestone; SO — Seminula Oolite; DL — Drybrook Limestone; LDS — Lower Drybook Sandstone; UDS — Upper Drybook Sandstone; LCS — Lower Cromhall Sandstone; MCS Middle Cromhall Sandstone; UCS — Upper Cromhall Sandstone; HL — Hotwells Limestone.)



(Figure 9.39) The spectacular outcrops of the Clifton Down Limestone at the Clifton Suspension Bridge in the Avon Gorge. (Photo: P.J. Cossey.)