Chapter 3 Post Devonian fossil arthropods

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Post-Devonian Upper Palaeozoic history

The building of the Laurentian–Avalonian–Baltic continent (see Chapter 2) was extended into Devonian times when Armorica and Iberia joined the assembly (*c.* 400–370 million years ago (Ma), see (Figure 2.2) and 2.3). Then the arrival of the greater mass of Gondwanan continents in Carboniferous times (*c.* 370–290 Ma) led to the Variscan Orogeny, which was the last dramatic crustal shortening event to impact upon the continental crust of north-west Europe. The thickening of the crust generated a Himalayan-scale mountain belt extending from Russia through western Europe and on into the eastern flank of America. Ireland and Britain lay to the north of the most intense deformation, although there was significant folding and faulting across the south of Ireland and Britain. Nevertheless, the orogeny had a major effect on the tectonic evolution of the whole of the region. The convergence assembled the supercontinent of Pangea, which stretched virtually from pole to pole. During these same Carboniferous times, the British Isles had moved northwards into the equatorial humid belt (Figure 3.1).

There are five GCR arthropod sites of Carboniferous age, four of which are within the old Laurentian region and the other is in the Variscan zone. All of the aforementioned are of Lower Carboniferous age, the latter is of Upper Carboniferous age. Together, they record both a diversity of marine arthropods and arthropod faunas associated with the continuing evolution of land plants and their terrestrialization during the period.

The Laurentian (Scottish) sites range in age from Foulden of earliest Carboniferous age (Tournasian *c.* 348 million years old) to Granton Shore of late Viséan age (*c.* 332 million years old). The Variscan (south-west English) site of Writhlington is by contrast of late Upper Carboniferous, late Westphalian age (*c.* 307 million years old).

The considerable sedimentological differences between the sites reflect the separate palaeogeographical provinces that were established by important tectonic features emanating from the Variscan Orogeny (Figure 3.2). East Kirkton and Granton Shore lie within the Scottish province north of the landridge known as the 'Southern Uplands High', while Foulden is in the 'IWeed Basin to the north-east of the High and Glencartholm is on the flank of the Solway Basin to the south-east of the High. Many fault-bounded basins with intervening shelf highs and the major Leinster–Wales–London–Brabant landmass separate these Laurentian sites from the single Variscan site of Writhlington. The latter lies south of the landmass in the Southern Province and just to the north-east of the Culm Basin with its deeper water deposits.

From late Devonian to early Carboniferous times there was back-arc extension throughout Ireland and Britain north of the Variscan subduction zone. The result was a series of fault-bounded half-grabens that largely controlled the palaeogeography of the Lower Carboniferous with its rates and depths of subsidence and types of sediments. The underlying structural control on the basins and highs was largely inherited from older Caledonian features.

The Scottish Province

During Carboniferous times there were a number of basins of deposition in Scotland, mostly within the structural and topographical depression of the Midland Valley (Figure 3.2). The Viséan age sites of East Kirkton and Granton Shore are located within the north-easternmost of these depocentres — the Fife Midlothian Basin. These Midland Valley depocentres were separated from depositional basins to the south by the Southern Uplands High and its north-eastern extension, the Mid-North Sea High. However, there was one embayment, the Tweed Basin, which extends south of the Midland Valley and it is here that the Foulden site is located. The remaining Scottish site, Glencartholm, lies on the south-western flank of the Southern Uplands High at the edge of the Solway Basin, which extends north-eastwards into the Northumberland Basin.

A significant factor in these environments of deposition was volcanism that continued throughout the Carboniferous Period ((Figure 3.3) and see (Figure 3.10)). The activity produced a topography dominated by volcanoes that separated the basinal depocentres (Figure 3.4). Within each basin, water circulation was restricted, leading to stratified water columns and the preservation of organic matter in the form of oil shales. These were interbedded with thin carbonates deposited in marginal marine and lacustrine environments with fluctuating oxygen and salinity levels. Eustatic movements also played an important part in the changitig conditions of deposition with occasional influxes of riverborn sediment. Within these environments, some unusual biotas developed, some of which have been exceptionally preserved, such as the crustaceans of Granton Shore and the associated conodont animal at nearby Wardie Shore.

The limestone at East Kirkton is intercalated with the lower part of the Bathgate Group and is placed in the upper part of the West Lothian Oil-shale Formation within the Viséan age Strathclyde Group see (Figure 3.5) and (Figure 3.6). The limestone is overlain by a lacustrine shale and a tuff. The whole sequence was deposited in an isolated lake fed by silica-rich hot springs. River deltas and volcanidastic detritus prograded into the lake at times. To begin with the lake was surrounded by extensive seedfern-dominated woodland that frequently suffered wildfire outbreaks. Subsequently drier conditions altered the woodland vegetation, the lake deepened and was subject to algal blooms and oxygen depletion. Finally, increasing rainfall encouraged a lycopsid-dominated vegetation. Throughout this time the lake became the depository of abundant animal and plant remains, both aquatic in origin and derived from the surrounding woodland. Altogether the biota is of international importance especially for its early tetrapod fauna and terrestrial arthropods that includes eurypterids, a scorpion, millipedes and the earliest known harvestman (opilionid).

The Tweed Basin was initially separated from the main Northumbrian Basin to the south by the slowly subsiding Cheviot Block. Here the deposits are strongly influenced by an axial river. The Kelso Lavas ((Figure 3.7)b) are overlain by deposits of the Cementstone Group, which includes gypsum bands, some horizons with marine fossils and occasional fluvial channel sandstones (known as the 'Ballagan Formation' of Courceyan (Tournaisian) age; (Figure 3.5)). The deposits have been interpreted as those of a semi-arid coastal plain intersected with intermittent rivers (Figure 3.8). There were also shallow freshwater lakes that supported restricted fish faunas but were also subject to flooding, which may have introduced other faunal elements such as the arthropods. The latter include the earliest-known limuloid and an unusual eurypterid.

The Solway basin in the west was part of a composite trough that included the Northumberland and Tweed Basins to the northeast (Figure 3.2). Volcanism was less influential than in the Midland Valley and marine influences were stronger. The northern boundary of the Solway Basin was bounded by active faults with a southerly downthrow. Detritus from uplifted landscapes to the north-west built alluvial cones and flood deposits out into the basin throughout much of early Carboniferous times (Figure 3.7) and (Figure 3.8). This terrestrial input was accompanied by periods of fluvial input from a persistent axial river system that flowed south-westwards into what was otherwise a marine open-shelf environment of deposition. There was an eruption of volcanicity that began locally (Langholm area) in early Tournasian times and subsequently became more extensive forming the Glencartholm Volcanic Beds (late Holkerian–early Asbian age, (Figure 3.3)) within the Middle and Upper Border Group. The latter includes marine mudstones and limestones with thin sandstones (many of which are volcaniclastic). The succession has yielded one of the richest and most important Carboniferous fish biotas in the British Isles (Dineley and Metcalf 1999), fossil plants (Cleal and Thomas, 1995) and, most significantly in this context, a diversity of arthropods including eurypterids, xiphosurans, scorpions and crustaceans.

The Southern Province

The only Upper Carboniferous site to have been selected for inclusion in this GCR volume is Writhlington, near Radstock in northern Somerset and north-east of the Mendip Hills. Thus it lies in the Southern Province of Westphalian (Coal Measure) sedimentation and to the south of the Leinster–Wales–London–Brabant High and is separated from the Cu1m Basin to the south by the Bristol Channel Fault Zone (see (Figure 3.2) for these features as shown in earlier Dinantian times). Writhlington is in the Bristol–Somerset coalfield and is part of an extensive west–east region of sedimentation which includes the coalfields of southern Wales, the Forest of Dean, Bristol–Somerset, Oxfordshire–Berkshire and Kent. The Westphalian (A–D) deposits of the western part of the South Wales Coalfield comprise an unbroken sequence some 1800 m thick in places but thin eastwards. Re-activation of older east–west basement structures during Variscan compression produced contemporaneous faulting, folding and positive areas over which the Westphalian succession thins.

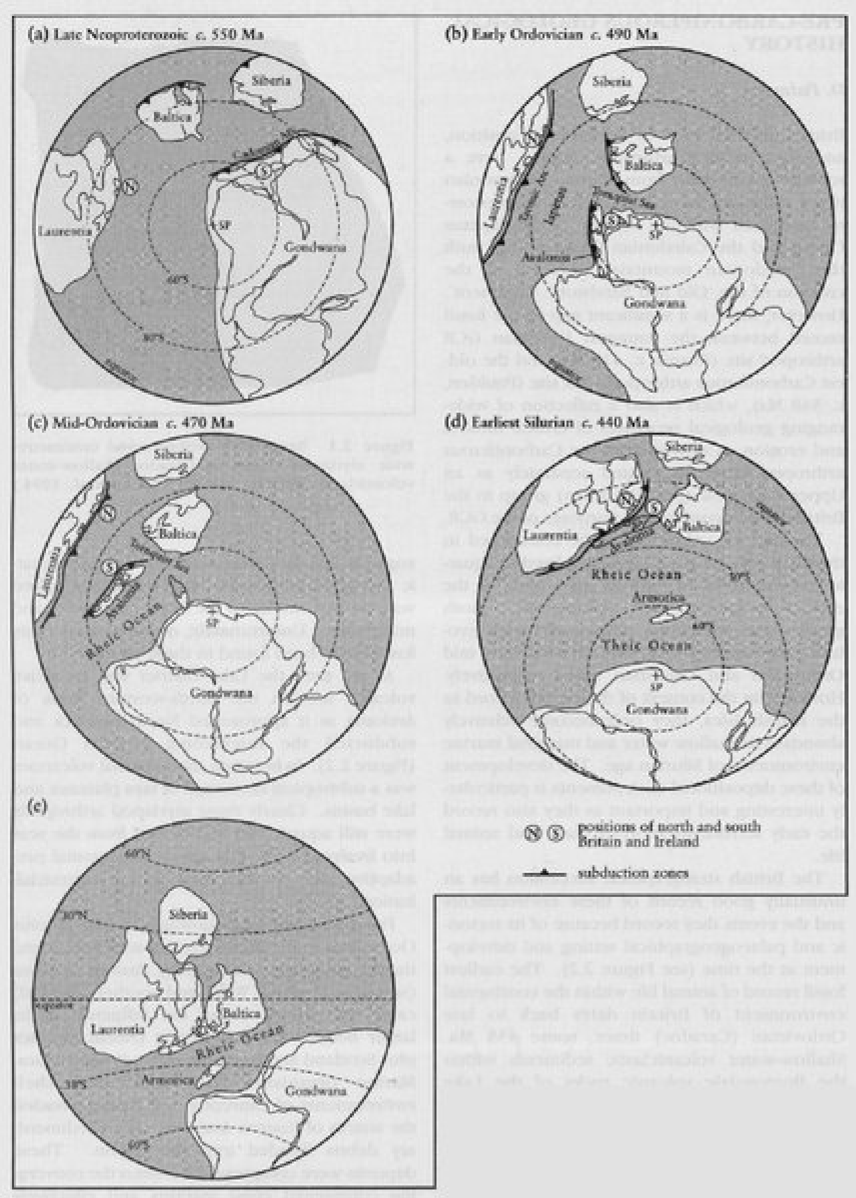
However, to the east and southeast of the Usk Axis the succession thickens again. A broad structural basin, known as the 'Radstock Syncline', accumulated a considerable thickness of around 7800 m of Upper Carboniferous sediments. In the upper part of the succession (upper Bolsovian–upper Westphalian D) includes coal seams and associated strata. They were deposited in densely vegetated fluvial plains. The Writhlington site consists of rejected shale debris that was adjacent to the worked coal seams. Careful collecting has provided abundant arthropod fossils including cockroaches (blattodeans) plus various other insects and a xiphosurid.

Climate

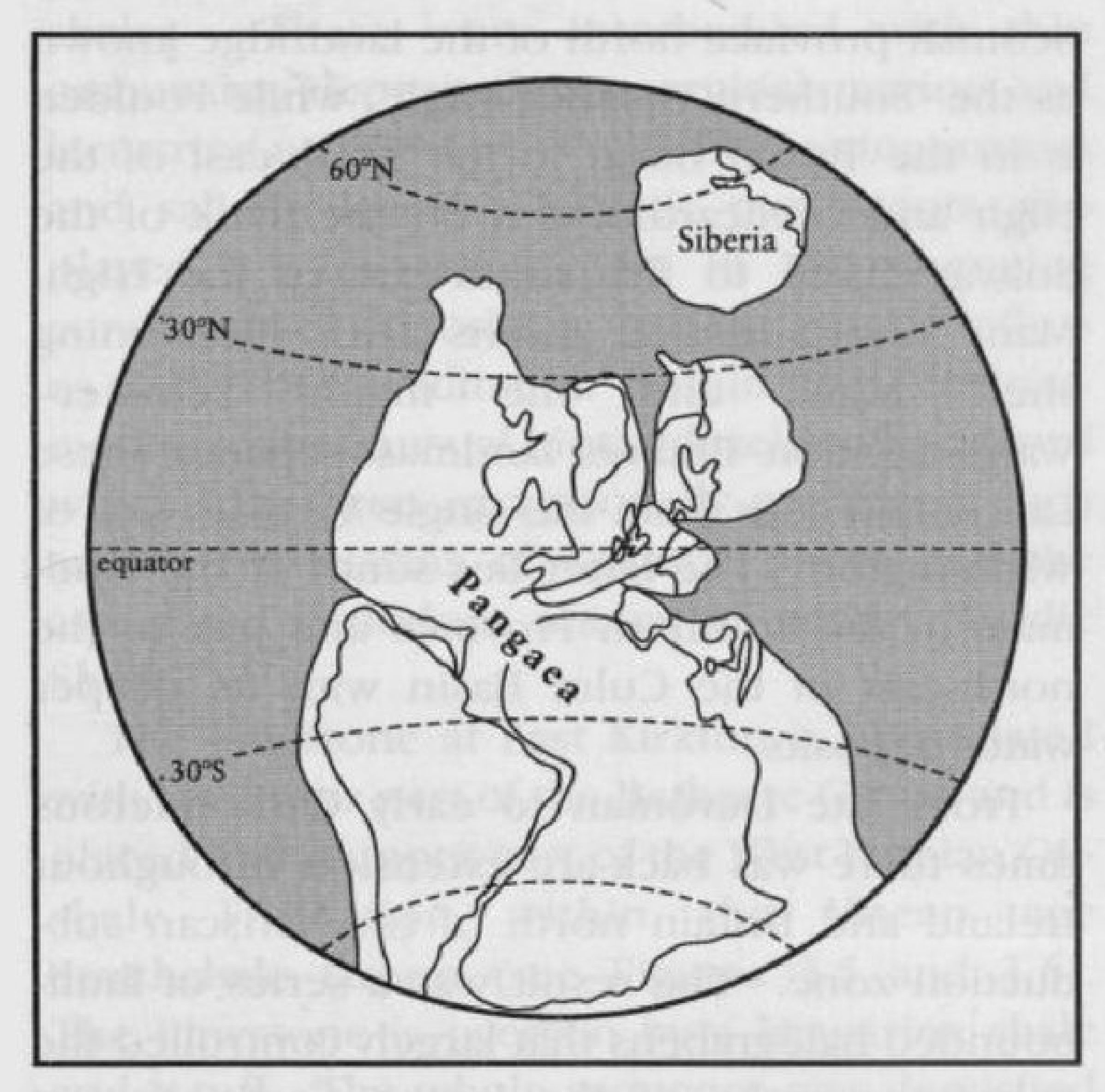
The Carboniferous period was one of progressive climate change enhanced by changes in atmospheric circulation as a result of Variscan mountain building and northwards plate movement, which took the British Isles and adjacent regions across the equator. Strongly seasonal, possible monsoonal, climates prevailed through early Carboniferous times and there is evidence for semi-arid conditions by late Viséan times.

Subsequently, during later Carboniferous times (Namurian and Westphalian) there were fluctuating seasonal to all-year humid climates with interspersed drier phases linked to glacial events. Changing freshwater input from major rivers and fluctuating sea levels, again linked to glaciation, resulted in complex depositional cycles with repeated formation of luxuriant vegetation and peats in lowlying areas. With subsequent burial they were transformed into the well-known coal deposits that eventually fuelled Britain's Industrial Revolution. By the end of Carboniferous times (late Westphalian to Stephanian times) there was increasing aridity caused by the rain-shadow in the lee of the Variscan mountains and prevailing tradewinds blowing from the east. Of late Westphalian age, the Writhlington deposits were laid down at the beginning of the latter phase of climate change.

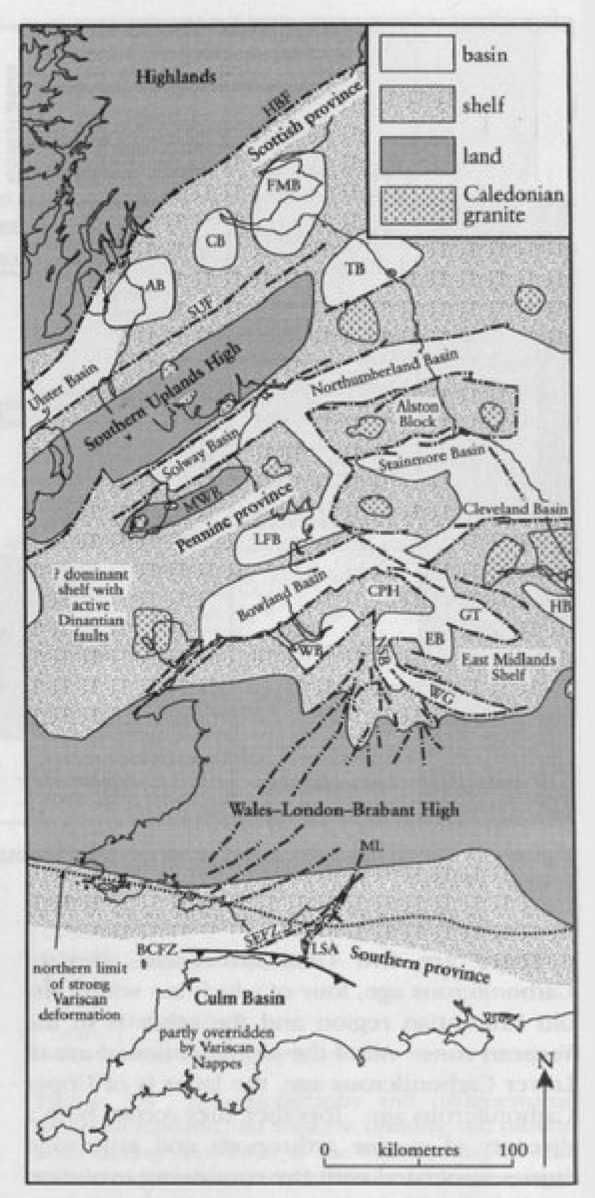
References



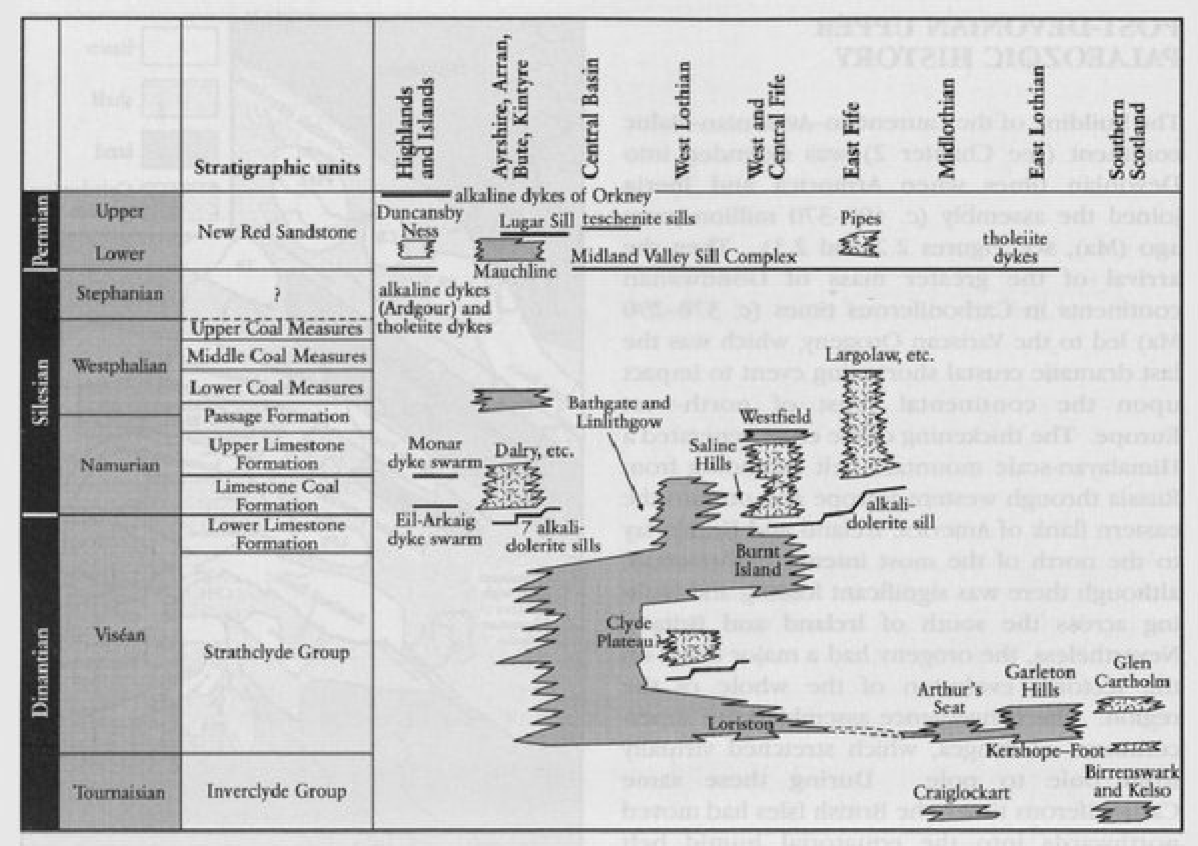
(Figure 2.2) Palaeozoic reconstructions of palaeocontinental positions showing the geological formation of the British Isles following the closure of the Iapetus Ocean. SP = South Pole. (Ater Holdsworth et al., 2000.)



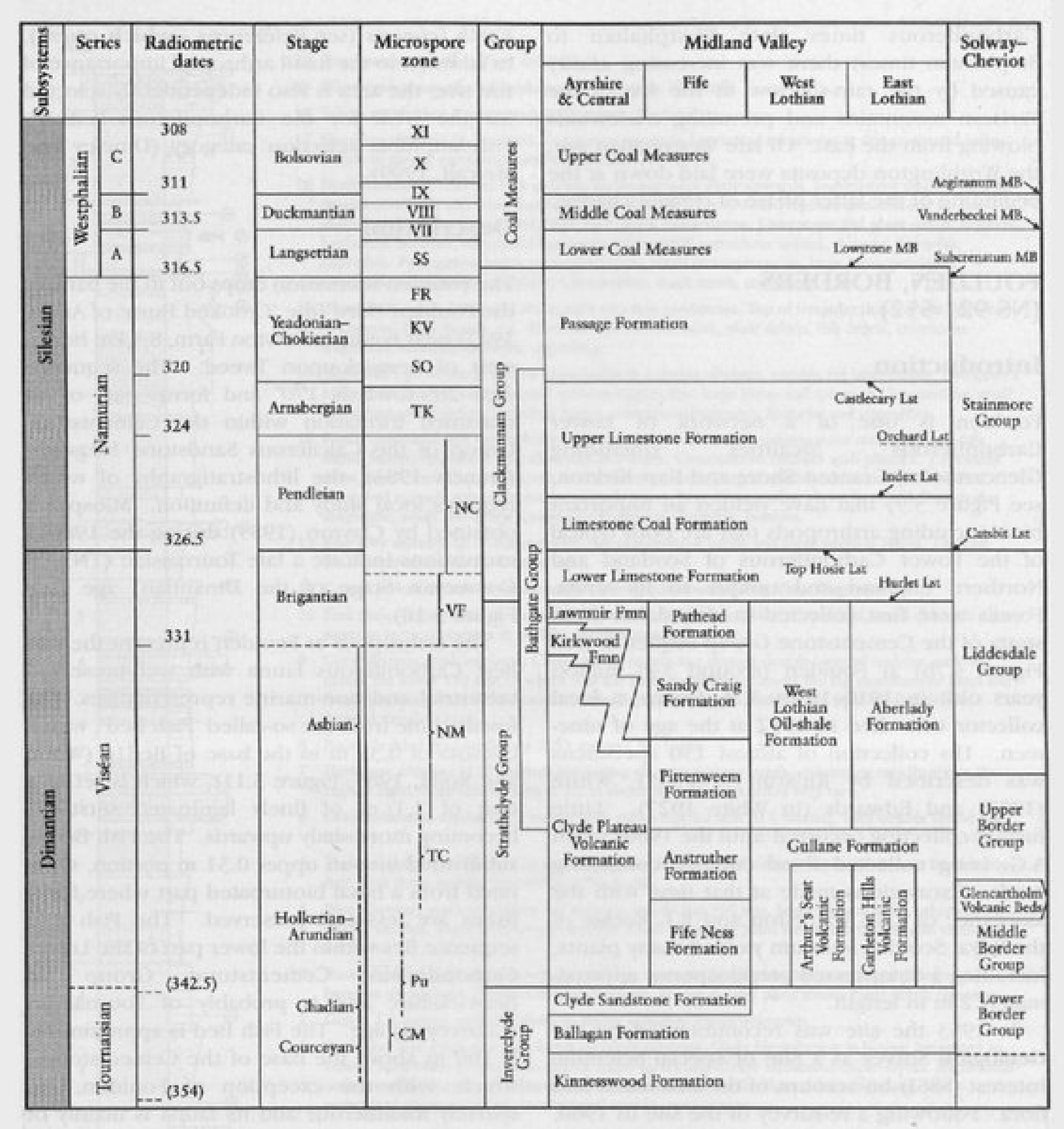
(Figure 3.1) Palaeogeographical reconstruction of the continents in Late Carboniferous times, c. 300 Ma. Proto 'UK' is equatorial, and shown at the centre of this depiction. (Holdsworth et al., 2000.)



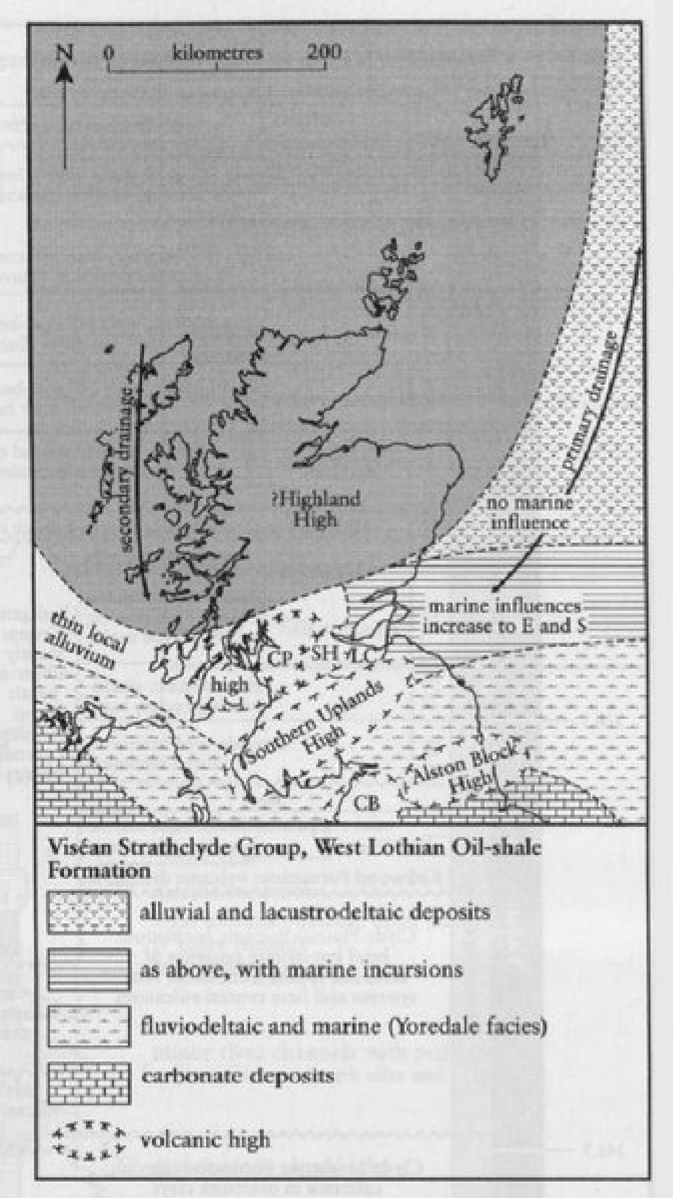
(Figure 3.2) Dinantian palaeogeography showing main provinces and fault-bounded extensional basins and platforms that influenced sedimentation through much of the Carboniferous Period. (After Corfield et al., 1996.) Key: AB: Ayrshire Basin; BCFZ: Bristol Channel Fault Zone; CB: Central Basin; CPH: Central Pennine High; EB:= Edale Basin; FMB: Fife Midlothian Basin; GT: Gainsborough Trough; HBF: Highland Boundary Fault; LFB: Lancaster Fells Basin; LSA: Lower Severn Axis; ML: Malvern Line; NSB: North Staffordshire Basin; SEFZ: Severn Estuary Fault Zone; SUF: Southern Uplands Fault; TB: Tweed Basin; WB: Widnes Basin; WG: Widmerpool Gulf.



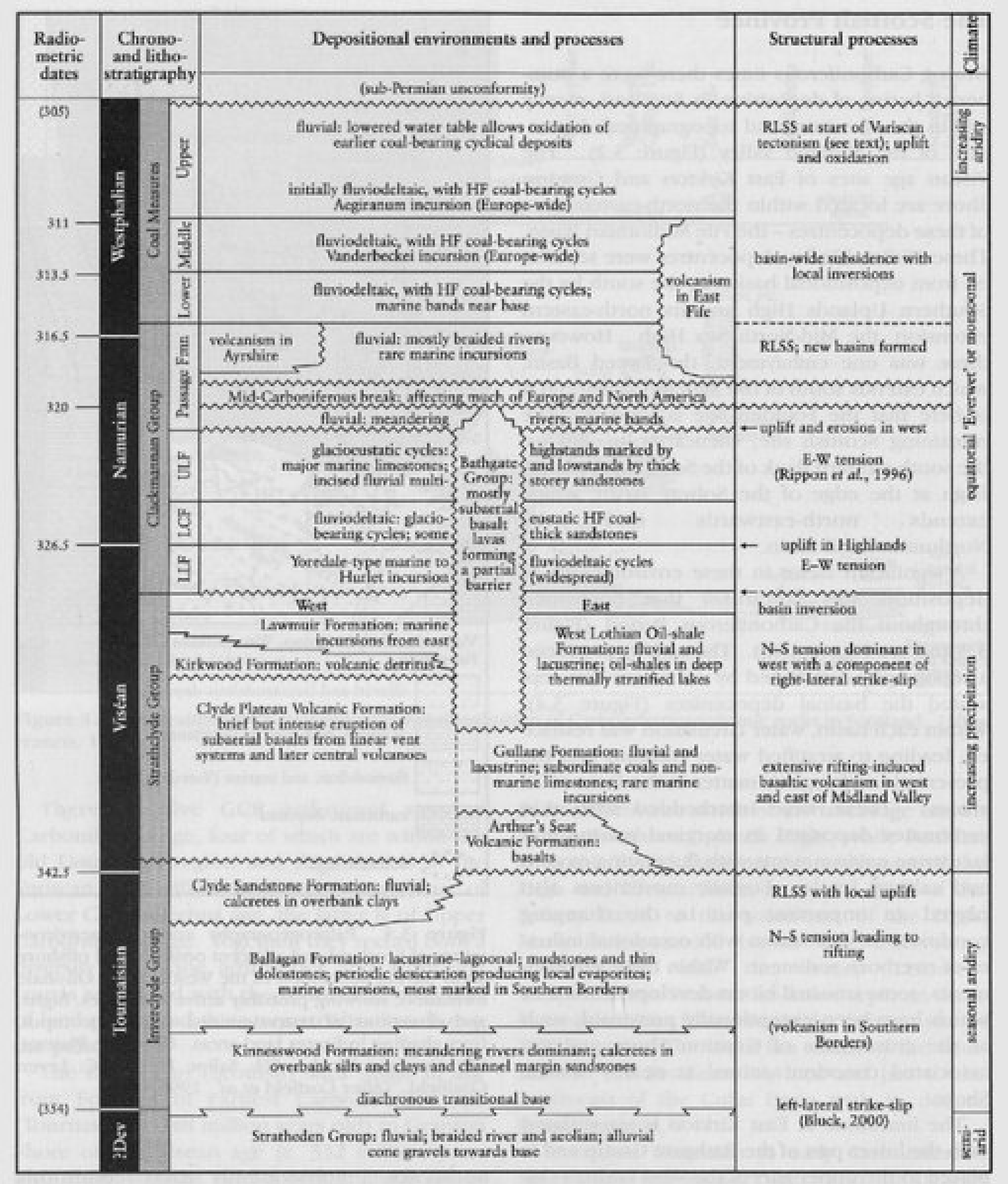
(Figure 3.3) The stratigraphical and geographical distribution of Carboniferous volcanic rocks in Scotland. (After Francis, 1991b.)



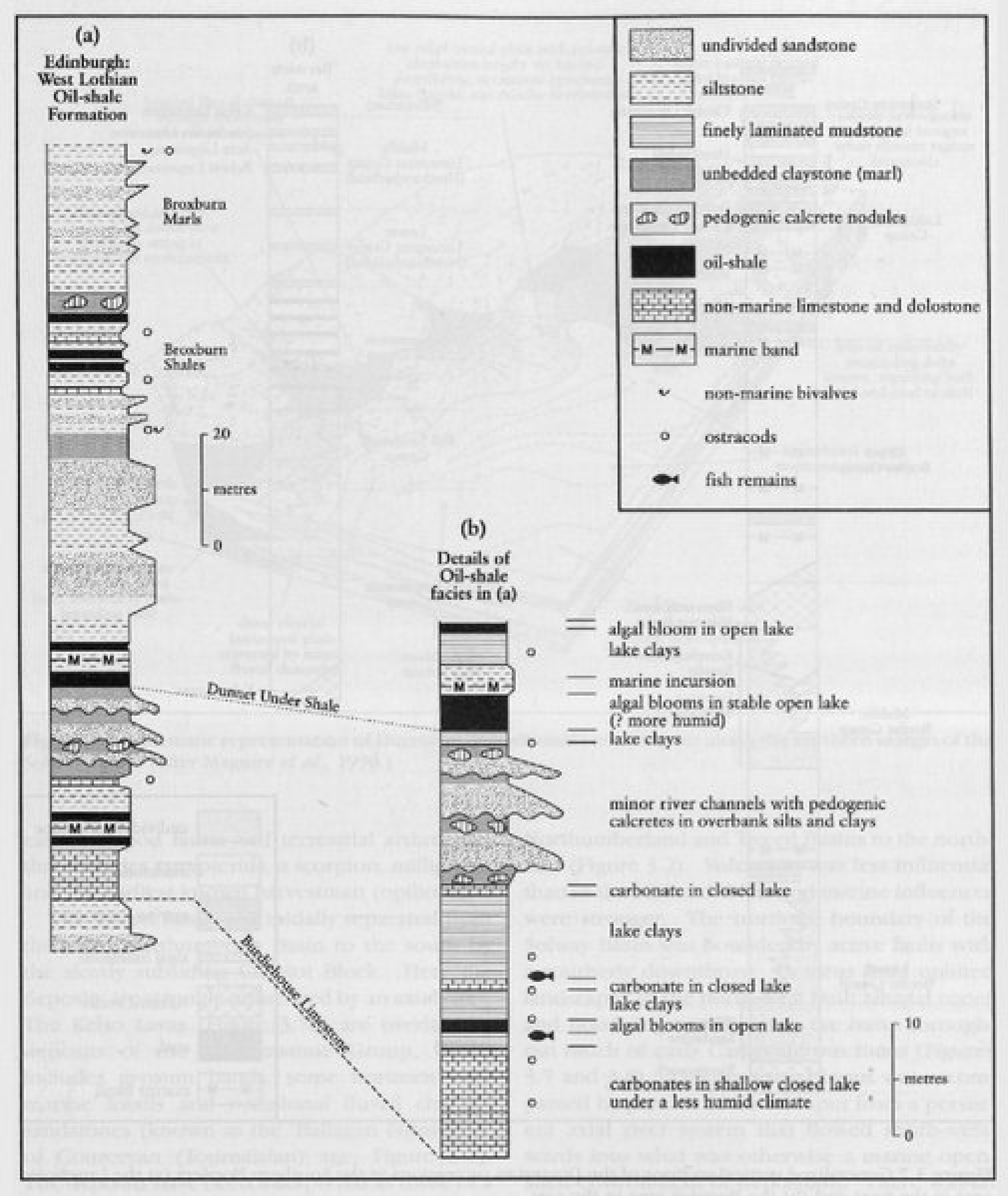
(Figure 3.10) Lithostratigraphical and chronostratigraphical divisions of the Carboniferous Period'in the Midland Valley and Southern Borders. Key marine bands (MB) and limestones (Lst) used in correlation are noted. No clear evidence for Chokierian or Alportian stages has been found in Scotland, possibly reflecting a mid-Carboniferous depositional break.



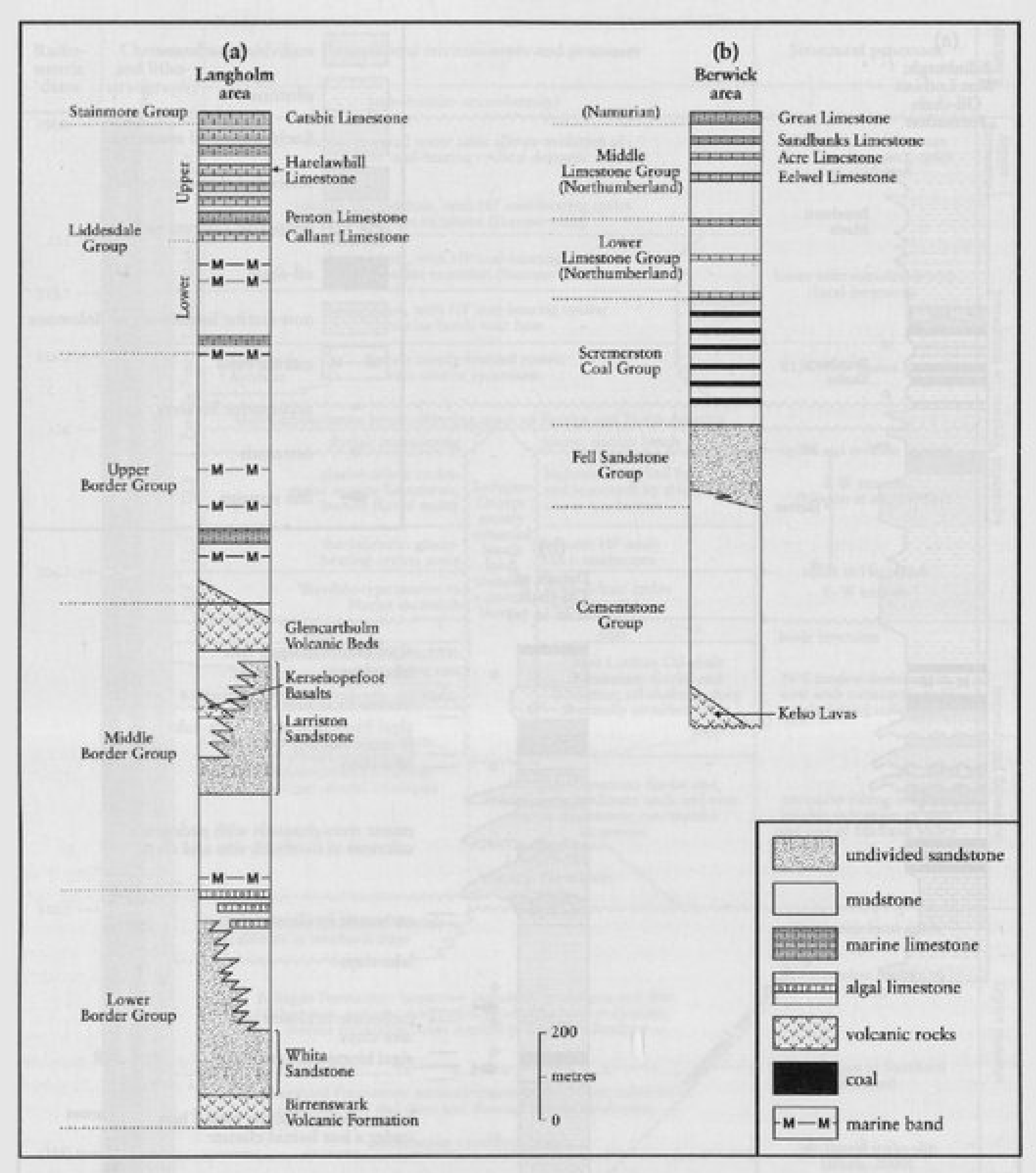
(Figure 3.4) Palaeogeography and palaeoenvironments of Scotland and adjacent onshore and offshore areas during deposition of the West Lothian Oil-shale formation, showing probably active structures, highs, and directions of coarse-grained sificiclastic input. Grey shading indicates land areas. CP: Clyde Plateau; CB: Cumbria Block; SH: Saline Hills; LC: Leven Coalfield. (After Corfield et al., 1996.),



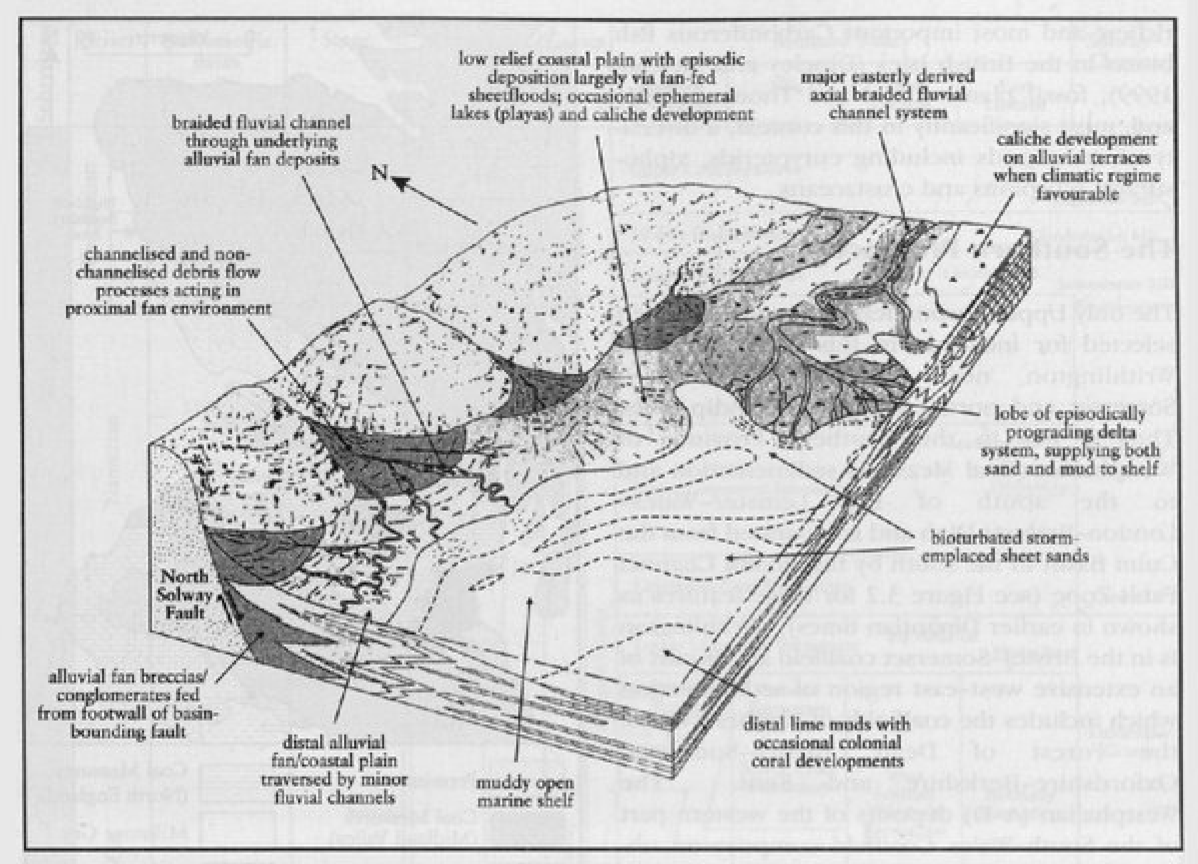
(Figure 3.5) Summary of Carboniferous geological history for the Midland Valley and adjacent areas, showing outlines of changes in depositional environments, structural control and climate. Radiometric dates are from Menning et al. (2001). RLSS = right-lateral strike-slip. LLF = Lower Limestone Formation; LCF = Limestone Coal Formation; ULF = Upper Limestone Formation; HF = high frequency.



(Figure 3.6) Generalized vertical sections of (a) the upper part of the West Lothian Oil-shale Formation in the Edinburgh area and (b), a detailed representative section.



(Figure 3.7) Generalized vertical sections of the Dinantian successions in the Southern Borders (a) the Langholm area in the west and (b) the Berwick area in the east.



(Figure 3.8) Schematic representation of Dinantian depositional environments along the northern margin of the Solway Basin. (After Maguire et al., 1996.)