Chapter 5 The Anglo-Welsh Basin

Introduction

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The Anglo-Welsh Basin formed on the southern margin of the newly amalgamated Laurussian (Old Red Sandstone) continent and the northern margins of the Rheic Ocean ((Figure 1.3), Chapter 1). The basin lay in a distal ('externar) setting relative to the main Caledonian Orogen in Late Silurian and Early Devonian times (Allen, 1979). Anglesey may have been the site of a small isolated internal basin within the orogen at the start of Old Red Sandstone deposition, but similar facies in the higher part of the succession point to contiguity with the main basin (Allen, 1965a). The basin lay in sub-tropical latitudes, palaeomagnetic data suggesting a latitude of 17 ± 5°S for the Lower Old Red Sandstone (Channel *et al.,* 1992). The abundance of calcrete palaeosols in the basin-fill points to a warm, semi-arid climate with seasonal rainfall.

Local variations on the regional subsidence pattern were exerted by synsedimentary extensional and transtensional faults. The former were particularly active during deposition of the Late Silurian–Early Devonian Milford Haven Group in south-west Pembrokeshire. The latter may have caused the intermittent emergence of a landmass in the Bristol Channel area in Early and Mid-Devonian times. Previous models of the basin's evolution invoked post-Caledonian flexural subsidence (e.g. King, 1994; Friend *et al.,* 2000; Woodcock, 2000a), but orogen-wide, sinistral pre-Acadian transtension and tectonic subsidence have been proposed recently (Dewey and Strachan, 2003; Soper and Woodcock, 2003).

The Old Red Sandstone is present in a narrow outcrop on Anglesey and in small outliers in Clun Forest and Long Mountain in central Wales. In south and south-central Wales, it is widely distributed in the Carmarthen Fans, Black Mountains and Brecon Beacons, around the northern and eastern rims of the South Wales Coalfield, and in the Welsh Borderland. It also crops out on the limbs of several Variscan folds in south-west Pembrokeshire, where it is magnificently exposed in sea cliffs. The main basin extended south-eastwards into south-east England where the Old Red Sandstone is concealed by younger strata. It may also have extended northwards to the southern Lake District, where a cover of at least 3.5 km of Old Red Sandstone sediments is estimated to have been removed during Acadian inversion (Soper and Woodcock, 2003). The outliers in Anglesey, Long Mountain and Clun Forest are remnants of this former cover.

Old Red Sandstone red-bed sedimentation generally began in Late Silurian P■ídolí times, when the Lower Palaeozoic marine Welsh Basin was finally filled, then inverted during the Acadian Orogeny. However, there are earlier occurrences of Old Red Sandstone facies at Marloes Sands, south-west Pembrokeshire, where it is of late Wenlock to early Ludlow age, and in the Llandovery area, where the Trichrug Formation is of mid-Ludlow (late Gorstian) age. The Old Red Sandstone extends throughout the Devonian and into the Early Carboniferous. with the Mid-Devonian largely unrepresented in the rock record, except perhaps for the southerly derived Ridgeway Conglomerate Formation of south-west Pembrokeshire and the northerly derived Hangman Sandstone Formation of north Devon. For the most part, the southerly advancing Acadian deformation front resulted in uplift and erosion of the Anglo-Welsh Basin in Mid-Devonian times, now represented by a regional unconformity at the base of the Late Devonian Upper Old Red Sandstone.

P■ídolí and Lochkovian–Pragian strata are widespread in south-central Wales and the Welsh Borderland, higher (Emsian and Famennian) strata occur mainly as narrow outcrops around the South Wales and Forest of Dean coalfields and as outliers, as for example in the Clee Hills of Shropshire. Good summaries of the Old Red Sandstone succession of the Anglo-Welsh Basin are given by Allen (1974a, 1977) and Hillier and Williams (in press). Bluck *et al.* (1994), Woodcock (2000a) and Soper and Woodcock (2003) presented recent regional overviews. A maximum of about 4.3 km of strata is present north of the Ritec Fault in Pembrokeshire, with up to about 2 km elsewhere. Two major Old Red Sandstone megasequences are recognized, traditionally referred to the Lower Old Red Sandstone and the Upper Old Red Sandstone. The Lower Old Red Sandstone succession is mainly of Late Silurian (Ludlow–P■ídolí) to Early

Devonian (Emsian) age, the Upper Old Red Sandstone of Late Devonian (late Frasnian–Famennian) to Early Carboniferous age.

(Figure 5.1) shows a correlation of the Old Red Sandstone successions and their lithostratigraphical subdivisions. (Figure 5.2) shows the location of the GCR sites described in this volume. The basal formation of the Old Red Sandstone (Downton Castle Sandstone/ Tilestones/Long Quarry Sandstone) is of early P■ídolí Series, Silurian age, and the GCR sites in these formations arc described by Lane (2000a) in the companion volume on Silurian stratigraphy (Aldridge *et al.,* 2000). A large part of the Raglan Mudstone Formation and its equivalents are also of P■ídolí age. Some of the GCR sites in this formation are also described by Lane (2000a) (Table 1.4, Chapter 1) and only brief descriptions are given in this volume.

The transition from marine, nearshore shelf deposition to continental red-bed Old Red Sandstone deposition was generally regarded as taking place in latest Silurian-Early Devonian time. However, the age of the lowermost Old Red Sandstone beds in the Marloes Peninsula of south-west Pembrokeshire has generated controversy. Sanzen-Baker (1972) suggested that they were Ludlow in age. Allen *et al.* (1976) and Allen and Williams (1978) proposed that an unconformity with no angular discordance separated the underlying Ludlow marine strata from red beds of P■ídolí age. Hillier (2000) recorded a transition from Wenlock shallow marine strata (the Gray Sandstone Group) into the Old Red Sandstone Red Cliff Formation, and the recent discovery of Ludfordian spores from the basal beds of the Red Cliff Formation (Hillier and Williams, 2004) confirms a transitional boundary.

The P■ídolí–Lochkovian (Silurian–Devonian) boundary remains imprecisely located (see 'Introduction', Chapter 1), but is tentatively placed on the basis of spore assemblages within the uppermost part of the Downton Group (in the Raglan Mudstone Formation and the Moor Cliffs and Sandy Haven formations, its equivalents in Pembrokeshire), at about the level of the Psammosteus Limestone (Bishop's Frome Limestone/Chapel Point Calcretes Member). This horizon marks a major fades change in the Old Red Sandstone, when marginal marine, coastal mudflats and marine-influenced alluvial floodplains were replaced by medial to proximal alluvial environments. The mudstone/siltstone-dominated sequences of the P■ídolí Series are succeeded by one in which sandstones occupy about 30% of the succession, this proportion increasing towards the top of the Lochkovian Stage. Also, the composition of the sandstones changes, with a decrease in mica and a change in heavy-mineral assemblages. A more distant northern metamorphic terrane during the P■ídolí was replaced by a more proximal source of earlier Palaeozoic sedimentary and igneous rocks of what is now north Wales. Although there is evidence of local marine influence in the Welsh Borderland, the Lochkovian succession is otherwise entirely terrestrial, representing alluvial riverine and floodplain deposition, the transition from Silurian marine to Devonian continental environments being essentially completed.

The Lower Old Red Sandstone is subdivided into three loosely defined local chronostratigraphical stages, locally applied to this area because of the general lack of faunas and floras directly correlatable with the standard European marine stages (Figure 5.1). The stages are the Downtonian (now incorporated into the Silurian P■ídolí Series; the name is retained in a lithostratigraphical sense as the Downton Group), the Dittonian (converted to lithostratigraphical usage by some authors as the Ditton Group (e.g. Dineley, 1999f), and of Lochkovian to Pragian age); and the Breconian (Croft, 1953) of late Pragian to Emsian age. The Upper Old Red Sandstone is ascribed to the Farlovian local stage and is of Frasnian–Famennian to early Tournaisian (Carboniferous) age.

The Lower Old Red Sandstone broadly comprises an upward-coarsening offlap succession, consisting, in upward succession, of marginal marine, coastal floodplain, alluvial channel and floodplain and alluvial-fan environments of increasing energy and proximity to the advancing Acadian front (Figure 5.3). Continuing southwards progradation of the fades belts and migration of the fluvial fall-line at the Acadian deformation front resulted in erosion and non-deposition throughout Mid-Devonian time in most of the basin, with the alluvial systems depositing sediment in north Devon. Interrupting this overall southward progradation is the regionally developed Psammosteus Limestone, representing a period of widespread (over 20 000 km^2) and prolonged carbonate soil (calcrete) formation. It represents basin shutdown and sediment starvation, and resulted in a change in basin-fill architecture and fish faunas. A regional airfall tuff the Townsend Tuff Bed, lies about 100 m below the Psammosteus Limestone (Allen and Williams, 1981a) and provides a further, synchronous correlative tool (Figure 5.1).

A series of extensional faults in south-west Pembrokeshire defined structural blocks and basins. The Benton and Ritec faults acted as intermittent sources of basin-margin alluvial-fans and sites of condensed deposition, with deposition of thick successions in their hanging-walls. The Lower Devonian Cosheston Group is confined to the Winsle area (Thomas, 1978; Marshall, 2000a,b), which is bounded to the north by the Benton Fault and to the south by the Ritec Fault. The ?Middle Devonian Ridgeway Conglomerate Formation is confined to the Tenby-Angle Basin to the south of the Ritec Fault. Correlation of the successions is achieved by the presence of the Townsend Tuff Bed and Psammosteus Limestone (Chapel Point Calcretes Member), but the latter is absent or poorly developed to the north of the Ritec Fault and west of the Llandyfaelog–Pontesford Lineament. Exotic clasts in the Brownstones Formation of the upper Swansea Valley may be related to transpressive movement on the Swansea Valley Fault (Tunbridge, 1980a). The pebbly Caeras Beds of the Cennen Valley (Caeras Quarry GCR site) may have a similar origin in relation to the Carreg Cennen Disturbance.

Most of the early deposits of the Lower Old Red Sandstone succession were derived from the Caledonian uplands north of the Highland Boundary Fault (e.g. Allen and Crowley, 1983). However, the exact nature of the dispersal systems remains controversial. Orogen-parallel drainage from the region of Scandian uplift to the north-east of the UK, through the Midland Valley of Scotland and southwards to the Anglo-Welsh Basin has been proposed (e.g. Simon and Bluck, 1982; Bluck *et al.,* 1992; Sherlock *et* al., 2002), but Scandian drainage may have terminated in the Midland Valley or Northern Ireland (Friend *et* at, 2000), with much of the later (post-Psammosteus Limestone) Lower Old Red Sandstone fill of the Anglo-Welsh Basin derived from closer Lower Palaeozoic sources in southern Scotland, southern Ireland and north Wales (Allen, 1974b; Allen and Crowley, 1983; Haughton and Farrow, 1989; Soper and Woodcock, 2003).

The P■ídolí Tilestones Formation of south-central Wales (Almond, 1983) was derived from the south. Palaeocurrents in the Ludlow–P■ídolí Red Cliff and Lindsway Bay formations of Pembrokeshire also indicate derivation from the south (Hillier, 2000; Hillier and Williams, 2004), although white micas in the former are said to have a Laurentian (Highland) origin (Sherlock *et al.,* 2002). Parts of the Lindsway Bay and the coeval Albion Sands formations were derived from the west, and probably deposited in a fault-controlled axial valley. The southerly source of sediment is thought to have been the remnants of the Early Palaeozoic landmass of Pretannia (Cope and Bassett, 1987; Bluck *et al.,* 1992), which formed the south-east shoulder of the Welsh Basin.

The ?Mid-Devonian Ridgeway Conglomerate Formation of Pembrokeshire, limited to the south (hanging-wall side) of the Ritec Fault, and the Pragian Llanishen Conglomerate Formation of the Cardiff district (Allen, 1975; Waters and Lawrence, 1987) were derived from the south. The Ridgeway Conglomerate Formation forms part of the West Angle Bay (North) and Freshwater East–Skrinkle Haven GCR sites, as well as part of the Freshwater West site. The source of these rocks is believed to have been an emergent area in what is now the Bristol Channel, known as the 'Bristol Channel Landmass' (Mechie and Brooks, 1984; Tunbridge, 1986; Cope and Bassett, 1987; Marshall, 2000a,b). South of the Bristol Channel, the Hangman Sandstone Formation, seen at the Glenthorne GCR site, is the only unit of northerly derivation and proven Mid-Devonian age.

The lowermost P■ídolí strata, traditionally referred to the Lower Old Red Sandstone, comprise the Downton Castle Sandstone Formation, and the Tilestones (Long Quarry Sandstone) Formation (its lateral equivalent in south-central Wales, seen at the Sawdde Gorge GCR site). These are shallow marine, barrier and shore-face deposits, with red-bed Old Red Sandstone deposits overlying them. Locally, a green, lacustrine/back-barrier facies (the Temeside Mudstone Formation) intervenes; the Pont-ar-llechau Member in the Sawdde Gorge is of similar fades, although red (Almond, 1983; Almond *et al.,* 1993). Higher P■ídolí strata (Sandy Haven, Moor Cliffs and Raglan Mudstone formations) are predominantly red mudstone/ siltstone-dominated successions with common nodular calcretes. Representing marginal marine, coastal mudflat and marine-influenced alluvial-floodplain environments, these strata are represented at the West Angle Bay (North), Freshwater West, Freshwater East–Skrinkle Haven, Sawdde Gorge, The Scar and Cusop Dingle sites. The Little Castle Head, and Albion Sands and Gateholm Island GCR sites are described in detail in the Silurian stratigraphy GCR volume (Aldridge *et al.,* 2000) and briefly described in the present volume. The mature calcretes of the Psammosteus Limestone at the top of the P■ídolí succession (the Chapel Point Calcretes Member in Pembrokeshire (Williams *et al.,* 1982) and the Bishop's Frome Limestone (Brandon, 1989) in south-east Wales, the Welsh Borderland and south-central Wales) are seen at the Devil's Hole, Freshwater West, Freshwater East–Skrinkle Haven, Sawdde Gorge, Liansteffan, Cusop Dingle and Lydney GCR sites.

The Lochkovian–Pragian (Dittonian) rocks (upper part of the Milford Haven Group, Gelliswick Bay, Freshwater West and St Maughans formations; Ditton Group; (Figure 5.1)) are characterized by the cyclic arrangement of their component facies (mudstone/siltstones, sandstones and intraformational conglomerates) in upward-fining, commonly calcretized alluvial cycles (Allen, 1964a). The thickest development (1000–1500 m) is north of the Ritec Fault in south-west Pembrokeshire. Overall, the succession coarsens upwards, with the sandstones becoming thicker and more dominant. Fish fragments are common in the conglomerates, plant microfossils and megafossils are present locally (e.g. Wellman *et* ed., 2000). There are a few instances of complete fish specimens being discovered, such as in the St Maughans Formation at the Cwm Mill GCR site near Abergavenny [SO 311 156] and the Wayne Herbert Quarry site [SO 335 320] in Herefordshire farther north (Dineley, 1999f). These fish occur in finer lithologies and were probably entombed in overbank deposits during flooding. The swimming and resting traces of fish (*Undichna*) are recorded at Tredomen Quarry near Talgarth (Morrissey *et al.,* 2004). Arthropod traces include the ubiquitous burrow trace *Beaconites barretti* (Morrissey and Braddy, 2004) and crawling traces (*Diplichnites;* Smith *et al.,* 2003; Morrissey *et al.,* 2004).

The intraformational conglomerates, along with some extraformational varieties, are interpreted as channel-lag deposits. The sandstones exhibit a range of architecture (Williams and Hillier, 2004), and although predominantly comprising the in-channel sandbodies of high-sinuosity streams, laterally accreted bodies and sheet-flood deposits also occur. The fine-grained lithologies are thought to represent deposition in floodplain environments that were subjected to frequent desiccation and carbonate soil formation; at least some of the mudrocks may have originated as wind-blown dust, perhaps reworked into lacustrine sediment in floodplain ponds (Marriott and Wright, 2004). Some mudrocks are interbedded with thin point-bar type gravelly lenses of calcrete clasts in low-angle cross-bedded sets and have pelleted fabrics, indicating deposition of pedogenic, pelleted mud aggregates from bedload in small sinuous channels (Ekes, 1993; Marriot and Wright, 1996, 2004). In addition to the immature calcretes, more mature, massive to rubbly calcretes occur sporadically, including the Coldra, Ruperra and Pontypool limestones of south-east Wales (Squirrel and Downing, 1969), the Ffynnon limestones of the Black Mountains and the Abdon limestones of the Clee Hills (Ball and Dineley, 1961; Allen, 1961, 1974c). Some tuffs are present in the Gelliswick Bay Formation in south-west Pembrokeshire and in the St Maughans Formation at Tredomen Quarry (Morrissey *et* ed., 2004).

Sites representing the Dittonian rocks include Oak Dingle, Freshwater West (potential GCR site), Freshwater East–Skrinkle Haven, Llansteffan, Cusop Dingle (potential GCR site) and Lydney. In addition, the disused quarry at Pantymaes near Sennybridge exposes a fine section through a thick channelized sandstone complex and overlying floodplain mudrocks (Owen and Hawley, 2000), as well as a suite of arthropod crawling traces (Smith *et al.,* 2003), and is recommended for GCR status.

Above the St Maughans Formation near Cardiff and Newport in south-east Wales is the Llanishen Conglomerate Formation. Its pebbles include Llandovery quartzites and ?Silurian volcanic rocks, in a suite unlike the northerly derived pebbles of most of the Old Red Sandstone succession, and a nearby southerly source is thus favoured (Allen, 1975; Waters and Lawrence, 1987).

In Anglesey, about 500 m of Old Red Sandstone rocks crop out from the coast between Dulas Bay and Lligwy Bay (see Porth-y-Mor GCR site report, this chapter) inland to near Llangefni. The succession records the burial of an already deformed and dissected Anglesey platform by Caledonian molasse shed from the mountain belt to the north. Asymmetric folding and an associated cleavage are attributed to the late Emsian Acadian deformation. The correlation and age of the succession, probably deposited at least initially in a palaeovalley isolated from the main part of the Anglo-Welsh Basin, and with no fossils yet found, are uncertain. Basal conglomerates and pebbly sandstones (the Bodafon Formation) are interpreted as the localized deposits of a series of coalescing alluvial-fans banked against a north-west-facing valley side. The Traeth Bach Formation comprises mainly red-brown siltstones with abundant calcrete nodules which are correlated by Allen (1965a) with the P■ídolí Raglan Mudstone Formation of south Wales, although he interprets them as playa-lake deposits, unlike the floodplain alluvial fades of the Raglan Mudstone Formation. The Porth-y-Mor Formation is correlated with the Dittonian succession of south Wales. Thick calcretes at the top of the Traeth Bach Formation invite comparison with the Psammosteus Limestone and support this correlation. The succession of fining-up alluvial cycles and sedimentary structures, including epsilon cross-stratification (first identified by Allen (1963a) in ancient deposits here), is interpreted as the deposits of south-eastward-flowing, meanderingstreams and their floodplains. The Traeth Lligwy Formation consists of bioturbated sandstones and siltstones and conglomerates, interpreted by Allen (1965a) as the

deposits of permanent lakes, a facies not seen in south Wales, except for some minor examples in the Senni Formation at Ferryside (Almond, 1983) and Laughorne (B.P.J. Williams, pers. comm.).

Strata of probable Emsian age are referred to the Breconian local stage. Its type area is the Brecon Beacons, where it comprises the Senni and Brownstones formations (Croft, 1953). The Senni Formation, and the equivalent Cosheston Group in south-west Wales and Clee Sandstone Formation in Shropshire, are characterized by their olive-green colour. The Senni Formation is known particularly for its early vascular plant remains, including *Gosslingia breconensis, Hostinella heardii, Krithodeophyton croftii, Sennicaulis hippocrepiformis, Tarella trowenii, Uskiella spargens* and *Zosterophyllum llanoveranum* (Cleat and Thomas, 1995). The Heol Senni Quarry GCR site provides a characteristic section of the formation, which is interpreted as the deposits of low-sinuosity, seasonally flowing, sandy, braided streams in a mid-fan setting (Owen, 1995). The Cosheston Group (Thomas, 1978; Wellman *et al.,* 1998) is much thicker (1500–1800 m), having been deposited in a zone of active rifting in the hanging-wall of the Benton Fault. The alluvial deposits of braided to meandering, generally southerly flowing stream systems contain, in their lower part, soft-sediment deformation structures that probably reflect seismic activity associated with the tilting of the basin. High water-table conditions are invoked for the preservation of the plant remains and the predominantly green colour of these formations, due to the presence of chloritized micas. A possible climatic cause of the high water-table has yet to be investigated. Only four vertebrate localities are known — the Breconian index fossil fish *Rhinopteraspis dunensis* (= *cornubica*)at Primrose Hill Quarry, Crickhowell [SO 207 200]. *R. dunensis* occurs in the Mid-Siegenian of mainland Europe (Dineley, 1999f); *Althaspis senniensis* at Heol Senni Quarry ([SN 9145 2210]; see GCR site report, this chapter); *Pteraspis dixoni* and *Cephalaspis* sp. at Pengau (Pen-y-gau) Farm [SN 3732 0850] near Ferryside, Pembrokeshire; and *Protopteraspis gosseleti* at Allt ddu near Brecon [SO 027 242] (Habgood, 2000; Edwards and Richardson, 2004).

The Brownstones Formation (the Black Nore Sandstone Formation east of the Severn) is the highest Lower Old Red Sandstone formation in the Anglo-Welsh Basin. It is characterized by red-brown, fine- to coarse-grained, fluvial sandstones, with red-brown, locally green mudstone and siltstone interbeds. Maximum development is in the Forest of Dean, where 1200 m are present; the Ross-on-Wye, Royal Hotel GCR site is a typical section. In the type area of the Brecon Beacons and Black Mountains, the sandstones generally form extensive sheets, as seen in the magnificent north-facing scarps of the Brecon Beacons, the succession tending to become more sandstone-dominated in its upper parts (Tunbridge, 1981a). The succession is interpreted as the deposits of a prograding fan system formed in a semi-arid, seasonally wet climate. Channelized sandstones are the product of mid-fan, wet season, flashy deposition, with more distal floodplain environments represented by sheet-flood sandstones and mudstones and siltstones. Gravelly, pebbly and conglomeratic sandstones are locally common, particularly in the upper part of the formation in the Forest of Dean and parts of the north and east crops of the South Wales Coalfield. Pebbly beds at Llyn-y-Fan Fawr [SN 834 216], 4 km west of the Swansea Valley are sourced from the east and perhaps attributable to uplift on the Swansea Valley Fault (Tunbridge, 1980a); similarly, the pebbly Caeras Beds in the Cennen Valley between Llandybie and Kidwelly may have been deposited as a result of uplift on the Carreg Cennen–Llandyfaelog Fault (Caeras Quarry GCR site). Pebble suites at Ross-on-Wye and in the Clee Hills comprise igneous, metamorphic and sedimentary rocks of Ordovician to Devonian age thought to have been derived from north Wales (Allen, 1975). The Brownstones Formation of Wales has yet to yield animal body fossils, but the Dittonian index fossil fish *Althaspis leachi is* recorded from the basal Brownstones Formation at the Wilderness Quarry GCR site in the Forest of Dean (Allen *et al.,* 1968). East of the Severn Estuary, the Black Nore Sandstone Formation, seen at the Portishead GCR site, provides the only occurrence of sandstones of aeolian origin at this level in the basin (Dodd, 1986).

No Middle Devonian strata are yet proved in south Wales, except perhaps for the southerly sourced Ridgeway Conglomerate Formation of south-west Pembrokeshire (see above). Mid-and Early Devonian ages have been suggested, but, bounded by unconformities and lacking in diagnostic fossils (only some crossopterygian fish fragments and plant fragments have been found), the age remains uncertain. It consists of petromict conglomerates, sandstones, and siltstones with calcretes. The clasts in the conglomerates are mainly of quartzite, lithic greywacke, siltstone and vein quartz, with a marked influx of phyllite clasts in the higher beds. The formation is interpreted as the deposits of a braided stream/alluvial-fan complex sourced from a nearby, southerly Lower Palaeozoic-?Precambrian source. A northward-prograding alluvial-fan occupied the area of Freshwater West, with more distal braided stream environments at West Angle Bay (North) (Williams *et al.,* 1982). Some large-scale, cross-bedded siltstones have been interpreted as

bedload-transported pedogenic mud aggregates (Ekes, 1993).

Late Devonian (late Frasnian–Famennian) Upper Old Red Sandstone rocks, referred to the Farlovian local stage, overlie the unconformity that truncates the Breconian and older successions. The West Angle Bay (North), Freshwater West (potential), Freshwater East–Skrinkle Haven and Portishead GCR sites provide sections of the unconformity. The strata are predominantly fluvial, deposited on a southerly facing palaeoslope, but lacustrine, possible aeolian and marginal marine facies occur locally in the Plateau Beds Formation (Mon y Waen and Duffryn Crawnon potential GCR sites) and aeolian sands are present in the Portishead Formation at the Portishead GCR site. The succession is thin in comparison with the Lower Old Red Sandstone, with up to a maximum of about 350 m in south-west Dyfed.

In the Pembroke peninsula, the Skrinkle Sandstones Group (see Freshwater West, West Angle Bay (North) and Freshwater East–Skrinkle Haven GCR site reports, this chapter) accumulated as a synrift succession of alluvial-fan, plain and lacustrine deposits in the hanging-wall of the Ritec Fault. Its distribution is confined to the Tenby-Angle Basin, thickening southwards from 100 m near the Ritec Fault to 330 m at Freshwater West (Marshall, 2000a,b). The beds lie unconformably on the Ridgeway Conglomerate Formation, overstepping it eastwards to rest on the Milford Haven Group, and there is a transition into grey Carboniferous beds at the top of the succession. The group is subdivided into the Gupton Formation and overlying West Angle Formation. The Gupton Formation is interpreted as comprising two axial basin-fill, fluvial, coarsening-upward sequences of mature, dean sandstones. The West Angle Formation is characterized by red sandstones, conglomerates rich in igneous, sandstone and phyllite clasts, and calcretes. The pebbles in the conglomerates were probably derived from the Precambrian Pebidian volcanic complex and associated Ordovician volcanic rocks of the northern south-west Pembrokeshire coast, either directly, or by recycling of the clasts of the Cosheston Group. The upper part of the West Angle Formation (the Red-Grey Member) comprises fining-upward fluvial sequences with mudstone and calcrete tops similar to the meandering channel deposits below, but shows an upward increase in grey beds and grey-green sandstones with plant remains (West Angle Bay (North) GCR site). The grey beds contain initially non-marine fossils, but increasing marine influence heralds the main transgression at the start of the Carboniferous Period.

In the Carmarthen Fans, Black Mountains and Brecon Beacons, the Upper Old Red Sandstone is represented by the Plateau Beds Formation, best known for its sporadic vertebrate and marine brachiopod faunas. Fish-bearing conglomerates include the Mon y Waen Fish Bed (see Mon y Waen GCR site report, this chapter). The succession represents a broadly transgressive sequence from fluvial (and possibly aeolian) deposition to marginal marine environments (Lovell, 1978a,b; Duffryn Crawnon potential GCR site). Fossils recovered include the brachiopods *Cyrtospirifer verneuili, Lingula* spp., *Ptychomaletoechia omaliusi,* the bivalves *Leptodesma* cf. *lichas, Pterinopecten* sp. and *Sanguinolites* sp. and fragments of the fish *Bothriolepis, Coccosteus, Holoptychius, Pseudosauripterus anglicus, cf. Rhinodipterus* and *Sauripterus* (Taylor and Thomas, 1975).

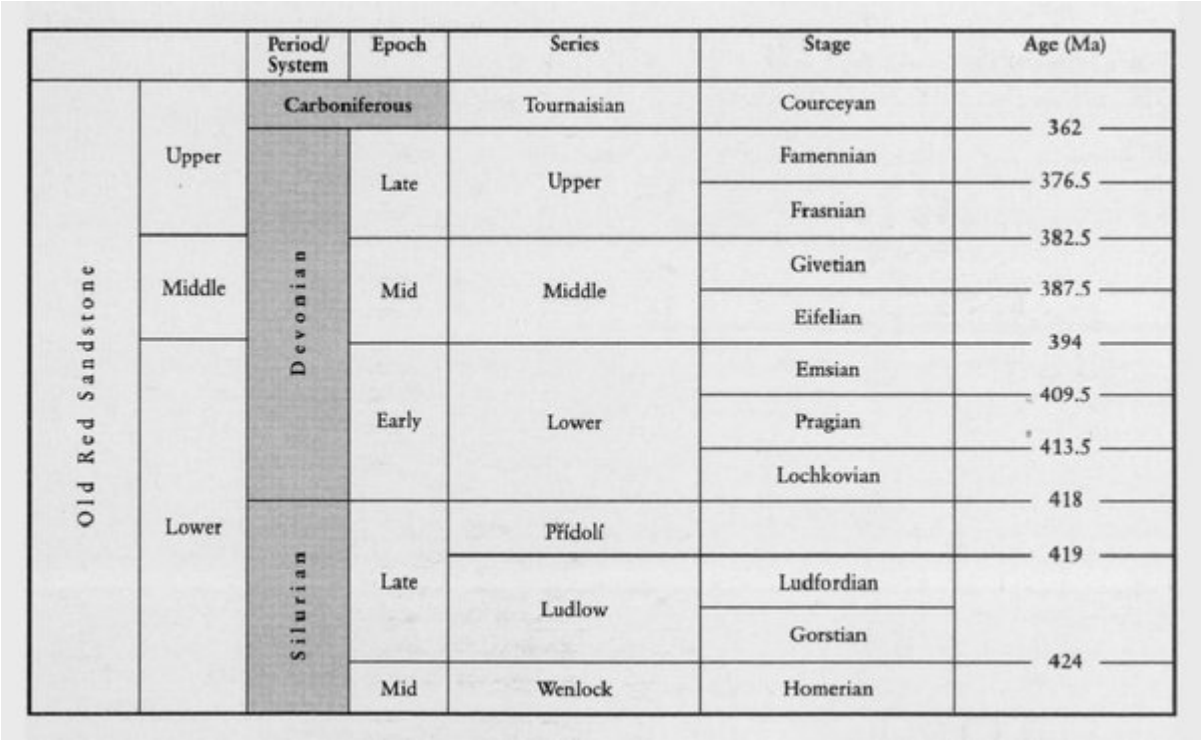
The Plateau Beds Formation is overstepped by the Grey Grits Formation (seen at the Abercriban Quarries GCR site), which consists mainly of quanzitic sandstones. Thin, green mudstone inter-beds and quartz pebble layers occur sporadically. Fauna is restricted to fish fragments and the bivalve *Sanguinolites,* along with some burrows, including forms resembling *Skolithos* and *Arenicolites.* Cross-bedding indicates a predominant southerly or south-easterly flow, but north-east currents are also recorded, as well as some herring-bone cross-bedding. Braided stream deposition is suggested, although a shallow marine origin for at least part of the formation cannot be discounted (Lovell, 1978a,b).

The Upper Old Red Sandstone is represented by the Quartz Conglomerate Group on the northeast, east and south-east crops of the South Wales Coalfield (see Craig-y-cwm potential GCR site report, this chapter). In the Cardiff area, a 114 m-thick succession of thinly bedded quarrzitic sandstones, siltstones and mudstones with subordinate thick, commonly pebbly sandstones and calcretes (the Cwrt-yr-ala Formation; Waters and Lawrence, 1987) underlies the Quartz Conglomerate Group. Quartzitic sandstones at the base of the group on the north-east of the coalfield (the Wern Watkin Formation) correlate with the Grey Grits Formation. They are overlain by quartz pebble conglomerates (the Craig-y-cwm Formation) that contain sporadic fish fragments, including *Bothriolepis.* The topmost part of the formation comprises micaceous, feldspathic and garnet-rich sandstones and interbedded red mudstones (the Garn-gofen Formation). Vertebrate remains from these beds include a fragment of *Osteolepis macrolepotus.* The bivalve *Archanodon jukesi* was collected from the Quartz Conglomerate Group in Monmouthshire, and *Holoptychius nobilissimus* is recorded at

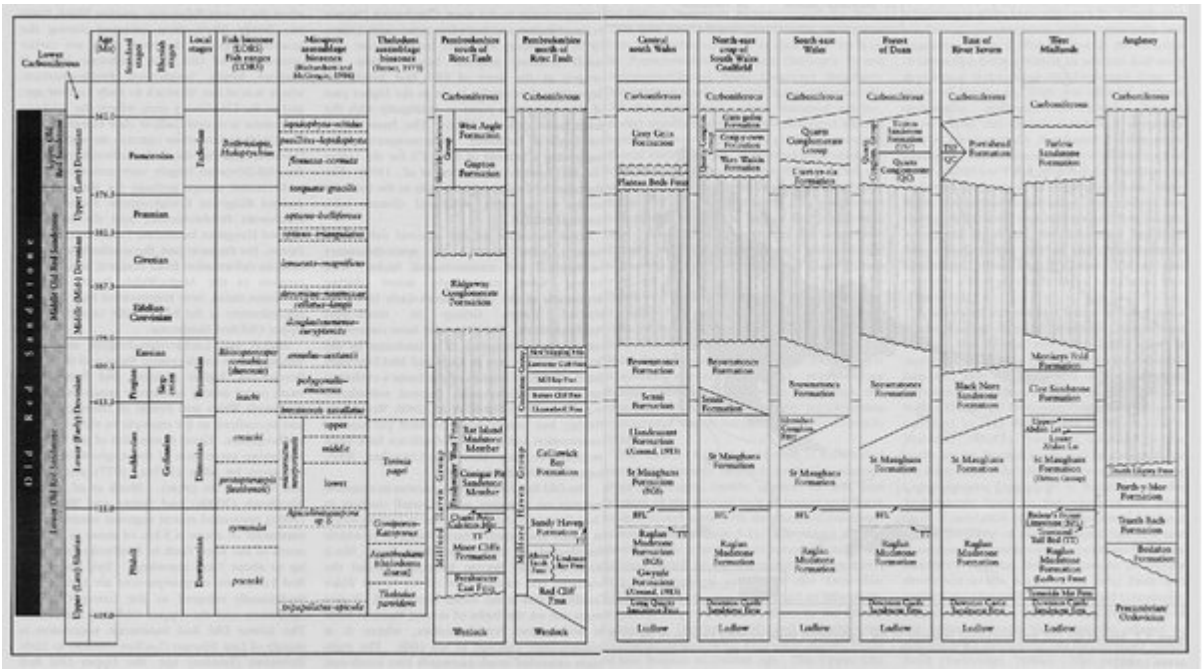
Tongwynlais. The group crops out around the Forest of Dean Coalfield in Monmouthshire and Gloucestershire, where it comprises basal quartz conglomerates overlain by the Tintem Sandstone Formation. East of the Severn, the sandstone and conglomerate fades become indistinguishable as the succession thickens southwards and the beds are named the Portishead Formation. In the Clee Hills, the Upper Old Red Sandstone is represented by the Farlow Sandstone Formation, which consists of lower yellow, and upper grey, sandstones.

The uppermost beds of the Quartz Conglomerate Group in south-east Wales locally show a transition into the lower Tournaisian Tongwynlais Formation (Avon Group) of the Carboniferous Limestone, with interbedded marine limestones and red-brown sandstones. Spores from 18 m below the top of the group at Tongwynlais are now regarded as earliest Famennian in age. Elsewhere, there is generally a depositional break between the uppermost beds of the group and the Carboniferous Limestone, but interdigitation of shallow marine beds occurs in Pembrokeshire, as seen at the West Angle Bay (North) and Freshwater East–Skrinkle Haven GCR sites.

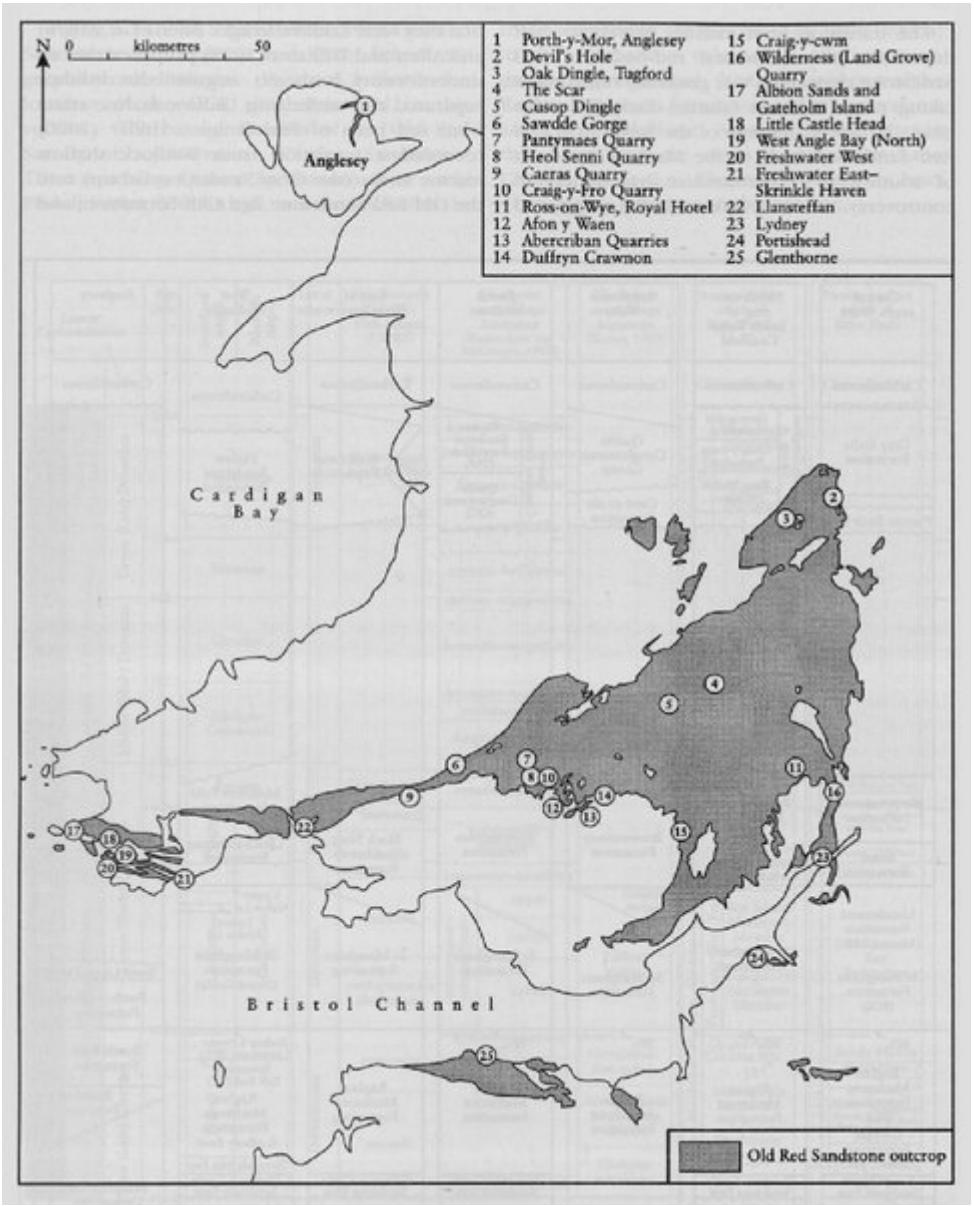
References



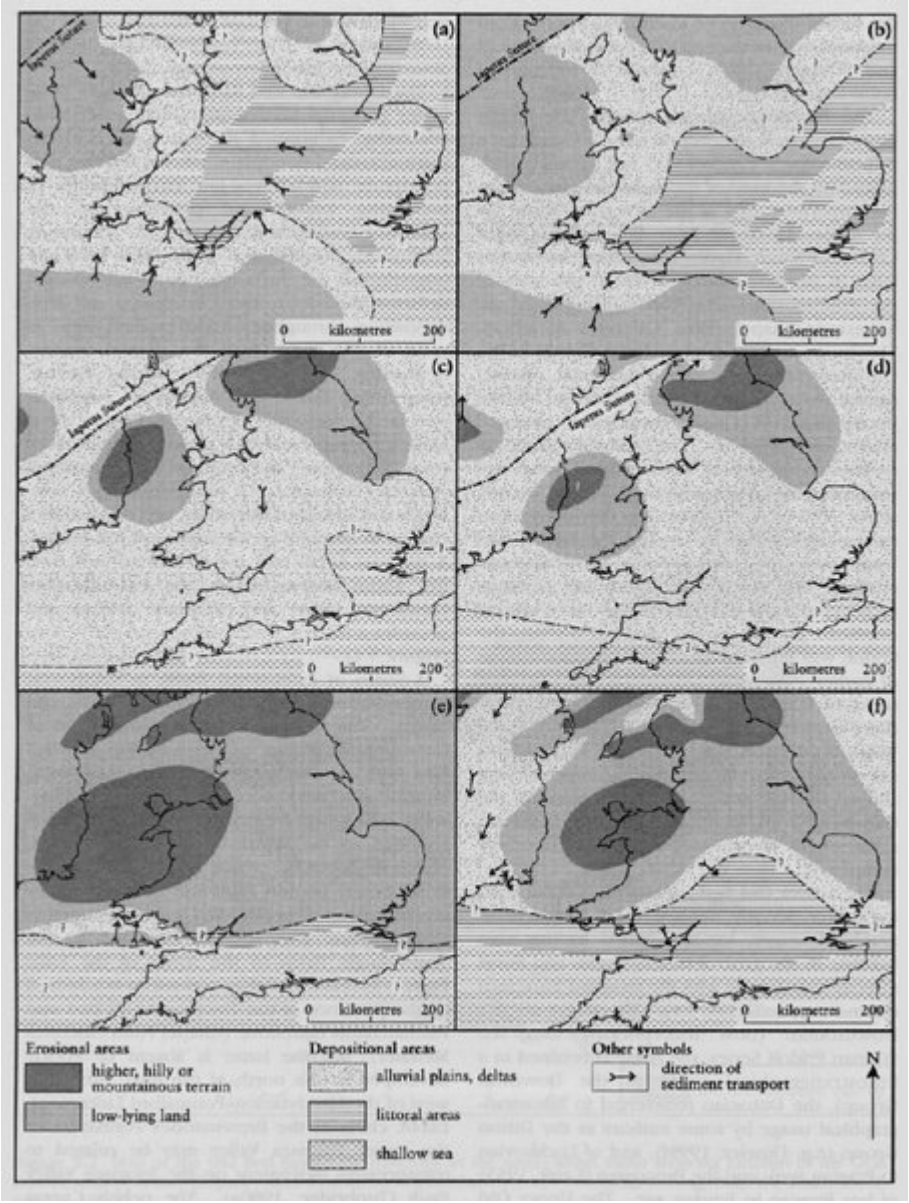
(Figure 1.3) Sketch maps showing the movements and amalgamation of the early Palaeozoic continents that produced the Old Red Sandstone (Laurussia) continent. (a) and (b) are global views to illustrate the fragmentation of Avalonia from Gondwana and its drift northwards as the Iapetus Ocean closed (adapted from Torsvik et al., 1992, by Trench and Torsvik, 1992). (c), (d) and (e) show the later stages of the Caledonian Orogeny. Sinistral strike-slip movements in relation to the Laurentian margin culminated in the Acadian Orogeny in late Early Devonian (Emsian) times (after Stephenson et al., 1999, adapted from Soper et al., 1992).



(Figure 5.1) Correlation of the successions and biostratigraphical classifications of the Old Red Sandstone in the Anglo-Welsh Basin. Ages in millions of years ago (Ma) are from Williams et al. (2000). Broken lines denote imprecisely located boundaries.



(Figure 5.2) Map of the Old Red Sandstone outcrops in the Anglo-Welsh Basin showing location of the GCR sites described in this chapter. After British Geological Survey 1:625 000 Solid Geology Map UK South Sheet, 4th edn (2001).



(Figure 5.3) Palaeogeographical evolution of the Anglo-Welsh Basin. (a) Earliest P■ídolí; (b) mid-P■ídolí; (c) Lochkovian; (d) late Pragian–early Emsian; (e) Givetian; (f) Frasnian–early Famennian. (a) and (b) after Bassett et al. (1992); (c)–(t) after Bluck et al. (1992).