The Permian red beds of Devon

Introduction

The Permian deposits in Devon occur in a number of sedimentary basins and are extensively exposed on the coast. A broad outcrop extends southwards from Somerset to Devon (Figure 2.1) and (Figure 2.31), and then under the English Channel (Figure 1.5). The Permian succession, dipping east at low angles, continues beneath the Triassic and Jurassic strata of east Devon and Dorset into the Wessex Basin, where it is detected in boreholes (Holloway, 1985a; Holloway *et al.,* 1989). The total thickness of the Devon Permo-Triassic red-bed succession is perhaps 2.75 km (Laming, 1965) but varies locally.

The stratigraphy of the Permo-Triassic red beds of Devon has proved immensely complex (Smith *et al.,* 1974, pp. 27–30; Warrington *et al.,* 1980). Datable fossils (fishes, amphibians, and reptiles) from the Otter Sandstone Formation in eastern Devon are Anisian (Mid Triassic) in age, and the underlying Budleigh Salterton Pebble Bed is generally accepted as Triassic, and is placed in the Lower Triassic Series (see Chapter 3). A lower limit on the age of the red-bed succession is provided by the fact that it rests unconformably upon clearly Carboniferous rocks up to Westphalian C in age (Laming, 1965). The succession of red beds from that level up to the basal Budleigh Salterton Pebble Beds was generally regarded as Permian in age.

Formal stratigraphical units for the Permian succession around Exeter were introduced by Bristow and Scrivener (1984), new palaeontological evidence for the age of some of the units was provided by Warrington and Scrivener (1988, 1990), and the information was formalized by Edwards *et al.* (1997) and Edwards and Scrivener (1999) in thorough revisions of the stratigraphy of the Permo-Triassic around Exeter, and in the Crediton Trough to the west (Figure 2.30). The Permian succession comprises most of the Exeter Group, an 800-m-thick sequence of breccias and subordinate sandstones and mudstones that may represent latest Carboniferous and Permian time, but which includes a major unconformity that may represent up to 20 million years of Permian time. The Cadbury Breccia in the Crediton Trough overlies the Carboniferous Bude Formation unconformably. It contains mostly locally derived Carboniferous clasts, with only rare fragments from the Devonian of north Devon. The Cadbury Breccia can be dated only as post-Westphalian, and may span the Permo-Carboniferous boundary or be entirely Early Permian in age.

The succeeding Bow Breccia rests unconformably on the Cadbury Breccia. It contains clasts of Carboniferous sandstone, as well as shale and hornfels and sporadic igneous rock fragments including quartz-porphyry; it is succeeded by the Knowle Sandstone in the western Crediton Trough, and is partly coeval with the Thorverton Sandstone in the eastern Crediton Trough. Around Exeter, the Permo-Triassic red-bed succession begins with a thin representative of the Knowle Sandstone. The Bow Breccia, and the Knowle and Thorverton sandstones are associated with thin lamprophyric and basaltic lavas which have been dated radiometrically and yielded ages in the range 291–282 Ma, hence placing these units low in the Lower Permian Series. The base of the Permian succession may be dated as about 298 Ma (Edwards *et al.,* 1997) or 291 Ma (Wardlaw, 2000).

After a long hiatus, the Knowle and Thorveton sandstones were succeeded by younger Permian sandstones and breccias (Figure 2.30). In the western Crediton Trough, mudstone units in the Creedy Park Sandstone and the Crediton and Newton St Cyres breccias have yielded miospores that indicate a Mid to Late Permian age. The Crediton Breccia interfingers with the Yellowford Formation, composed mainly of mudstones, in the eastern Crediton Trough, and these units are succeeded by the Shute Sandstone, which is probably equivalent in age to the Newton St Cyres Breccia, and is, in turn, succeeded by the Dawlish Sandstone Formation. Around Exeter, the basal Whipton Formation, equivalent in age to the Creedy Park Sandstone, has also yielded miospores that indicate a Mid to Late Permian age. It is succeeded by the Alphington Breccia, the Heavitree Breccia, the largely arenaceous Monkerton Formation, and a thin representative of the Dawlish Sandstone Formation. The latter has yielded invertebrate trace fossils and vertebrate tracks near Exeter; the vertebrate tracks are probably *Chelichnus,* which is essentially a Permian ichnogenus, and perhaps comparable to *Chelichnus* from the Hopeman Sandstone Formation of Morayshire (dated as latest Permian, Tatarian, in age; see above). The revision of the date of the Dawlish Sandstone Formation, and the underlying units, into the Mid to Late

Permian succession, came as a surprise since, hitherto, the aeolian Dawlish Sandstones had been equated with the presumed Early or Mid Permian Bridgnorth Sandstone and the Yellow Sands of central and northern England respectively.

Throughout the region, the Exeter Group is succeeded by the Aylesbeare Mudstone Group, 200–500 m largely of mudstones, divided into the Exmouth Mudstone and Sandstone Formation and the Littleham Mudstones Formation (Smith *et al,* 1974). The Aylesbeare Group was tentatively dated as Permian or Triassic in age by Smith *et al.* (1974) and Warrington *et al.* (1980), and as ?Early Triassic in age by Henson (1972, 1973), Edwards *et al.* (1997) and Edwards and Scrivener (1999). It lacks fossils and other evidence of age, and underlies the Budleigh Salterton Pebble Beds, which also lack direct age evidence, but are generally dated as Early Triassic. Here, the Aylesbeare Group is treated as spanning the Permo-Triassic boundary, and a GCR site is described in this chapter.

Sedimentological studies show that the pre-Dawlish Sandstone Formation units comprise deposits of alluvial fan systems that were active for long periods. Deep channels were incised into the pre-Permian uplands around the depositional basins, and breccias were deposited in wadi channels and in braided streams on top of the fans. The active basins were complex in shape, some, such as the Crediton Trough, being long and narrow, others broad (Figure 2.31). Palaeocurrent directions, assessed from imbrication patterns in the breccias, cross-stratification, and other evidence, show a broad range of downslope orientations. The clast types allow fan systems to be distinguished (Laming, 1966), but individual fan lobes cannot be mapped because of poor exposure. The evidence suggests rapid erosion and deposition in a semi-arid climate. Breccia deposits continued to accumulate at the basin margins, even when aeolian sands became dominant and, in places, breccias and sands interdigitate, for example at Roundham Head (see below).

Aeolian sandstone interbeds are scarce in the basal breccia units, but dominate the higher parts of the Devon Permian sequence. The Dawlish Sandstone Formation, up to 350 m thick, includes sandstones with large-scale cross-bedded sets; grainfall, grainflow, and pinstripe lamination are seen. These suggest deposition in transverse aeolian dunes superimposed on larger draa bedforms. Interbedded sandstones, pebbly sandstones, and mudstones indicate deposition in interdune areas. The dominant wind direction was towards the north-west.

The breccias of the Exeter Group largely document progressive erosion of the hinterland to the west and south-west. Whereas the oldest breccia, the Bow Breccia, contains almost exclusively locally derived fragments of the underlying Carboniferous sedimentary rocks, the later units show evidence of progressive erosion, into the Variscan massif, and igneous bodies intruded into it. The Crediton and Alphington breccias, for example, have a mixed clast assemblage, including Carboniferous slate and sandstone, rhyolite fragments, large clasts of quartz-porphyry, and tourmalinized slate and hornfels, suggesting erosion of the country rock and the aureole and roof zone of the Dartmoor Granite. The Newton St Cyres and Heavitree breccias contain abundant fragments of a variety of sanidine, formerly murchisonite, as well as clasts of Dartmoor Granite, which indicates that erosion had, by this time, reached the granite itself.

The Teignmouth–Oddicombe–Torquay area, to the south of Exeter, displays a corresponding Permian succession largely exposed along the coast (Laming, 1966, 1968, 1969; Smith *et al.,* 1974; Selwood *et al.,* 1984) (Figure 2.30). There are several seemingly separate basins, or cuvettes, from south to north, the Paignton, Marldon, and Teignhead cuvettes, into which breccias and coarse sands were transported from uplands to the west. In the Paignton Cuvette, the basal Tor Bay Breccia rests unconformably on Devonian rocks and fines upwards into the Livermead Beds. In the deepest part of the Teignhead Cuvette, fine slate breccias of the Watcombe Breccia, rest unconformably on Devonian limestones and slates and are succeeded by the Oddicombe Breccias, up to 350 m thick, which contain abundant cobbles and pebbles of Devonian limestones. In different parts of this basin, the Oddicombe Breccias are followed by the Netherton and Ness formations, up to 45 and 67 m thick respectively. The Ness Formation comprises interbedded breccias composed alternately of units dominated by limestone and slate clasts, and by sandstone and porphyry clasts. These are in turn followed by the Teignmouth Breccia, some 115 m thick, with sandstone and porphyry clasts.

The geology of the Permian succession of Devon has been described by Whitaker (1869), Ussher (1875, 1876, 1878, 1902, 1913), Irving (1888), Hull (1892), Ussher and Lloyd (1933), Scrivenor (1948), Laming (1965, 1966, 1968, 1969, 1982), Simpson (1969), Henson (1970, 1972), Perkins (1971), Edmonds *et al.* (1975), Durrance and Laming (1982), Scrivener (1983), Bristow and Scrivener (1984), Warrington and Scrivener (1988, 1990), Edwards *et al.* (1997), and

Edwards and Scrivener (1999).

Seven GCR sites have been selected to document the Permian red beds of Devon on the coast between Torbay and Exmouth (Figure 2.31), where the most consistent and extensive exposures are to be seen. The representative GCR sites selected are Shoalstone, Brixham (?Permian Neptunian dykes), Saltern Cove (Tor Bay Breccia), Roundham Head (Tor Bay Breccia), Oddicombe (Oddicombe Breccia), Coryton's Cove (Oddicombe and Teignmouth breccias, Dawlish Sandstone Formation), Dawlish (Dawlish Sandstone Formation), and Orcombe Rocks (Exmouth Mudstone and Sandstone Formation).

Shoalstone, Devon

Saltern Cove, Devon

Roundham Head, Devon

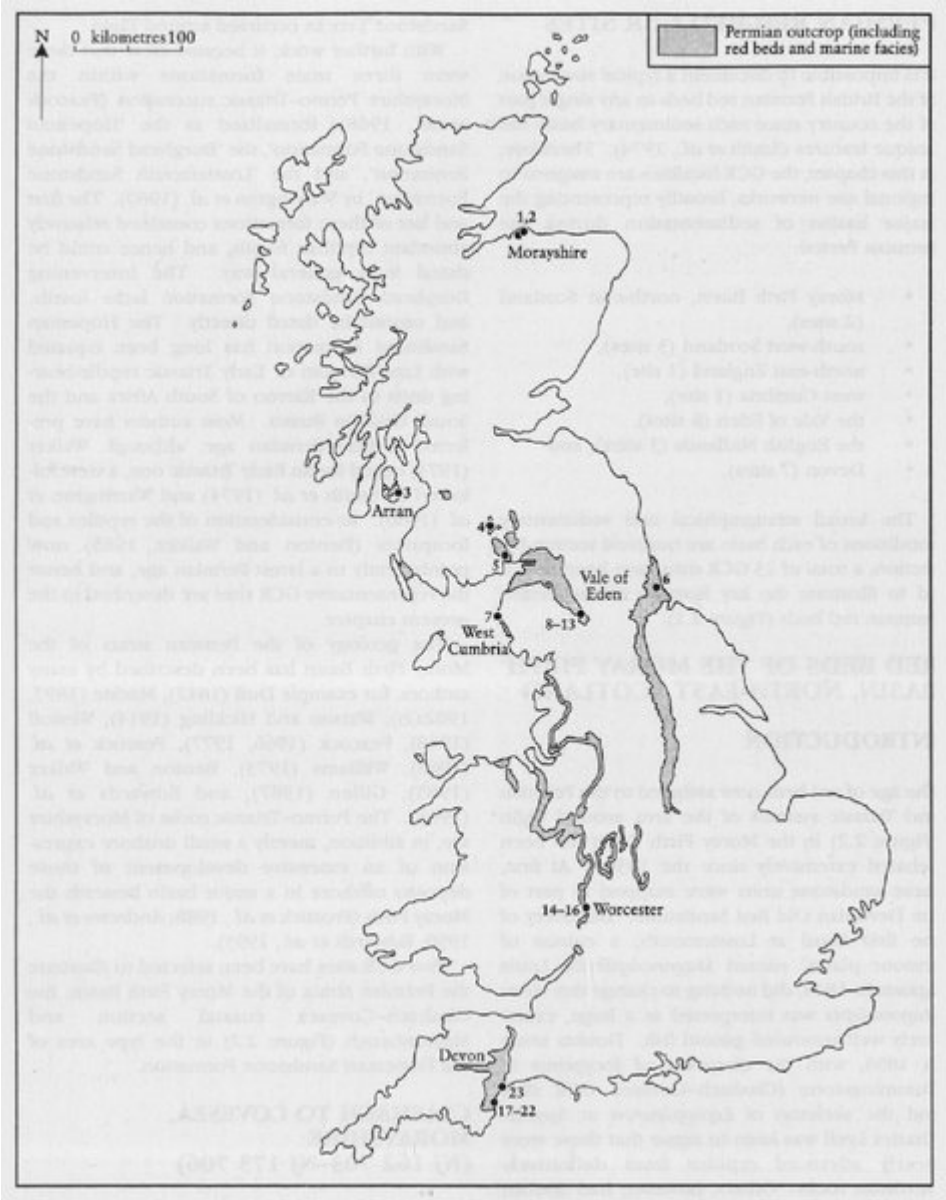
Oddicombe Beach, Devon

Coryton's Cove, Devon

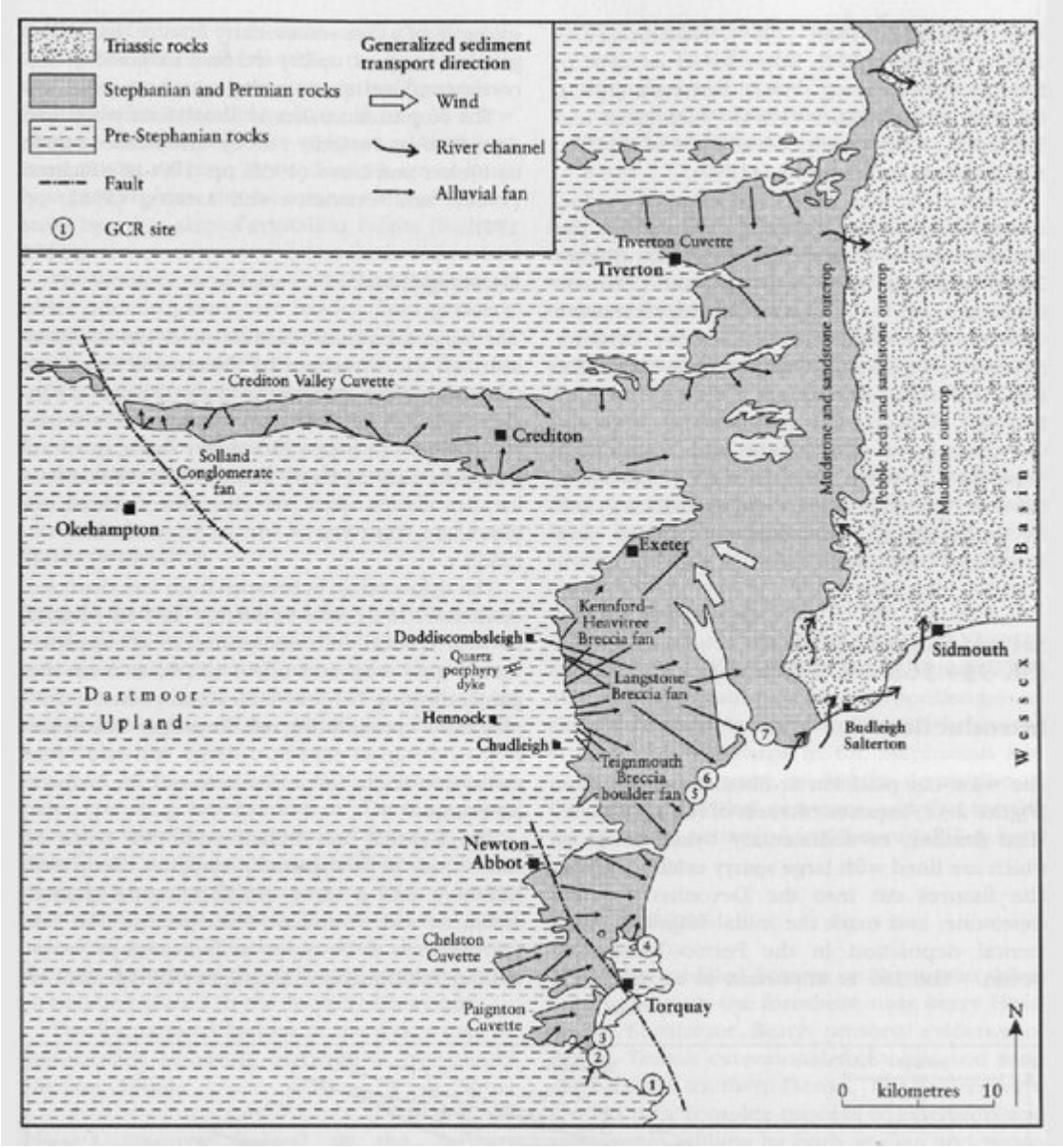
Dawlish, Devon

Orcombe Rocks, Devon

References

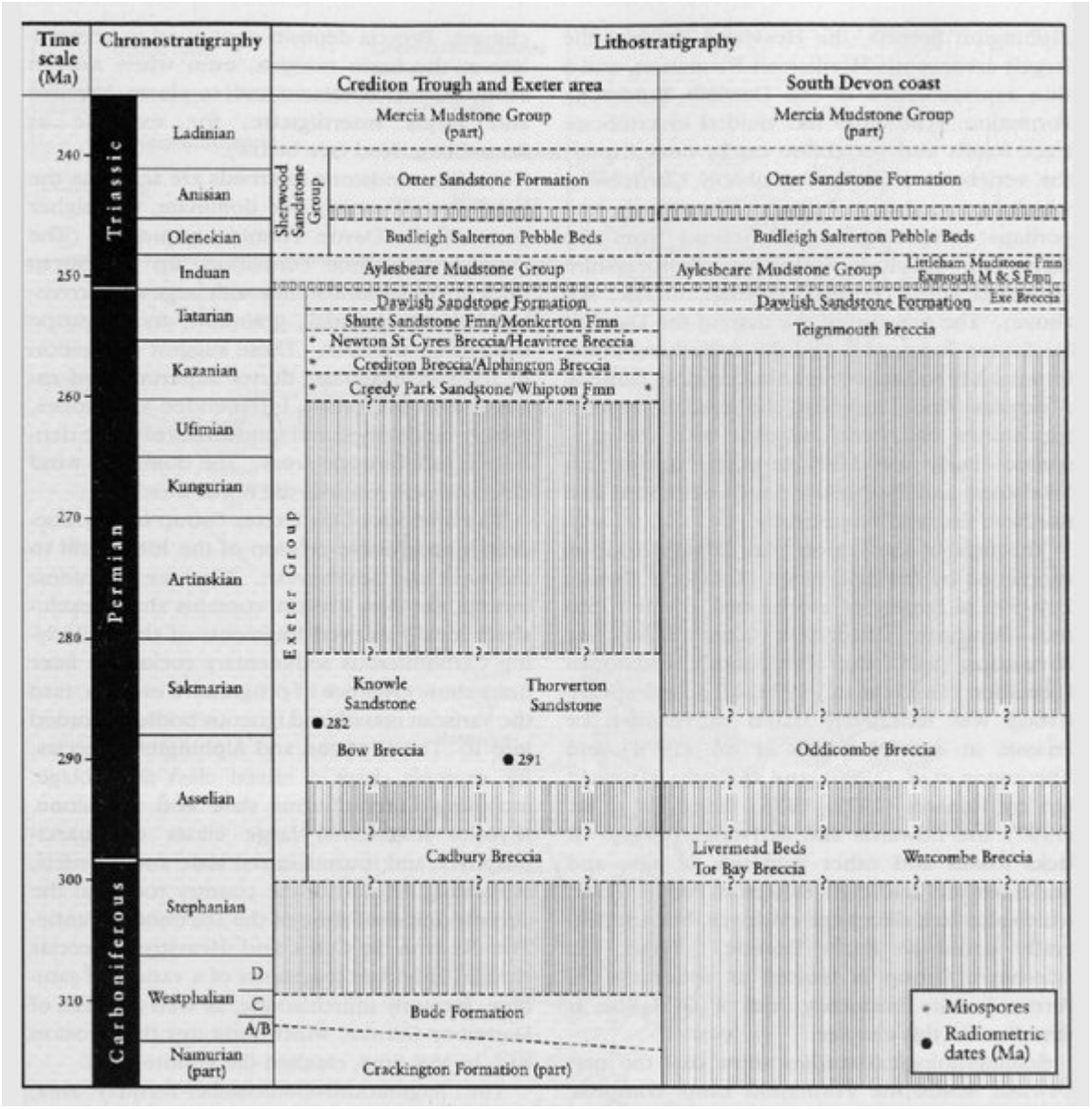


(Figure 2.1) Map showing the outcrop of Permian rocks in Great Britain. Some major basinal areas are indicated. GCR Permian red-bed sites are numbered as follows: (1) Clashach–Covesea; (2) Masonshaugh Quarries; (3) Corrie Shore; (4) Hapland Burn; (5) Locharbriggs North Quarry; (6) Crime Rigg Quarry; (7) Saltom Bay; (8) Burrells Quarry; (9) Cowraik Quarry; (10) George Gill; (11) Hilton Beck; (12) Stenkrith Beck; (13) River Belah; (14) Sling Common; (15) Osebury Rock; (16) Kinver Edge; (17) Shoalstone; (18) Saltern Cove; (19) Roundham Head; (20) Oddicombe Beach; (21) Coryton's Cove; (22) Dawlish; (23) Orcombe Rocks.



(Figure 2.31) Depositional basins and sediment transport trends in the Permian of Devon. GCR sites are: (1) Shoalstone; (2) Saltern Cove; (3) Roundham Head; (4) Oddicombe Beach; (5) Coryton's Cove; (6) Dawlish; (7) Orcombe Rocks. (After Laming, 1982.)

(Figure 1.5) The principal Permo-Triassic sedimentary basins and syndepositional normal faults in England. Intensity of stippling indicates sediment thicknesses. Abbreviations: CB, Cheshire Basin; CF, Clopton Fault system; DB, Dorset Basin; EMF, East Malvern Fault; IF, Inkberrow Fault; KB, Knowle Basin; LBB, Lyme Bay Basin; NB, Needwood Basin; PeB, Pewsey Basin; SB, Stafford Basin; SoB, Solway Basin; WaB, Wardour Basin; WB, Worcester Basin; WRRF, Wem-Red Rock Fault system.



(Figure 2.30) Stratigraphy of the Permian successions of the East and South Devon basins. Formal divisions for the Crediton Trough and Exeter area are from Edwards et al. (1997), and the successions around Torquay and Teignmouth are updated tentatively from Smith et al. (1974), Selwood et al. (1984), and Warrington and Scrivener (1990).