Orcombe Rocks, Devon

[SY 018 797]–[SY 023 795]

Introduction

The site is an excellent coastal section in the sandstones, siltstones, and mudstones of the Permo-Triassic Exmouth Mudstone and Sandstone Formation. The sandstones are fluvial in origin and show trough and planar-tabular cross-bedding, which indicate that the rivers that deposited these sediments flowed towards the north. The mudstones represent deposition in fluvial overbank (floodplain) and playa-lake environments, and contain sporadic plant fossils. This is an important site for the elucidation of Permo-Triassic palaeoenvironments in the south of England.

The Exmouth Mudstone and Sandstone Formation has been described by Irving (1888), Ussher (1902, 1913), Carus Wilson (1913), Laming (1966, 1982), Henson (1970, 1972, 1973), Smith *et al.* (1974), Bristow and Scrivener (1984), Selwood *et al.* (1984), Mader and Laming (1985), Clemmensen *et al.* (1994), Edwards *et al.* (1997), and Edwards and Scrivener (1999). Harrison (1975) documented the geochemistry of the concretions found within the argillaceous and arenaceous sediments exposed around Orcombe Point.

Description

Orcombe Rocks form part of the Exe Estuary Site of Special Scientific Interest (SSSI) and part of the Dorset and East Devon Coast World Heritage site (established December, 2001).

The Permo-Triassic sediments are faulted and comprise mudstones, with thick interbedded sandstones. Most of the faults follow the line of strike (Harrison, 1975; Selwood *et al.,* 1984, pp. 104–5).

The cliffs and foreshore expose the Exmouth Mudstone and Sandstone Formation of the Aylesbeare Mudstone Group (Figure 2.42). The upper formation of the Group, the Littleham Mudstone, crops out to the east between Littleham Cove and Budleigh Salterton. These formations, which are equivalent to the former 'Lower Marls' (Ussher, 1875, 1876, 1913) were established by Laming (1966, 1968) and Henson (1970) and were united in the Aylesbeare Mudstone Group, introduced by Smith *et al.* (1974, pp. 38–9). Henson (1972, 1973) referred to the 'Exmouth Sandstones and Mudstones' and the 'Littleham Mudstones', and these were formalized as the Exmouth Sandstone and Mudstone Formation and the Littleham Mudstone Formation by Warrington *et al.* (1980, p. 43). The more inclusive unit term was transmogrified into the Aylesbeare Mudstone Formation by Bristow and Scrivener (1984) and Warrington and Scrivener (1990), and the two constituent subunits became members. These units were restored to higher rank by Edwards *et al.* (1997) who refer to the Aylesbeare Mudstone Group' (Figure 2.30), equivalent in rank to the underlying Exeter Group (essentially all the Devon Permian strata), and the overlying Sherwood Sandstone, Mercia Mudstone, and Penarth groups of the Triassic succession (see Chapter 3).

Sedimentology

The Exmouth Mudstone and Sandstone Formation at Orcombe consists of some 255 m of red and green sandstones interbedded with structureless reddish siltstone and blocky mudstones (Figure 2.42). This unit succeeds the Dawlish Sandstone Formation or the Exe Breccia unconformably (Selwood *et al.,* 1984; Edwards *et al.,* 1997). The mudstones are dark red and have a blocky texture; in the past, they were described as 'marls', although the carbonate content is too low for this term to apply. The sandstones typically infill large channels cut into the interbedded thin sandstones and mudstones, and may be laterally extensive over distances of approximately 200 m. They form discrete lenses that overlie scoured surfaces and preserve evidence of internal planar and trough cross-bedding; the foresets are generally concave-up and gently curving. Mudstone lenses are common throughout the sandstone bodies, and the sandstone may be interbedded with siltstone lenses. The sandstones associated with the siltstones are frequently pale green in colour, and may be mottled (Laming, 1966, 1982; Henson, 1970).

Three distinct sedimentary facies have been distinguished in the Exmouth Mudstone and Sandstone Formation (Henson, 1970).

1. Poorly sorted, locally impersistent, green sandstone beds, 0.15 to 1.0 m thick, interbedded with mudstones. Sedimentary structures include small-scale cross-bedding and small channels cut into the underlying sediments.
2. Red and green, cross-bedded sandstones with mudstone lenses, arranged in fining-upwards sequences, with trough and planar cross-bedding, and a few intraformational mud-pellet conglomerates. The lenses are between 1.25 and 3.0 m thick, and generally rest on erosion surfaces cut into the underlying silts.
3. Red and green sandstone beds, with mudstone beds and lenses. Large- and small-scale cross-bedding structures and fining-upwards sequences are common (Figure 2.43). Thicker units may display sun cracks and bioturbation. The clay lenses have well-developed small-scale cross-bedding and pipes and burrows infilled with sandstone.

A more detailed sequence of facies divisions has been outlined by Mader and Laming (1985), who divided the formation into lower, middle, and upper parts. The middle and upper parts are further divided into five and four units respectively. These authors note channels, sheet floods, some development of sand dunes, and limited pedogenesis in the upper units.

At Orcombe Point, bleached sandstone beds are present, with grey-green sandstone dykes radiating from them and penetrating the underlying reddish-brown marls to a depth of 0.1 to 0.2 m. The bleaching is associated with malachite (Carus-Wilson, 1913). Clay minerals in the sandstones include kaolinite, swelling chlorite, and mixed-layer illite. Euhedral calcite crystals, rare dolomite, and possible gypsum crystals have also been noted (Henson, 1973).

Palaeontology

A few poorly preserved plant fossils have been reported from the argillaceous overbank and playa-lake sediments and from a rubbly unit at the base of a sandstone bed (Laming, 1966, p. 955, 1982; Selwood *et al.,* 1984). A well-preserved assemblage of reworked Devonian and lower Carboniferous plant microfossils, for example *Densoisporites, Dictyotriletes, Savitrisporites,* and *Hymenozonotriletes,* has been recovered from a horizon within the Exmouth Mudstone and Sandstone Formation (Warrington, 1971; Owens, 1972; Selwood *et al.,* 1984).

Trace fossils have also been described from sandstone and siltstone bedding surfaces in the formation at Orcombe Point (Laming, 1966; Selwood *et al.,* 1984; Mader, 1985, pp. 23–5). These include horizontal and vertical burrows. The horizontal burrows are slightly sinuous tubes, 5 to 20 mm wide and 30 to 300 mm long, with meniscus fill, and may form densely packed, complex cross-cutting structures that thoroughly rework the sediment. Vertical tubes reach depths of 10 mm and may be up to 20 mm wide; they are either isolated or tightly packed, and are filled with massive medium- to coarse-grained sand. Less distinct bioturbation traces are also visible in mudstone units in the Aylesbeare Mudstone Group formations.

Interpretation

The Exmouth Mudstone and Sandstone Formation was interpreted as representing predominately fluvial sedimentation in low-sinuosity braided streams in a semi-arid climate (Laming, 1968; Henson, 1970, 1973; Selwood *et al.*, 1984).

The first facies association (see above) with poorly sorted, greenish, laterally discontinuous sandstone beds, was interpreted as overbank deposits with evidence of crevasse splays and the gradual accumulation of fine-grained material. The red and green, cross-bedded sandstones of the second and third facies were interpreted as being deposited in river channels, probably on large-scale point bars. The mudstones, common throughout much of the sequence, represent low-energy sediment accumulation, possibly in pools, or deposition on the interfluve areas of the floodplain during the falling stage of floods (Laming, 1966).

Mader and Laming's (1985) three divisions of the formation reflect changing environments of deposition The lower part is interpreted as part of an alluvial fan complex, with sediments deposited in floodplain and playa-lake environments. The middle part represents a change from fluvial braidplain to fluvial braidplain and playa-lake conditions, characterized by

channel and sheetflood processes and limited pedogenesis. The upper part sees a return to fluvial braid-plain conditions, with channels and sheet floods, and with sand dunes that are aeolian in origin but which previously had been interpreted as fluvial. The overlying Littleham Mudstone Formation reflects a return to fluvial plain and playa-lake environments, indicating that sedimentation was cyclical.

The bleached sandstones and sedimentary dykes were probably discoloured by oxidation of malachite and vanadium minerals. Where vanadium minerals are concentrated, small halos of paler bleached sediment occur, the bleaching resulting from a change in the oxidation state of iron minerals within the sediment, from ferric to ferrous oxides (Carus-Wilson, 1913; Harrison, 1975). Laming (1966, p. 955) suggested that the malachite might have been a weathering product of diagenetic copper mineralization, probably chalcocite, nucleated around plant debris.

The proportions of clay minerals in the mudstones of the Exmouth Mudstone and Sandstone Formation confirm that the environment of deposition was fluvial and thus corroborate the sedimentological interpretation. The euhedral calcite crystals, rare dolomite, and possible gypsum crystals suggest that evaporation of ephemeral lakes and ponds took place, forming bodies of hypersaline water (Henson, 1973).

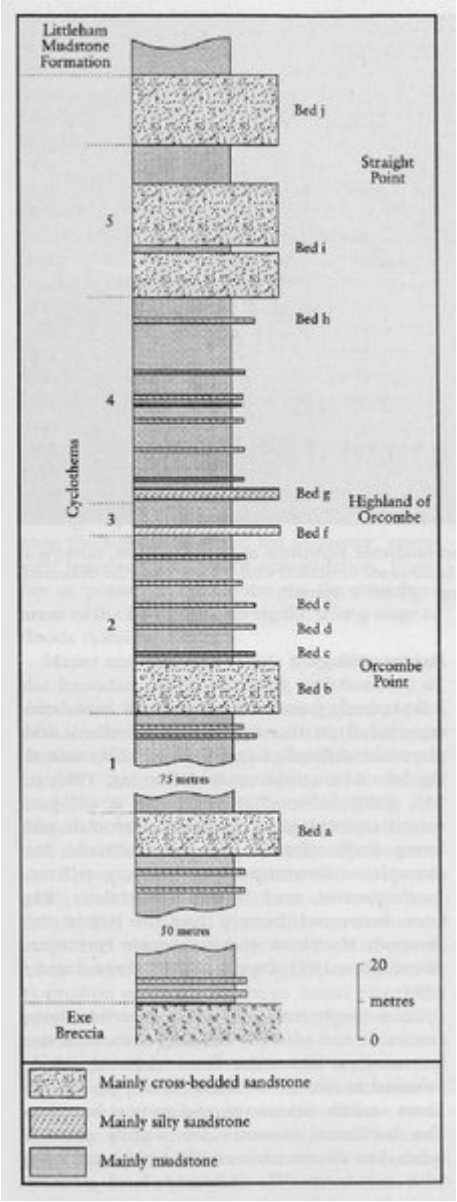
The poorly preserved, sporadic plant fossils offer little information, other than to confirm that the sediments include terrestrial elements. The burrows appear to have been produced by invertebrates rather than amphibians or reptiles, in contrast with much larger meniscate burrows at Saltern Cove (see GCR site report, this volume). They were classified as dwelling structures by Henson (1970), but they occur so densely in the fluvial sandstones (Mader, 1985, p. 23) that they are more likely to be feeding traces of animals churning the river-bed sediments as they consumed organic debris.

The Aylesbeare Mudstone Group may be entirely Permian in age (Laming, 1968, 1982), or it may span the Permo-Triassic boundary (Smith *et al.,* 1974; Warrington *et al.,* 1980), or be entirely Early Triassic in age (Edwards *et al.,* 1997; Edwards and Scrivener, 1999); there is no evidence yet to confirm which of these views is correct. Its age is poorly constrained by the position between Late Permian Exeter Group below (Figure 2.30) and by the possibly Early Triassic Budleigh Salterton Pebble Beds above.

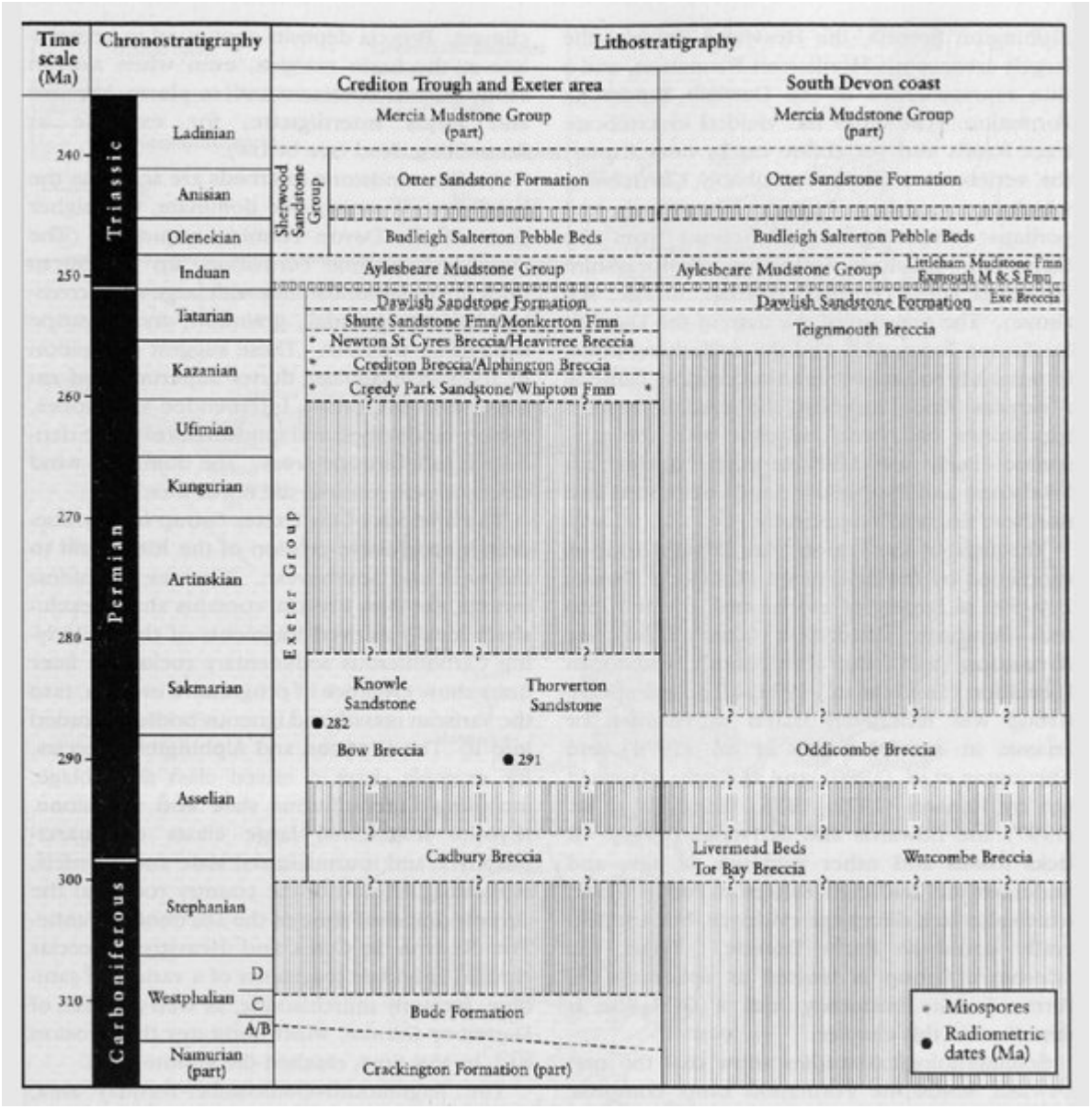
Conclusions

The Permo-Triassic sediments exposed at Orcombe Rocks show evidence for deposition in a range of fluvial and playa-lake environments. The section consists of a thick sequence of red and greenish-grey sandstones and siltstones with mudstones. The thick beds of coarser-grained sediments represent channel deposits such as bars, or, in some cases, aeolian dunes; the thinly bedded sandstones and mudstones accumulated in overbank areas and in playa lakes. This is a key site for understanding the palaeogeography of south-west Britain around the time of the Permian–Triassic transition.

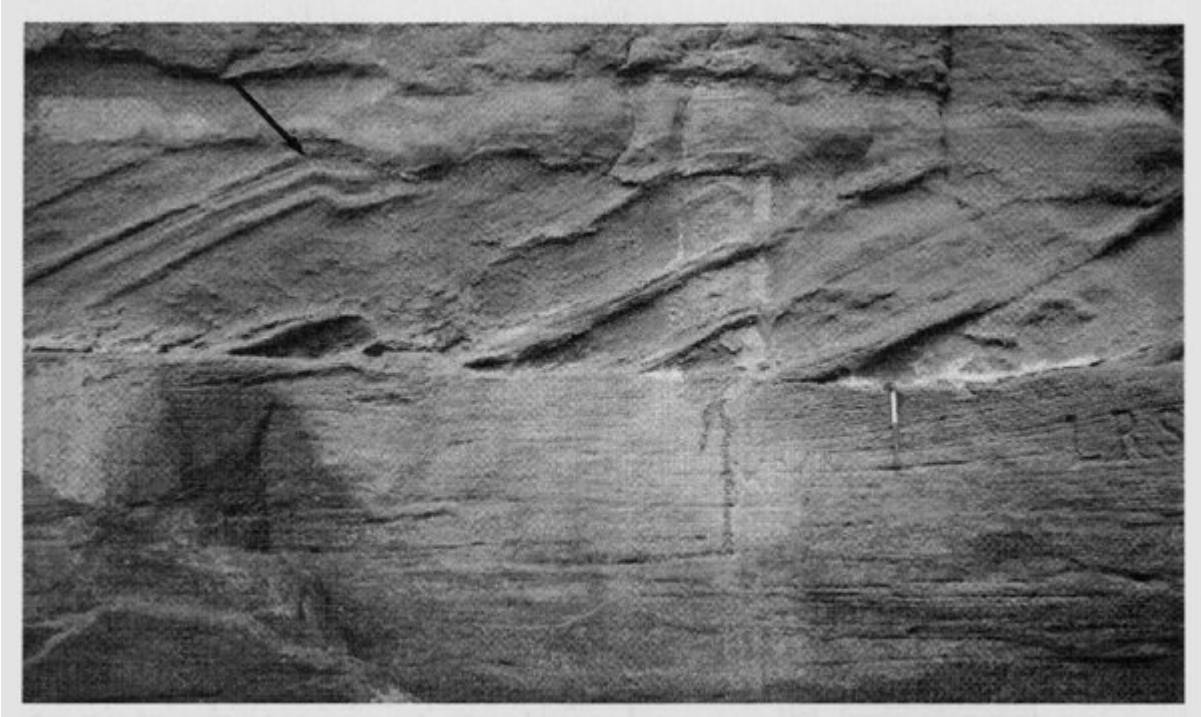
References



(Figure 2.42) Summary log through the Exmouth Mudstone and Sandstone Formation in the coast section between Orcombe Point and Straight Point, east of Exmouth. (From Selwood et al., 1984.)



(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).



(Figure 2.43) Sandstones of the Exmouth Mudstone and Sandstone Formation at Orcombe Point, showing a transition from planar to tabular cross beds. Prominent laminae are cemented with calcite. Note the deformed foresets, upper left (arrowed). The hammer is 0.3 m long. (Photo: P. Turner.)