Glenthorne, Devon

[SS 795 499]–[SS 805 495]

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Introduction

The coastal outcrops at Glenthorne (Figure 5.76), which extend from Giant's Rib [SS 795 499] to The Caves [SS 805 495], provide the most representative section of the Hangman Sandstone Formation (*sensu* Edwards, 1999), the only substantial continental deposit of northerly derivation and proved Mid-Devonian age in southern Britain. The site is nationally important because it provides evidence of the southerly progradation of continental facies into the mainly marine area of north Devon and west Somerset when most of the Wales-Brabant Massif to the north was being eroded. It includes abundant examples of unconfined sheet-flood sandstones, which have not been widely recognized elsewhere in the Old Red Sandstone of Britain until recently.

Description

The Hangman Sandstone Formation conformably overlies the shallow marine Lynton Formation (Simpson, 1964; Evans, 1983; Edmonds *et al.,* 1985) and is succeeded by the fully marine Ilfracombe Slates (Holwill, 1962; Edmonds *et al.,* 1985). Although largely unfossiliferous (see summary by Edwards, 1999), it is believed to be of mid-Eifelian age (Goldring *et al.,* 1978; Edmonds *et al.,* 1985), perhaps extending into early Givetian times (Evans, 1922; Knight, 1990; Edwards, 1999). A formal lithostratigraphical subdivision of the Hangman Sandstone proposed by Tunbridge (1978) broadly follows that of earlier workers (e.g. Lane, 1965), but the units are difficult to trace inland away from the well-exposed coast. The modified classification proposed by Edwards (1999) is therefore adopted in the following account. Estimates of the thickness of the Hangman Sandstone Formation vary considerably, principally because of structural complexities (Evans, 1922), ranging between 1097 m and 1658 m (Lane, 1965; Tunbridge, 1980b, 1981b, 1984, 1986). The Trentishoe Member makes up most of the formation (perhaps over 80%) and forms the entire section at Glenthorne. Its sedimentology has been studied in some detail, the most important contributions being by Tunbridge (1978, 1980b, 1981b, 1983a, 1984), Jones (1995) and Edwards (1999). The source of the sediments was discussed by Tunbridge (1983b, 1986) and Cope and Bassett (1987), and the nature of the upper and lower boundaries of the formation were described by Webby (1965a, 1966a) and Tunbridge (1983a). Descriptions of the sections at Glenthorne and nearby exposures were given by Tunbridge (1978), Jones (1995) and Edwards (1996, 1999). Details of the sequences preserved in the nearby inliers forming the Brendon Hills and Quantock Hills were given by Webby (1965b, 1966b).

Glenthorne is situated in a complex structural zone on the northern limb of the Lynton Anticline (Shearman, 1967; Sanderson and Dearman, 1973; Edwards, 1999). The exposed sequence is intensely folded and cut by numerous sub-vertical faults striking north-west or ENE. Most of the folds are open, plunge to the north-east and ENE at 10° to 30° and have axial surfaces dipping about 40° to the south-east. Locally, an axial planar fracture cleavage is developed in the more argillaceous units, and some of the sandstones are affected by bedding-parallel shear. Because of the structural complexity, it is not possible to examine a continuous sequence through the Trentishoe Member at the site, or to assess major vertical facies variations. However, the locality exposes the most important constituent facies of the unit (Tunbridge, 1984; Jones, 1995; Edwards, 1999) (Figure 5.77). Estimates of the abundance of each of these facies in the Minehead district by Jones (1995) appear to be representative of the sequence exposed at Glenthorne and are quoted below.

About 75% of the succession at Glenthorne comprises a variable suite of grey, purple and red, fine- to medium-grained, metre-scale beds of well-sorted, hard, lithic, quartzose sandstones and subordinate siltstones (Tunbridge, 1986; Strong, 1995). Approximately 40% of the succession consists of distinctive sheet-like sandstones, in which two facies are distinguished by differences in sandstone thickness (Tunbridge, 1984; Jones, 1995; Edwards, 1999). The thicker sheet sandstones (facies 4 of Edwards, 1999) form laterally persistent, 0.1–1.0 m-thick beds that are traceable over tens of metres with no obvious thinning. They have sharp, planar bases that rest on erosion surfaces and locally contain intraformational mudstone and siltstone clasts. Internally, they are dominated by low-angle planar or trough cross-bedding that commonly passes up into cross-lamination. Current- and wave-ripple sets occur in the topmost parts of some of the beds, and convolute lamination, climbing ripples and primary current lineation occur locally. In places, these thick sheet sandstones are stacked to form composite units, particularly good examples of which are exposed at Giant's Rib and Yellow Hammer Rock (Figure 5.78), and in the cliffs between the eastern end of Glenthorne Beach and The Caves.

The thinner sheet sandstone facies (facies 5 of Edwards, 1999) consists of laminae and thin beds (up to 0.1 m thick) of very fine- to fine-grained sandstone with sharp bases not characterized by erosion surfaces. Most of these sheets persist laterally for only a few metres. Many of them exhibit unidirectional cross-lamination and a fining-upward trend, or more rarely, wave ripple cross-lamination. Typically, this facies is interbedded with mudstones containing abundant desiccation cracks. It is best exposed on the foreshore at the base of the cliff approximately midway between Giant's Rib and Yellow Hammer Rock.

Facies	**Main characters**	**Interpretation**
Single-storey channel sandstone	erosion surface-based sandbodies, up to 3.5 metres thick	high-energy river channels
Multi-storey channel sandstone	erosively based, vertically stacked sandbodies, up to 12 metres thick	high-energy river channels
Laterally accreted channel sandstone	erosively based sandbodies, up to 1 metre thick	low-energy minor river channels
Thick sheet sandstone	sharp or erosively based beds of sandstone in laterally persistent sheets, up to 1 metre thick	high-energy sheet-floods deposited on subaerial mudflats
Thin sheet sandstone	laminae to thin beds of sandstone up to 0.1 metres thick, typically interbedded with facies 7	distal or weak sheet-floods deposited into lakes; later modification by emergence and desiccation
Massive to laminated mudstone	mudstones in beds up to 2 metres thick; local carbonate nodules	deposition from suspension in perennial lakes
Desiccated and remobilized mudstone	mudstones, with common desiccation cracks; typically interbedded with facies 5; abundant bioturbation and local carbonate nodules	deposition from suspension in ephemeral lakes; emergence caused drying of sediment surface; folded and convoluted laminae caused by water escape
Mudstone with extraformational pebbles	mudstones with scattered quartz pebbles	cohesive, subaerial debris flows

Interbedded with the sheet sandstone facies, or separated from them by thin mudstone- and siltstone-dominated units, are single-storey, channelized sandstones, each up to 3.5 m thick (facies 1 of Edwards, 1999). Most of these sandstones rest on erosion surfaces and their bases are commonly marked by laterally impersistent intraformational conglomerates. Internally, they are dominated by low-angle, unidirectional, planar or trough cross-bedding, and their upper surfaces are generally sharp and locally preserve asymmetrical ripple forms. Convolute bedding is also common and thin mudstone beds are present locally. This facies comprises approximately 20% of the sequence and is best exposed on the eastern side of Yellow Hammer Rock just above a modern storm beach ridge (Figure 5.78), (Figure 5.79). At several points, the channelized sandstones are stacked to form composite, multi-storey units (facies 2 of Edwards, 1999). These comprise approximately 15% of the succession and some are over 5 m thick. Some e.g. [SS 7963 4980] display convolute bedding and de-watering pipes.

In addition to the sandstone facies described above, Tunbridge (1984, fig. 17b) logged a 1.75 m-thick laterally accreted channel sandstone at the site (facies 3 of Edwards, 1999). Such sandstones are volumetrically unimportant at Glenthorne and only form about 1% of the sequence in the Minehead district. All of the sandstone facies show a consistent southerly palaeocurrent flow.

Interbedded with the sandstone facies, in units generally 0.1–2.5 m thick, are two finer-grained, mudstone-dominated facies. The first (facies 6 of Edwards, 1999) comprises approximately 9% of the succession and consists of red, purple and grey-green mudstones, silty mudstones and siltstones, some in interbeds mainly less than 5 cm thick. Some siltstones are internally cross-laminated. The mudstones are massive or laminated, and some contain simple, vertical burrows. The second facies (facies 7 of Edwards, 1999) comprises about 15% of the sequence and is characterized by an abundance of desiccation and remobilization structures. These include folds, diapirs, pipes, upcurled mudstone laminae and sand-filled desiccation cracks up to 6 cm deep, many of which penetrate multiple laminae.

Locally, these structures are so common that the sediment appears comprehensively brecciated or even homogenized. Sand- and mud-filled burrows, probably attributable to *Beaconites* and *Planolites,* are also common at certain levels.

Two other fine-grained facies (mudstones with pedogenic calcretes and mudstones with extraformational pebbles; Jones, 1995; Edwards, 1999) together comprise less than 2% of the succession in the Minehead district and are not important in the Glenthorne section.

Interpretation

The Mid-Devonian Epoch was marked across much of southern Britain by an episode of uplift and erosion corresponding to the final (Acadian) stage of the Caledonian Orogeny. Only in the predominantly marine basin of south-west England did sedimentation continue uninterrupted from Early Devonian up into Mid-and Late Devonian times (Dineley, 1999g). North Devon and west Somerset occupied a position between the mainly continental upland area of the Wales–Brabant Massif to the north and the wave-dominated shoreline to the south (Webby, 1965a, 1966a; Edmonds *et al.,* 1975). Shifts in the position of the shoreline in response to fluctuations in sea level (House, 1975) are recorded by the alternation of shallow marine and terrestrial facies. The Hangman Sandstone Formation is dominated by the terrestrial Trentishoe and Rawn s members, but includes important shallow marine units at its base (the Hollowbrook Member of Tunbridge, 1983a) and top (the Sherrycombe and Little Hangman members; Goldring *et al.,* 1978; Edmonds *et al.,* 1985).

The Trentishoe Member prograded over a low-lying coastal plain on the northern margin of the Rheic Ocean (Evans, 1922) from a source to the north during a period of eustatic sea-level rise (Tunbridge, 1983a, 1986), the sediment supply keeping pace with rising sea level. The source of the sediment has been the subject of debate. Petrographic and heavy-mineral analyses show a close, but not identical match with the Lower Devonian Brownstones Formation of south Wales and the Welsh Borderlands. This unit, having then been recently deposited, is likely to have been poorly consolidated and particularly susceptible to rapid erosion during Acadian uplift (Tunbridge, 1984). However, garnet, which is the dominant heavy mineral in the Brownstones Formation, is rare and generally highly etched in the Trentishoe Member. This led investigators todiscount south Wales as the source of the Trentishoe Member in favour of a landmass, either in the Bristol Channel area (Dewey, 1982) or in some other, as yet, unidentified lateral source (Hallam, 1934). The rarity of garnet in the Trentishoe Member has been interpreted more recently as a diagenetic phenomenon and the Brownstones Formation has been re-instated as the most likely source (Tunbridge, 1981b, 1984, 1986; Edwards, 1999), which is entirely consistent with the palaeocurrent evidence. In marked contrast, the overlying Rawn's Member consists of much coarser and more immature facies, including abundant conglomerates, that contain exotic, angular clasts which do not match any possible source rocks in south Wales. It records a dramatic switch in sediment source and is widely believed to have been derived from the intermittently exposed Bristol Channel landmass (Tunbridge, 1984; Cope and Bassett, 1987).

Tunbridge (1984), following Evans (1922), but contrary to Holwill *et al.* (1969), interpreted the Trentishoe Member as an extensive sandy ephemeral stream and clay playa complex. Three facies associations represent a down-slope transition from a system of low sinuosity channels, through an ephemeral flood complex, into a playa lake. The proximal sequence is represented by the multi-storey channelized sandstone facies which were deposited by a network of small, sandy, low-sinuosity, ephemeral streams, each channel being cut and filled during a single flood event, resulting in avulsion and the incision of new courses. The medial facies association is represented by cyclical, upward-coarsening units several metres thick containing the sheet sandstone facies. These thicken and coarsen upwards, some stacking into multiple bodies and some being incised and cut out by erosion surfaces underlying channelized sandstones. Tunbridge (1981b, 1984) proposed that the dimensions of these sheet sandstones and the abundance of parallel lamination are consistent with deposition from unconfined flood waters fed by ephemeral streams during peak flood periods, with the cyclicity being a response to progradation of lobes during consecutive floods. The distal facies association comprises mainly the desiccated mudstone and sandstone facies, but also contains rare thin sheet sandstones. It represents the final stage in the down-slope decline in flow velocity and the main site of muddy flood deposition.

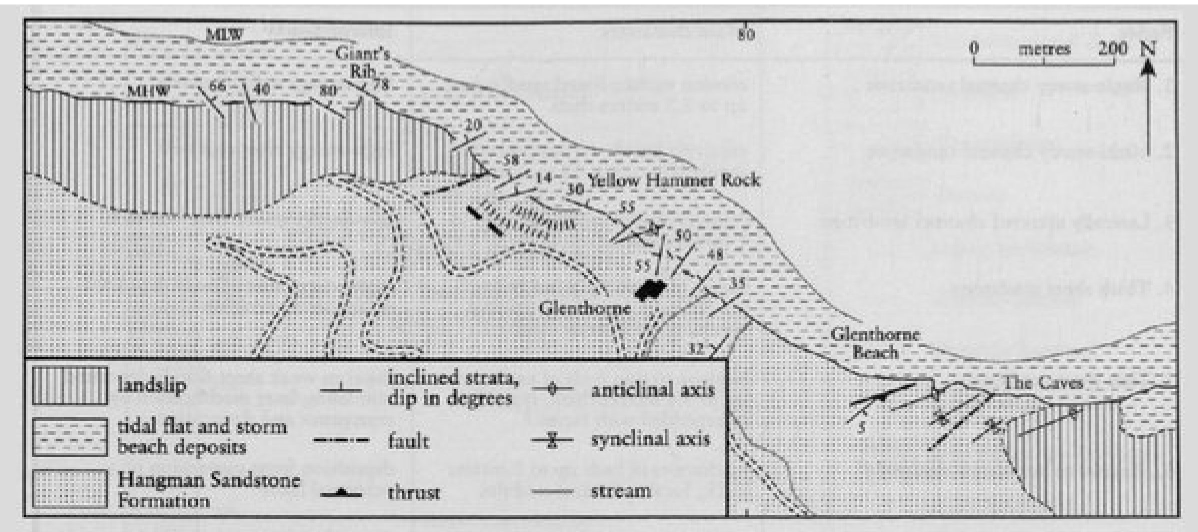
Jones (1995) and Edwards (1999) supported Tunbridge's (1981b, 1984) tripartite division of the facies, but suggested that it does not necessarily reflect down-slope changes. Instead, they proposed that it may be due to variations in channel flux, fan retrogradation, and/or lateral shifts in fan position. Consequently, they interpreted the entire sequence as having been deposited on the distal part of an alluvial-fan complex, with periodic development of ephemeral mudflats. This, they suggested, is more consistent with the relative abundance of both sheet and channel sandstones, which imply continual proximity to a sediment source. In this model, periods of high and frequent discharge resulted in the formation of sandflats, whereas mudflat–playa-lake environments formed during periods of low discharge. Ephemeral lakes may also have formed after sheet flooding.

Tunbridge (1984) recognized some problems with his model and conceded that the presence of a sandy coastline to the south (Tunbridge, 1983a) showed that not all of the sands could have been deposited inland of the clay playas. Similarly, he recognized that his most distal facies could represent periods of greater aridity, or may have been deposited within local depressions (cf. Jones, 1995; Edwards, 1999).

Conclusions

The cliffs at Glenthorne Beach provide excellent exposures of the only substantial Middle Devonian Old Red Sandstone facies development in southern Britain — the Trentishoe Member of the Hangman Sandstone Formation. Although the section is intensely folded and faulted, it affords an excellent opportunity to examine representative examples of the most important constituent lithologies of the member, one of which (sheet-flood sandstone) is poorly represented elsewhere in the Old Red Sandstone. The site is of national importance because of the evidence that it provides of the southerly advance of continental Old Red Sandstone facies into the mainly marine area of north Devon and west Somerset at a time when the rest of the Anglo-Welsh Basin to the north was undergoing erosion. This has important implications for the palaeogeography of the basin, and for the relationship between sea-level changes and the rates of source erosion and sediment transport during Mid-Devonian times.

References



(Figure 5.76) Geological map of the Glenthorne area, north Devon. Based on British Geological Survey 1:10 560 Sheet SS 74NE (1983) and 1:10 000 manuscript map 84NW (1993).

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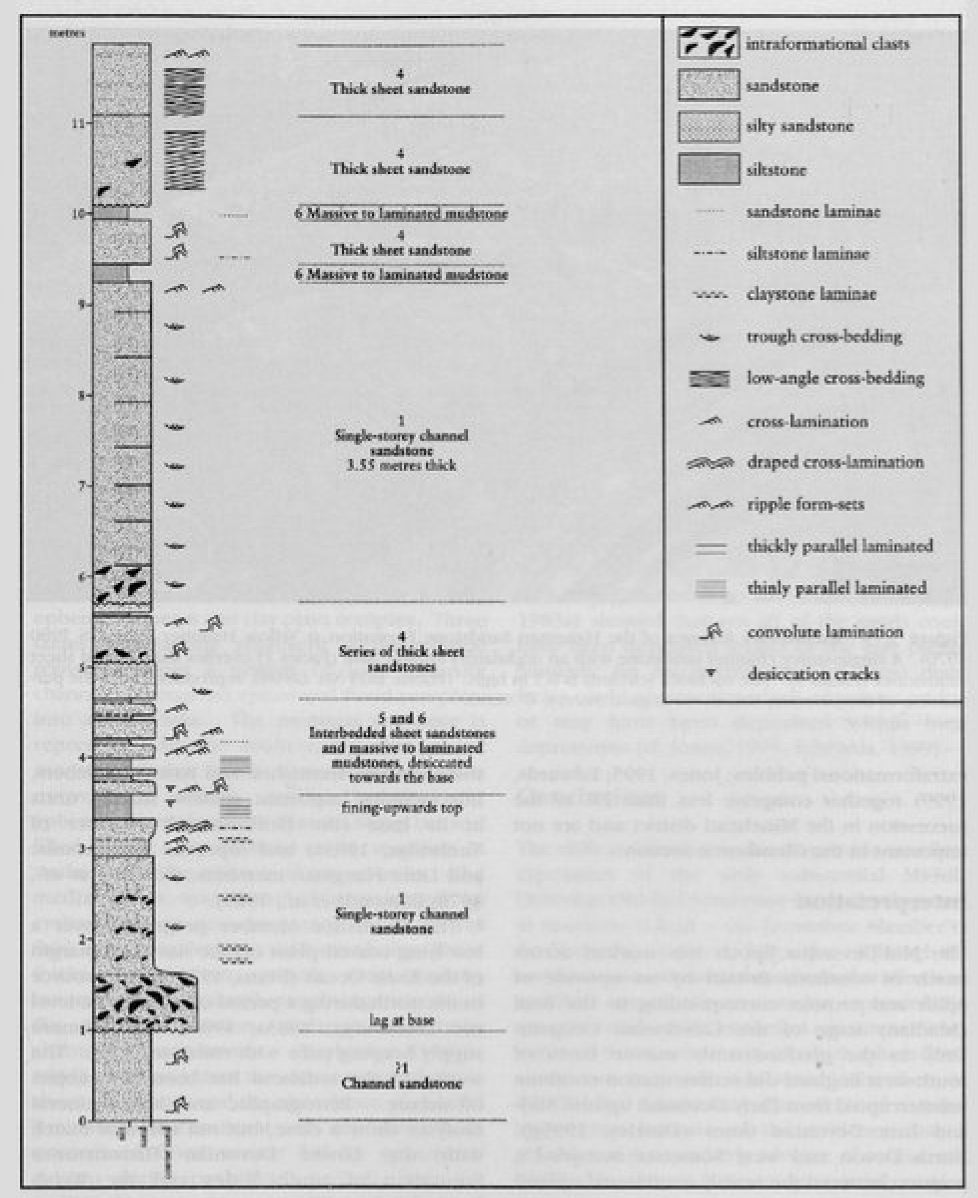
(Figure 5.77) Summary of the sedimentary facies of the Hangman Sandstone Formation and their interpretation. After Edwards (1999).



(Figure 5.78) Graphic sedimentary log and interpretation of the Hangman Sandstone Formation at Yellow Hammer Rock [SS 7980 4975]. After Edwards (1999).

(Figure 5.79) Sedimentary features of the Hangman Sandstone Formation at Yellow Hammer Rock [SS 7980 4970]. A single-storey channel sandstone with an undulatory erosive base (Facies 1) overlies sharp-based sheet sandstones (Facies 4). The rucksack (circled) is 0.5 m high. (Photo: BGS No. GS480, reproduced with the permission of the Director, British Geological Survey, © NERC.