Aberarth–Morfa

[SN 485 645]–[SN 497 654]

Introduction

Strata of the Aberystwyth Grits Group form a broad crescentic outcrop in west-central Wales sub-parallel to the shoreline of Cardigan Bay (Figure 3.37). They are particularly well exposed in cliff sections along the coast extending intermittently for some 40 km. The name Aberystwyth Grits' was introduced by Keeping (1881), who completed the first detailed study of these rocks, including a listing of the graptolite fauna. Jones (1912) also reported a number of graptolites, including *Spirograptus turriculatus,* from the grits, discussed their age and correlation, and interpreted the geological structure of the area; later, he suggested that the source of the greywackes in the unit lay to the west (Jones, 1938). It appears that Jones regarded the coarser sediment layers in the unit to have been deposited in fairly shallow water (see Wood and Smith, 1959), but Bailey (1930) considered that graded beds such as those seen in the Aberystwyth Grits indicated a deeper environment. In his view, the graded sandstones 'mark the intermittent delivery of a mixture of grit, sand and mud into the waters that overlie the mud floor of the sea *beyond the reach of ordinary sand-pushing bottom currents'* (Bailey 1930, p. 88). A similar conclusion was reached by Rich (1950), who thought that the sediments had been deposited from density currents flowing down a continental slope; his evidence came from flow markings and groove marks preserved on the undersides of the greywacke beds, together with the presence of convoluted laminations, which he attributed to the movement of beds downslope. Keunen (1953) also considered the greywackes to be the product of density flows, noting especially the grading in the beds. Rich (1950) and Keunen (1953) both used the evidence from the sedimentary structures to conclude that the greywackes, at least in the Aberystwyth district, were introduced into the area from the SSW. Wood and Smith (1959) produced a detailed report on the grits throughout their outcrop, providing several lines of evidence to support the growing consensus that they were deposited in relatively deep water from turbidity currents that flowed close to the sea floor. Bailey (1930) had suggested that submarine tremors ('seaquakes') were necessary to generate such flows, and this mode of origin was supported by Wood and Smith (1959). They envisaged the rise of a 'whale-backed ridge' to the south-west or SSW from which previously deposited sediments were remobilized by uplift accompanied by earthquakes. They also suggested that some, maybe many, of the currents may have originated from terraces of sediment that had been built out beyond the position of stability.

Graptolites are not uncommon in darker, muddier horizons in the Aberystwyth Grits Group. The first specimens were recorded and illustrated by Hopkinson (1869), and lists were produced by several subsequent workers, indicating that the group should be assigned to the *turriculatus* Biozone. The taxonomy and biostratigraphy of graptolites from the area was revised and refined by Loydell (1991, 1992–93), who divided the lower Telychian *turriculatus sensu lato* Biozone into two new biozones (the *guerichi* and *turriculatus* biozones) and subdivided the two into a total of seven sub-biozones. He also showed that the base of the turbidite system was everywhere within the *geurichi* Biozone and that diachroneity at the base of the unit equates to approximately one sub-biozone, rather less than previously believed. The production of a high-resolution biostratigraphy also provided a framework for detailed facies analysis of the turbidite fan, allowing consideration of such variables as sediment supply, sea-level changes and tectonic activity (Dobson, 1995). The whole sequence was viewed by Dobson (1995) as the remains of a small, deep water (perhaps about 500 m) submarine fan built by sediment deposition from turbid flows. In general, the flows were from the south-west or SSW, and the more proximal turbidite facies are therefore found in the southern part of the outcrop. Wilson *et al.* (1992), however, regarded a simple turbidite fan model to be inappropriate for the Aberystwyth Grits, and attributed control of the depositional system to syndepositional faulting to the east, represented in part by the Bronnant Fault Zone. A thorough summary of this model for the development of the Aberystwyth Grits Group, as a fault-controlled sandstone-lobe turbidite system, has been presented by Davies *et al.* (1997, pp. 126–32, 145–50).

The rocks in the Aberystwyth area are highly folded and faulted, with structural trends dominantly NNE to SSW. Davies and Cave (1976) interpreted much of the smaller-scale folding and some of the faulting to be attributable to soft-sediment deformation caused by the sliding of thick packets of turbidites westwards down the palaeoslope. Fold axes are more or less parallel to the coastline of Cardigan Bay (Figure 3.37); in the south of the region the strata plunge northwards, and in

the north they plunge southwards, so the youngest beds are found in the central region, around Llanrhystud [SN 539 697].

The cliffs between Aberarth and the farm of Morfa, 3 km to the north-east, show excellent representative sections in turbidite beds of the Aberystwyth Grits Group; the strata here were referred to the Mynydd Bach Formation by Wilson *et al.* (1992). The area is a few kilometres south of Llanrhystud, so the beds here generally young northwards. One of the noteworthy features of the Aberarth section is the occurrence of structures referred to as 'prolapsed bedding' by Wood and Smith (1959, p. 172), in which a set of flat-lying folds in alternating mudstones and greywackes are incorporated in an otherwise normal greywacke–mudstone sequence (Figure 3.38).

Description

The cliffs 500–800 m north-east of Aberarth display a sequence of turbidite beds 30–50 m thick, dipping at 40° to the south-east. These beds belong to Subzone 4b (*utilis* b), at the base of the *turriculatus* graptolite biozone (Dobson *et al.,* 1995a). Graded greywacke beds form the base of each turbidite unit; the bases are irregular or undulate and many display flute and groove marks. The greywackes grade up into fine sandstones and are separated by mudstone horizons up to 8 cm in thickness. Several levels show examples of the 'prolapsed bedding' described by Wood and Smith (1959); one such horizon can be seen immediately north of a small fault 36 m north of the start of the exposure and can be traced for about 100 m to the north-east. This unit is 1 m thick, and contains rafts of folded and contorted thin-bedded strata in a slurried matrix (Bates, 1982a).

About 325 m north-east of the beginning of the section a fault brings in a sequence of finer-grained beds, with most turbidite units less than 10 cm thick. At Clochtyddiau Pridd [SN 4877 6468], a normal fault occurs, beyond which a sequence of thick turbidites can be seen (Figure 3.39). One particularly prominent bed, 5 m thick and comprising an amalgamation of several greywackes persists to the small promontory at [SN 4909 6498]. The base of this bed displays prominent horseshoe-shaped flute moulds.

Dobson *et al.* (1995a) described the sequence from the beginning to this promontory as comprising five successive packets of strata, each with a thickness between 25 and 50 m. The basal units of each package include massive coarse sandstones and conglomerates with deeply scoured bases and containing ripped-up mudstone clasts; the packages generally fine upwards, with bed thicknesses also decreasing. Palaeocurrent directions measured from the cross-bedded units range between eastwards and north-eastwards, whereas the orientations of flute moulds are consistently towards the north-east (Dobson *et al.,* 1995a).

North of the promontory an alternation of groups of thick and thin greywackes continues for some 700 m to the end of the exposure.

Interpretation

During the latest Aeronian and early Telychian submarine fans built out north-eastwards into the Welsh Basin from the marginal areas to the south. Sediment was transported by turbidity flows, which eroded the upper levels of the underlying beds and produced scour features such as flutes, which are preserved as moulds on the bases of the overlying greywackes. As the flows waned, the finer sediments settled out, and in the quiet periods between flows a background deposition of fine hemipelagic muds pertained. Nearer to the sediment source, in the south, the energy of the flows was highest and greywacke deposition predominated, resulting in a turbidite sequence with a high sand–mud ratio. To the north-east, smaller amounts of coarse material reached the area, and the proportion of fine sand and mud is much higher.

At Aberarth, the fining-up turbidite packages were interpreted by Dobson *et al.* (1995a) as episodic sandy lobe progradations reflecting pulsed sediment supply. This may itself relate to periods of rising and falling sea level. The sandstone lobes in the Cardigan Bay area do not show evidence of channelling, and represent a series of 'Type 1' turbidite systems of Mutti and Normark (1987). The elongate SW–NE shapes of the lobes suggest derivation from a

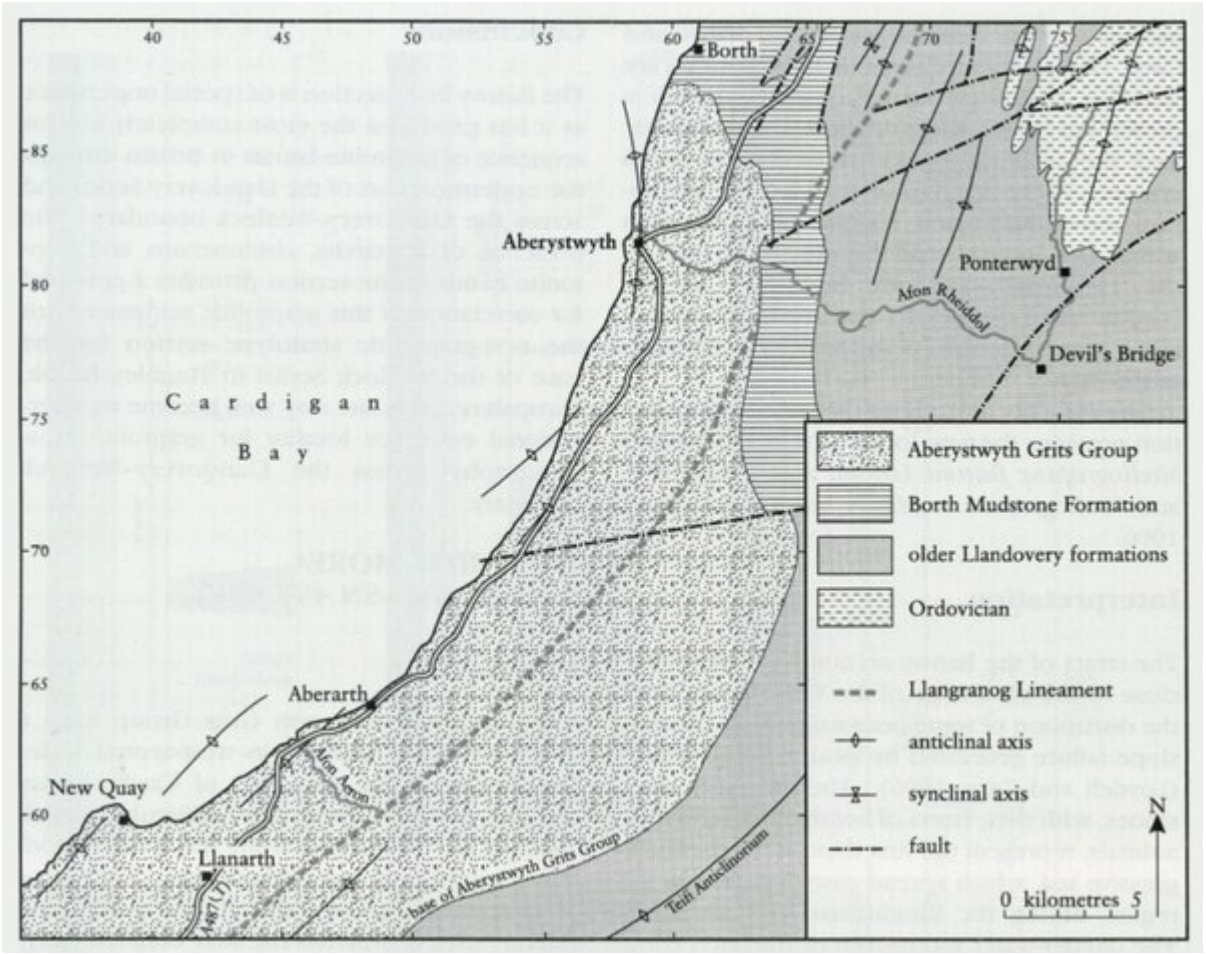
series of point sources to the south-west, perhaps large rivers or delta systems. The relatively high greywacke/mud ratio in the Aberarth sections suggests that these are relatively proximal sandy lobe sequences (Figure 3.39), and this interpretation is supported by the presence of coarse sands and conglomerates and the recognition of upward coarsening (reverse grading) at the base of each greywacke bed followed by upward fining (Dobson *et al.,* 1995a). The amalgamation of successive sandstone beds into multiple units is evidence of erosive downcutting by successive flows. The turbidite beds at Aberarth mostly preserve only the Ta, Tab or Tabc portions of a typical Tabcde Bouma turbidite cycle (Figure 3.40). The thicker finer-grained units reflect periods of lobe abandonment. The 'prolapsed beds' have been interpreted either as rafts of previously deposited turbidites that have slumped down the slope or as levels that have foundered and experienced soft-sediment deformation during deposition.

The exposures between Aberarth and Morfa, therefore, display excellent sections in typical deposits of the Aberystwyth Grits Group in the proximal to intermediate part of a series of sandy lobes. Similar exposures in proximal sandy lobe sequences can be seen to the southwest, beside the sea-food factory at New Quay [SN 3868 6044]. The sequences at Aberarth and New Quay contrast with the more mud-dominated sections to the north-east at Craigyfulfran, Aberystwyth. They also relate temporally to the unconformity in the shelf section at Marloes; it is likely that this unconformity and the generation of the turbidites are both causally linked to uplift of part of Eastern Avalonia (Pretannia), perhaps during collision with the Laurentian plate (Soper and Woodcock, 1990).

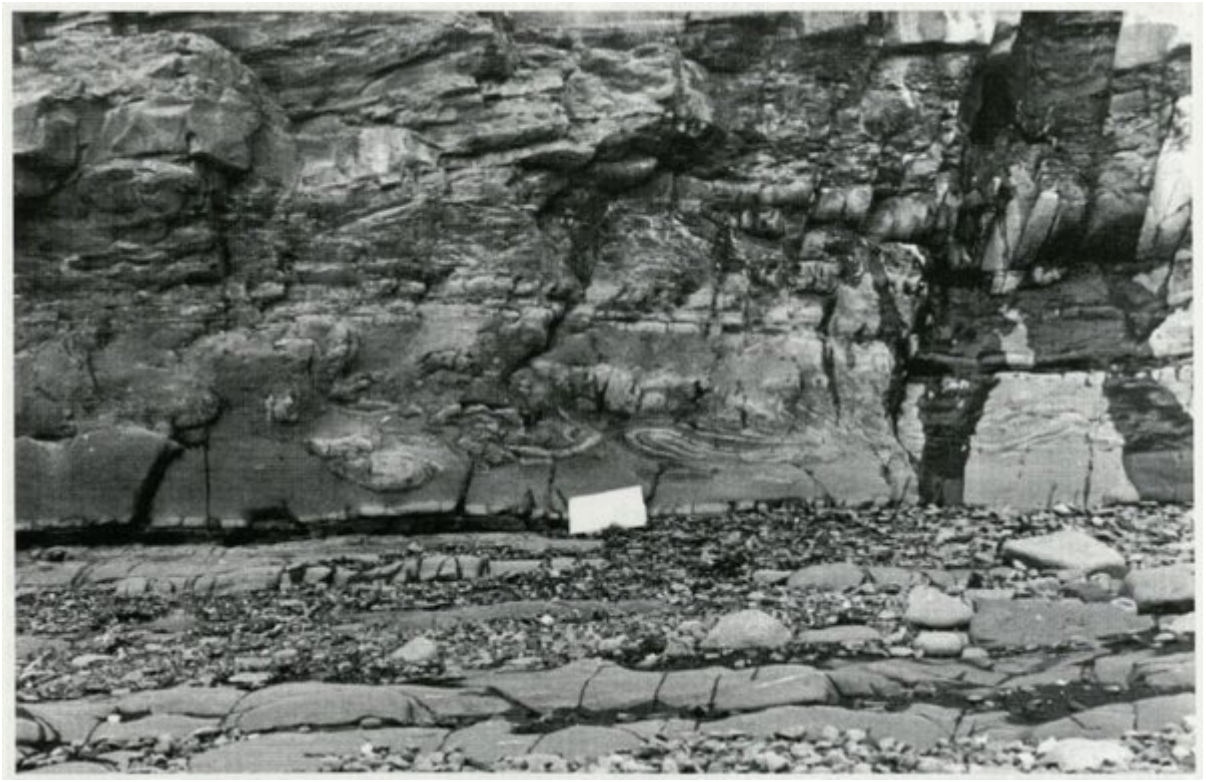
Conclusions

These excellent coastal exposures provide sections through sandy submarine lobes that built out into the deeper parts of the Welsh Basin during latest Aeronian and early Telychian times. The sediments on the lobes were deposited from turbid currents of sediment and water that flowed close to the sea floor, eroding the preexisting sediments until the flow waned and deposition began. Each unit is coarse at the base, sometimes conglomeratic, and fines upwards into fine sands or muds. Cross-bedding in the sandstones and erosive scours show that the direction of current flow was from the south-west. These rocks belong to the Aberystwyth Grits Group and are among the most classic turbidite deposits in the world. They have been widely discussed in the literature, and their study has made a major contribution to the understanding of turbidite systems. They are also crucial in the interpretation of the evolving environment of the Welsh Basin and in the understanding of the relationship between tectonics and sedimentation in the early Silurian of the region.

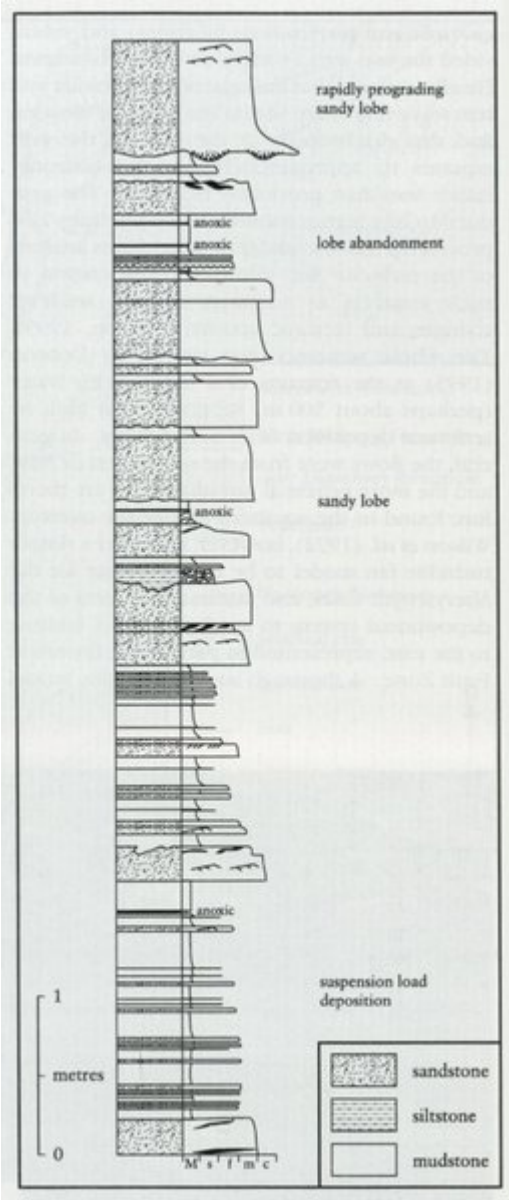
References



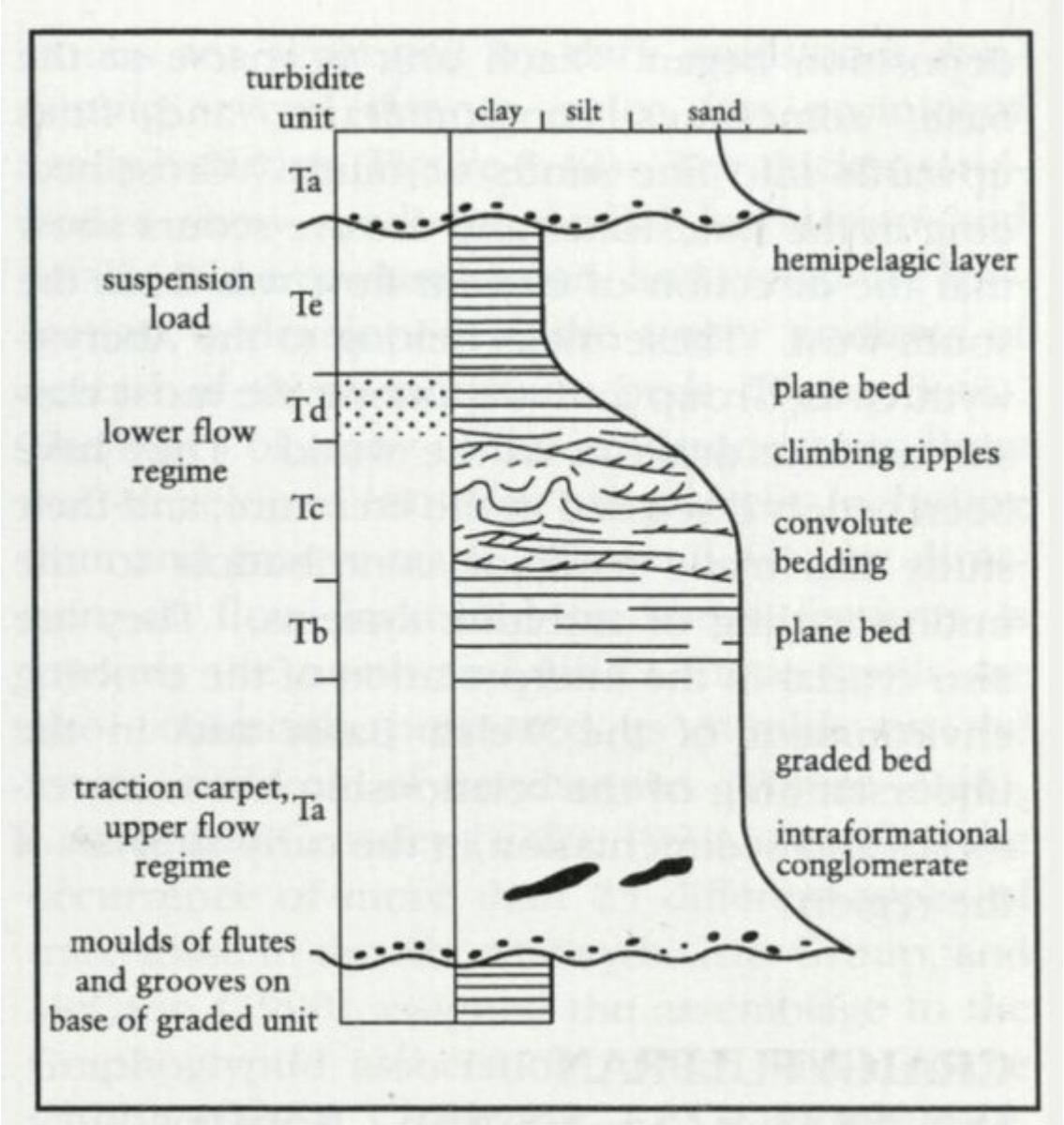
(Figure 3.37) Geological sketch-map of central western Wales, showing the extent of the Aberystwyth Grits Group and the GCR network sites at Aberarth and Craigyfulfran (Aberystwyth) (after Siveter et al, 1989).



(Figure 3.38) Deformed bedding in the Aberystwyth Grits Group (Subzone 4b) at Aberarth. (Photo: M.R. Dobson.)



(Figure 3.39) Representative measured section in the turbidite sequence, Aberystwyth Grits Group, between Aberarth and Morfa, with environmental interpretations (after Dobson et al., 1995a).



(Figure 3.40) Idealized graphic log of the full Tabcde Bouma turbidite cycle (modified from Selley, 1978, after Bouma, 1962).