The Mid Wales coast

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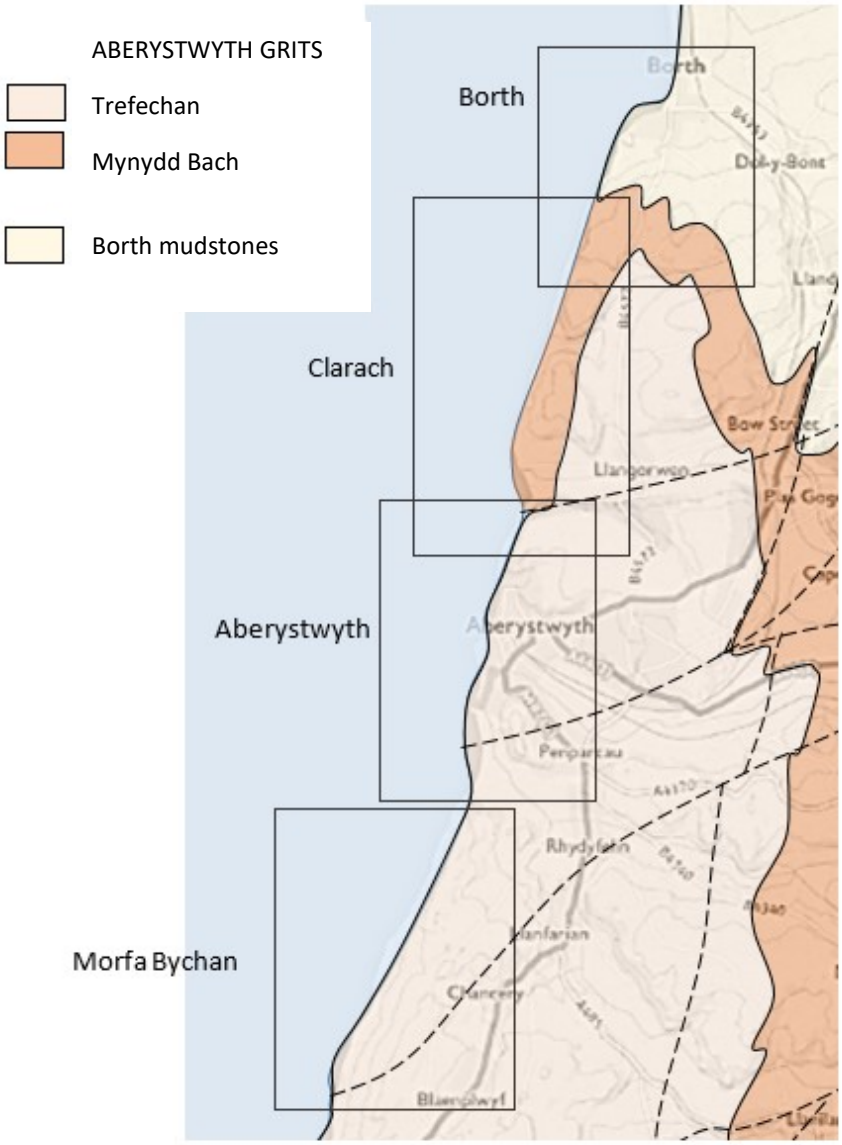


Figure 580: Field excursions.

The lower Silurian rocks of mid-Wales are generally not well exposed. An important exception is along the mid-Wales coast, where an almost uninterrupted outcrop of Silurian strata can be examined in the cliffs and wave cut platforms from Borth to Aberystwyth and beyond. This provides a unique opportunity to look in detail at two aspects of geology: the mechanisms by which the sediments were deposited; and the manner in which they were later folded and faulted during the Devonian Acadian orogeny.

A suggested reconstruction for the geography of Wales at the time of deposition of the Aberystwyth Grit is given in fig.581. The Midland platform, which had emerged as land during the late Ordovician ice age, was now largely covered by a shallow sea following a rise in global sea levels. This shallow shelf was an area of accumulation of sand and mud. Plate tectonic movement of the Avalonian microcontinent into warmer waters closer to the tropics also allowed limestones to form.

Subsidence along a series of step faults produced a deep elongated marine trough in the western part of the basin, roughly corresponding with the current coastal region of Cardigan Bay. A land mass to the south of the Welsh basin, given the name **Pretannia**, provided a major source of

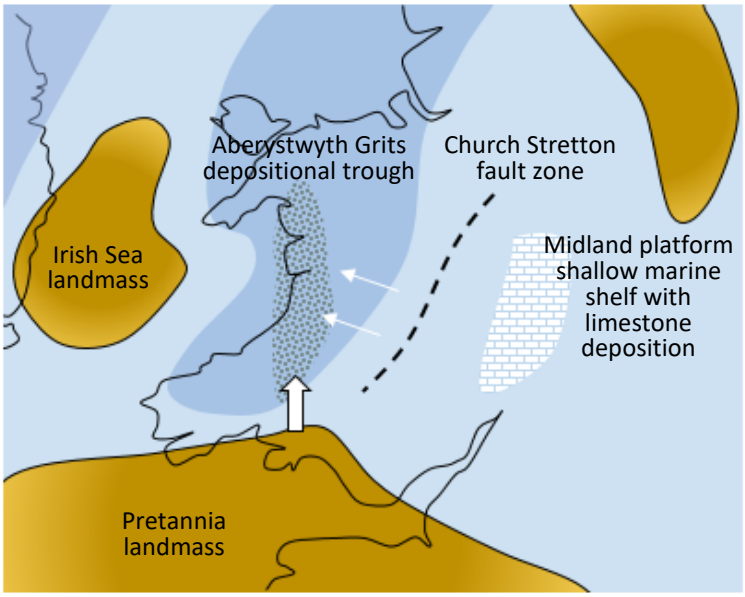
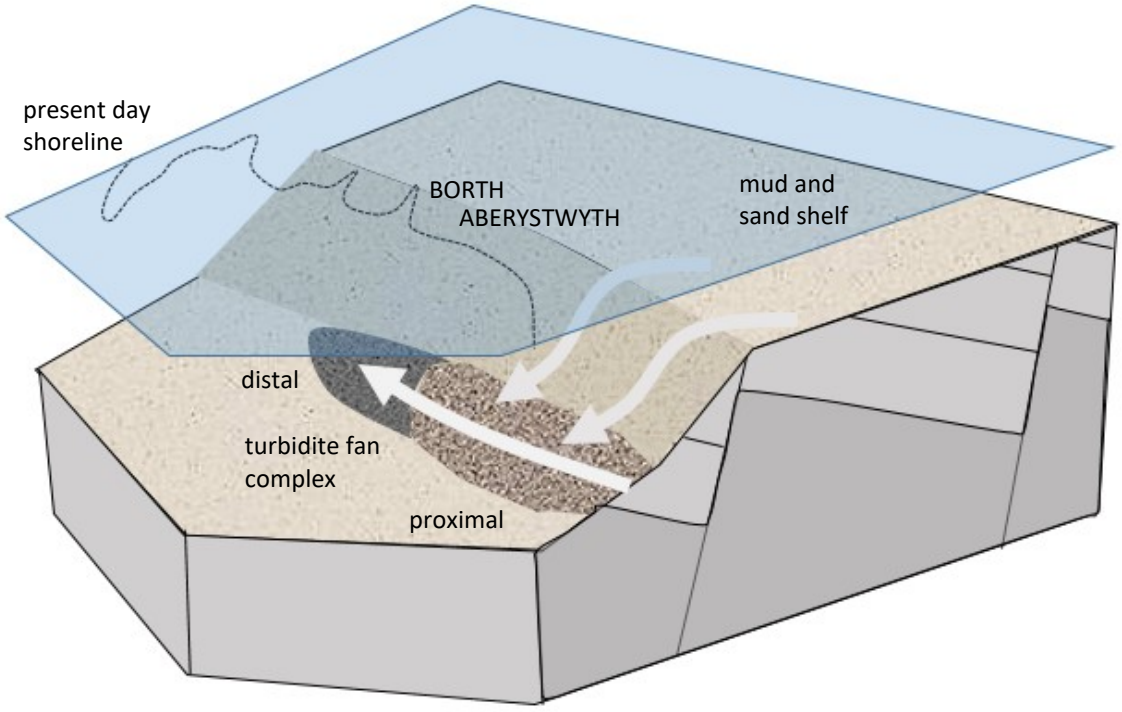


Figure 581:

Palaeogeography for the lower Silurian at the time of Aberystwyth Grits deposition.



sediment for the deep trough. After initially accumulating as river deposits on the shallow shelf, masses of sediment were periodically discharged down the shelf slope as turbidity flows which were then deposited along the axis of the basin. Coarser sands made up much of the deposits in the proximal area close to the source of the flows in the south, whilst finer material was carried in suspension and deposited at a distal location further to the north. A boundary between predominantly sandy and predominantly muddy sediments lies between the present day locations of Borth and Clarach. The model is made slightly more complex because turbidite flows can be discharged into the deep basin from the shelf seas of the Midland platform. This produces occasional turbidite beds which contrast in thickness or grain size with the majority of the sedimentary sequence.

We now move forward to the Devonian period, when plate movements linked to closure of the Rheic ocean to the south of Britain initiated the Acadian mountain building event. Folds and faults produced at this time are clearly visible along the mid-Wales coast. Many folds have a complex shape, due to several phases of compression in the

Welsh basin (fig.582). Earth movements were initiated by the strong and rigid crustal block of the Midland platform being forced westwards against the softer sedimentary succession of the Welsh basin. Horizontal compression produced a series of large anticlines and synclines with an approximately north-south orientation. The effect of this deformation was to shorten but also greatly thicken the mass of basin sediments.

At a later stage the horizontal forces were reduced, but the over-thickened mass in the basin produced a downwards force on lower levels of sediments. This caused re-folding of the original structures to allow vertical compression to take place. Minor parasitic folds can now be found on the limbs of major anticlines and synclines, and have a north-south axial orientation approximately parallel to the major folds.

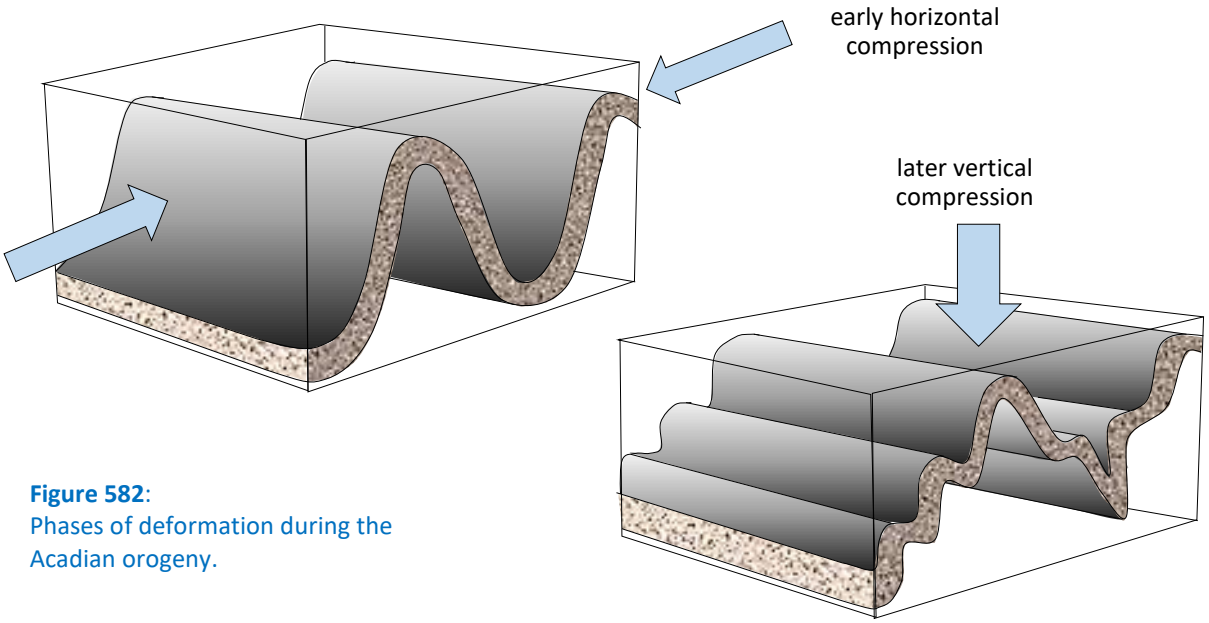


Figure 582:
Phases of deformation during the Acadian orogeny.

Our field excursions cover the section of coast between Borth and Morfa Bychan. Borth mudstones outcrop in the north, with rocks of the Aberystwyth grits formation making up most of the coastal section. The Borth mudstones underlie the Aberystwyth grits in a regional synclinal basin. Many minor folds with north-south axes are superimposed on this structure (fig.583).

The Borth Mudstones overlap in age with the Aberystwyth grits, so that both materials were being deposited simultaneously by turbidite flows in proximal and distal areas. Mudstones were initially deposited over a larger area of the sea bed, but were eventually engulfed as the depositional area of the grits extended northwards. This suggests an increasing rate of erosion of the main sediment source area of Pretannia to the south, due either to fault uplift or a temporary fall in global sea level.

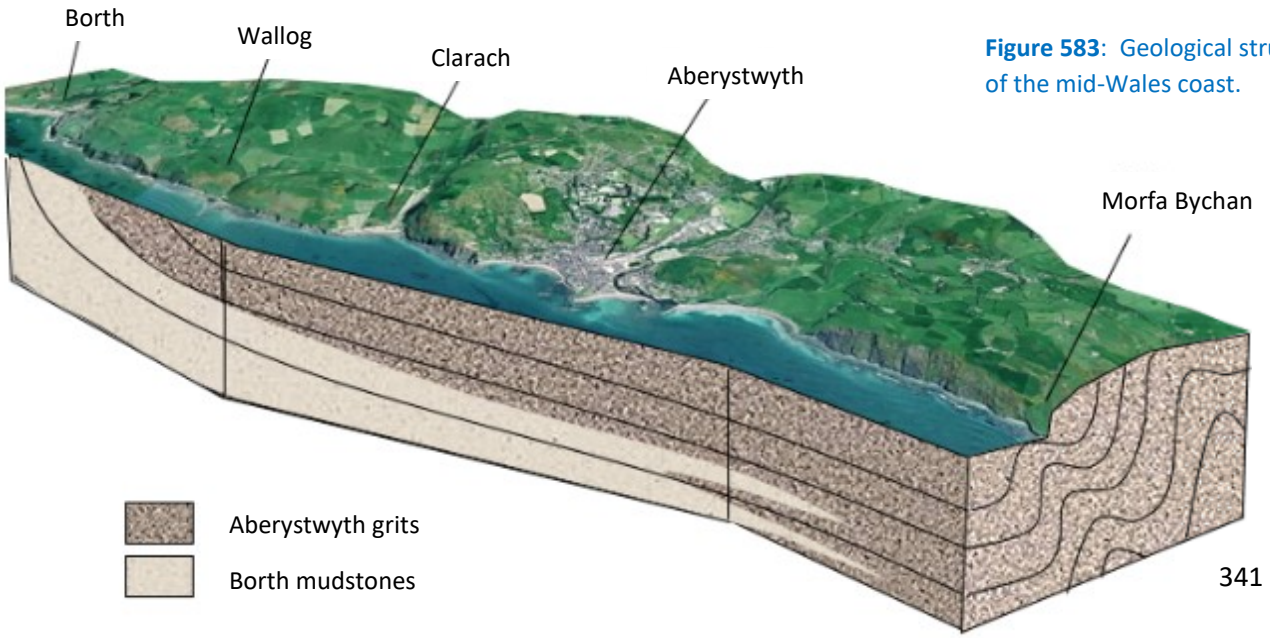


Figure 583: Geological structure of the mid-Wales coast.

Excursions

Four sections of coast will be examined between Borth and Morfa Bychan. It is possible to walk the complete distance along the shoreline below the cliffs in each of these sections if the time of low tide is chosen carefully. However, the routes can be very difficult in places. It may be necessary to scramble over boulders and along slippery rock ledges covered by seaweed. There is also a risk of misjudging the tide times and becoming trapped in an isolated inlet with no easy escape route up the steep and sometimes unstable cliffs.

The strategy suggested in each of the itineraries is to first explore the shoreline around the start point, then walk along the cliff path to the end of the section and explore the shore around that point. In this way, nearly all the important features of the rock succession will be seen and the excursions can be undertaken at most states of the tide. You may return either along the cliff path, or more quickly along one of the minor roads which run parallel to the coast a short distance inland.

Borth

5 miles: approximately 2 hours

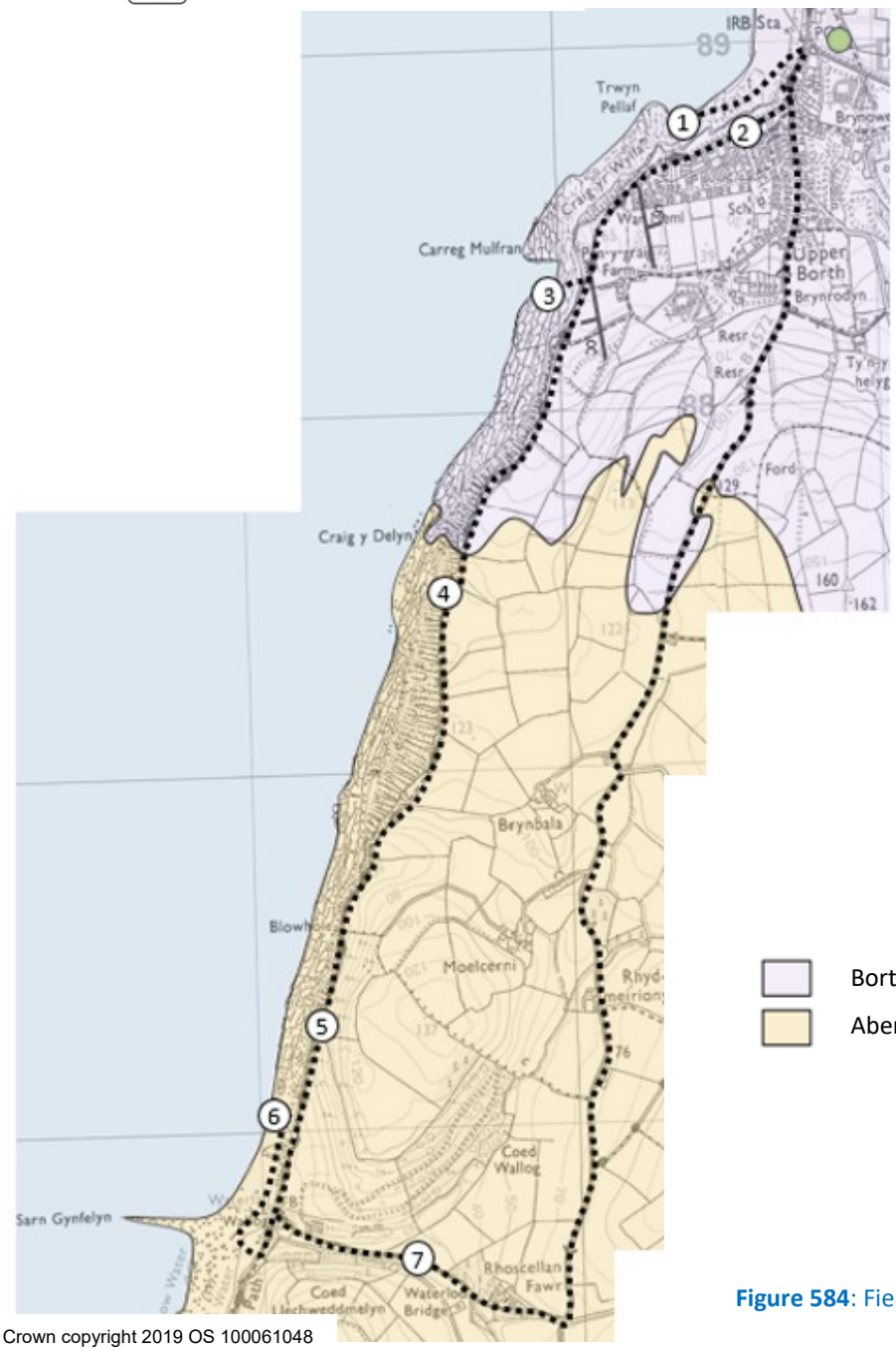


Figure 584: Field excursion.

During this excursion, we explore the transition from fine mud turbidites to coarser grit turbidites, which occurs at Craig y Delyn between Borth and Wallog.

Start: Park in Borth. A car park is provided near the road junction at the southern end of the promenade [SN608889].

1: Cross the promenade to reach the beach. Walk to the base of the cliffs where a wave cut rock platform begins. The Borth Mudstones Formation is exposed. The sequence of distal turbidites each consist of a Bouma D unit made up from alternations of light grey siltstone and darker grey mudstone, overlain by a Bouma E unit of uniform dark grey mudstone (fig.585).

Figure 585:

Borth mudstones outcropping in a fold structure near Trwyn Pellach, Borth.

Casts of burrows of *Palaeodictyon* can be found on the bases of some silt units, indicating that the bottom mud was colonised by burrowing organisms between turbidity flows. The waters of the basin appear to have been well oxygenated, perhaps due to powerful stirring during storm events.

A series of tight folds are seen in the cliff outcrops, with dips changing over a few metres from horizontal to vertical. However, these minor structures are superimposed on a gentle dip southwards towards the centre of the regional synclinal basin. We are able to examine progressively younger strata as we move southwards along the coast.

2: Return to the promenade, then take the road in front of the row of houses on top of the cliffs. Continue along the coastal footpath past the war memorial at the headland.

3: The coastal path descends to cross a small valley at the head of a bay near Carreg Mulfran. Leave the path and go to the beach to examine the cliff outcrops.

The cliffs and beach platform again expose distal turbidites dominated by mudstones, but with thin siltstone laminae present. A fault in the cliff near the head of the bay is filled by a sheet of quartz, which is likely to have been emplaced by hydrothermal fluids released by low grade regional metamorphism which accompanied the compression and deep burial of the basin sediments. Movement on the fault is indicated by **slickenside** scratches on the adjacent rock surface.

Some zones of very uniform black mudstones in the cliff section are probably hemipelagic in origin, formed by slow sedimentation from sea water rather than turbidite activity. The absence of trace fossils suggests that the pause in turbidite activity led to anoxic conditions on the sea bed.

4: Return to the cliff path. Ascend southwards to the cliff top. After passing several hill crests, the path descends to cross a wooden bridge over a small ravine. At this point, there is a view down the cliff to Craig y Delyn. Craig y Delyn is composed of a series of turbidite flows which lie against the cliff face at a steep angle. This outcrop marks the northerly limit of the Aberystwyth Grits formation. Thicker sandstone units appear for the first time on our traverse, and will be examined shortly in the cliffs at Wallog.

Figure 586:
Craig y Delyn.

5: Continue along the cliff path. Descend to the bridge over the river next to Wallog House. A little further along the coast path, steps lead down to the beach alongside the old lime kiln.

6: Walk back along the beach to examine cliff outcrops to the north of the stream. The cliff is composed of unlaminated fine sandstone beds with some iron present, giving a rusty weathering appearance, along with interbedded grey mudstones. These deposits still represent distal Bouma D and E units.

A thicker and coarser Bouma C unit sandstone is also seen in the cliff (fig.587). This rock type, termed a **greywacke,** is composed of a mixture of quartz grains and lithic fragments from the breakdown of rocks such as microgabbro. Mud and silt units are present above this bed. It is possible that the greywacke originated as a proximal fan deposit from a nearby location on the shelf slope to the east, and has been inserted into a finer grained sequence of turbidites from a more distal southerly source.

Within the mudstones we see examples of **concretions**. These objects are quite common within the Aberystwyth Grits. They have a similar size and shape to a discus as used by athletes. Concretions are chemical precipitates which grew in the soft mud of the sea floor, perhaps around a nucleus such as a fragment of organic matter. They are composed of a mixed carbonate of calcium, magnesium and iron.

7: Return along the cliff path. An alternative easier option is to take the footpath which begins at the gate alongside the bridge at Wallog House. The path passes old stable buildings and climbs through woods to reach a minor road at Rhoscellan Fawr.

Figure 587: (left) Bouma A unit greywacke within the turbidite sequence. (right) Concretion in mudstone.

Clarach

3 miles: approximately 1½ hours

Figure 588: Field excursion.

In this excursion we examine the Aberystwyth Grit turbidites, in which the sand units become coarser towards the south. We see examples of complex fold and fault structures.

Start: Park at Clarach. A parking area is provided above the beach at the northern end of the bay [SN587840].

1: From the parking area, descend to the beach and walk northwards along the wave cut platform beneath the cliffs.

We reach an eroded anticline picked out by curved beds of fine sandstone Bouma D units interbedded with softer mudstones. The axis of the fold plunges to the north.

At the nearby headland, a sequence of Bouma D and E unit fine sandstones and mudstones are outcropping in a syncline (fig.590). Within the sequence are several thicker and coarser Bouma C unit sandstones, in places exhibiting contorted slump bedding. This is further evidence that the coarser sands were derived from the nearby shelf to the east, and continued to slide down the shelf slope under gravity after deposition, but whilst still saturated with water and in a fluid state. Rippled cross bedding can also be found, indicating redistribution of the sand by the downslope water flow after deposition.

Figure 589: Anticline in turbidite sandstones and mudstones.

Figure 590: (left) Sequence of turbidites in a synclinal fold. (right) Detail of a thicker Bouma C unit sandstone showing contorted slump bedding.

2: Return to the parking area and join the coast path which ascends along the cliff. If the tide is low, an extensive area of wave cut platform can be seen. Strata are picked out by erosion, and fold structures are also visible in the cliffs.

A short distance beyond the localities visited earlier on the shore, a bay has formed along a major synclinal fold with a north-south orientation, marked as fold 1 in fig.591. Convergent dips can be seen in the cliff face of the headland, and in outcrops at the shoreline along the head of the bay. Superimposed on this fold is a secondary syncline, marked as fold 2. This is a relatively open fold with a NNW-SSE orientation which slightly cross-cuts the major structure. We might suggest that the major structure was the first to be formed, as a result of horizontal compression, and the minor syncline was superimposed in a later phase of vertical compression of the basin strata.

Figure 591: Fold structures visible from the cliff path north of Clarach.

Continue along the cliff path to Wallog.

3: Descend along the path to Wallog House, where steps lead down onto the beach by the old limekiln.

4: Walk southwards along the shore to examine rock outcrops in the cliff.

We again see the familiar repeated sequence of fine sandstone and mudstone turbidites representing Bouma D and E units, along with several thicker and coarser C unit sandstones. Beyond the first headland we come to an indentation in the cliff line where a zone of tectonic disturbance is visible (fig. 592). At beach level, a tight asymmetric anticline can be identified. Following this upwards, the steep limb becomes detached from the fold. Alongside the zone of broken rock, a fault line is seen to extend up the cliff.

When pressures are applied gently to strata, folding can take place. However, if the pressure becomes too great, brittle failure occurs and a fault can develop. It appears that this structure began to form under gentle stresses directed towards the west.

As the stress increased, the fold became overturned and brittle failure finally occurred to produce a compressional **reverse** fault.

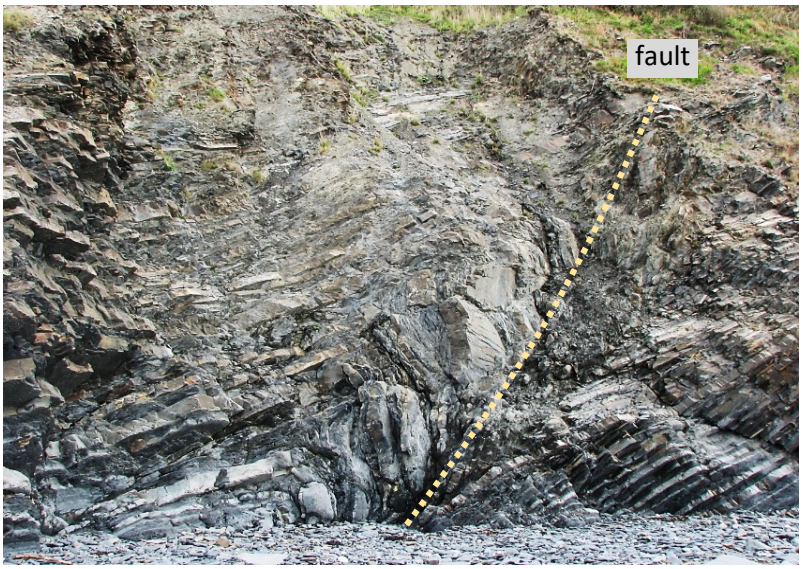


Figure 592:

(above) Zone of tectonic disturbance at Wallog.

(below) Detail of folding and faulting at the base of the structure.

Return along the beach, up the steps, then take the cliff path back to Clarach.

Aberystwyth

3 miles: approximately 1½ hours

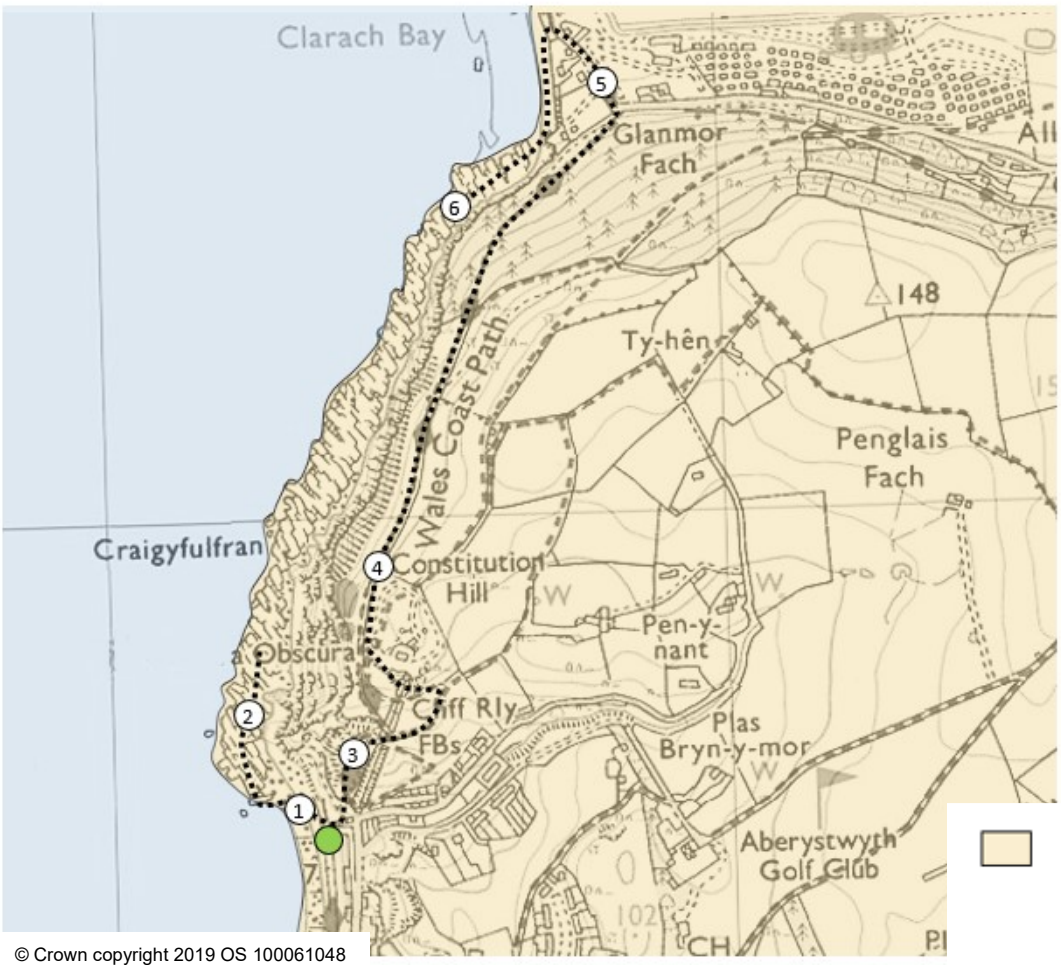


Figure 593: Field excursion.

In this excursion we examine the sedimentary features of turbidites deposited closer to the source area than at Borth and Clarach, and also see further examples of folding and faulting of strata.

Start: Car parking is available on streets in Aberystwyth, or at public car parks.

1: From the town, walk along the promenade to the northern end. Descend the concrete ramp to the beach and view the folds in the cliff (fig.594).

Figure 594: folding below Constitution Hill, Aberystwyth.

A series of tight folds run north-south parallel to the line of the cliff, superimposed on the regional inland dip at this point.

Continue along the beach to examine the Aberystwyth Grits outcropping in the cliff. Compared to Borth and Wallog, notice a significant increase in the proportion of coarser C unit current bedded and slumped sandstones and fine D unit unlaminated sandstones. We presume that the principal source of the turbidites lay to the south, and the proportion of coarser sediment increases as we move from the distal to the proximal area of the depositional fan.

2: Climb the iron ladder over the large groyne at the base of Constitution Hill. Continue along the wave cut platform to the first inlet. The landward dipping sequence of turbidites is cut by a steeper landward dipping fault, which has been a focus of wave erosion which has cut a cave through the headland. The fault plane has been filled by a thin sheet of quartz, crystallised from hydrothermal fluids flowing along the fracture.

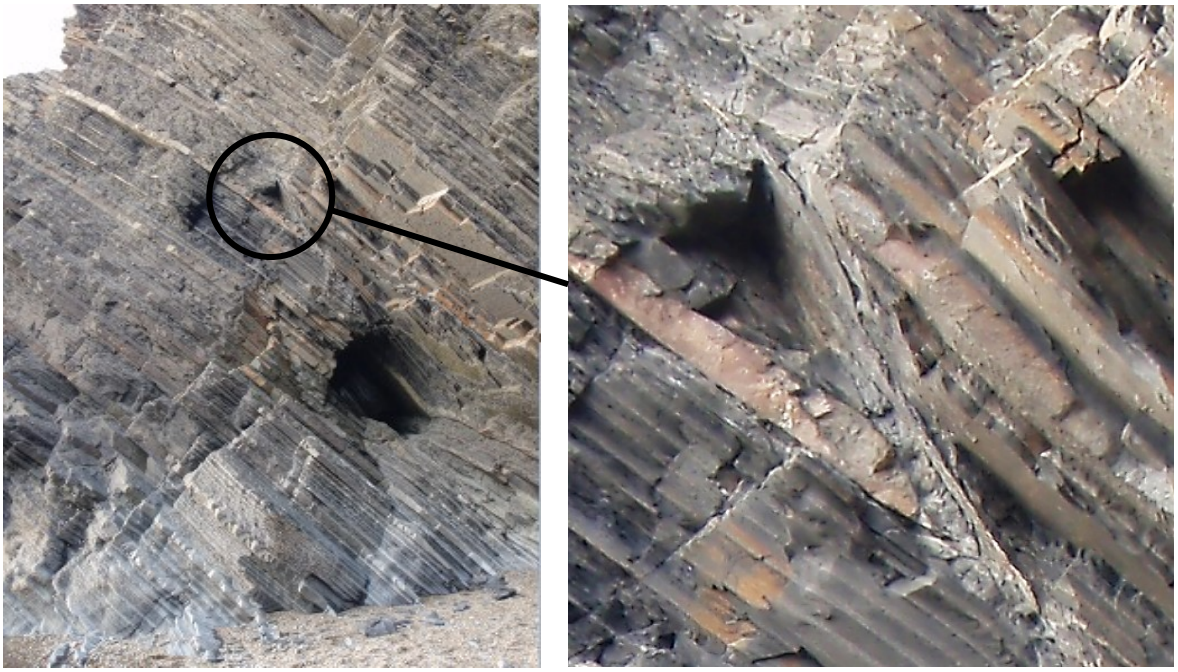


Figure 595: Faulting below Constitution Hill.

A number of coarser Bouma C unit sandstones can be examined around the inlet. These often exhibit sole markings of their base (fig.596). We find **flute casts** and smaller **groove casts** produced by scour of the underlying mud by the fast moving turbidite flow. These structures give directional information for the flow, and suggest a southerly source.

Figure 596: sole markings on strata below Constitution Hill. (left) Flute casts. (right) Groove casts.

3: Return to the promenade. Climb the path up Constitution Hill, or take the cliff railway to the summit.

4: Continue along the coast path to Clarach.

5: Descend through the caravan park to the beach.

6: Walk southwards to the cliffs, where a small cave can be seen (fig.597). Strata are again tubidites composed of Bouma C, D and E units.

Just above the cave is a thin band of a very fine grained light grey/cream rock. This band descends to sea level as the beach platform is followed southwards. The material has been examined under the microscope and is found to be a felsic volcanic ash, derived from a distant volcanic eruption. It is known that volcanoes were active in Pembrokeshire during the early Silurian, and the volcanic province probably extended across the landmass of Pretannia.

Figure 597:

Cave cut into Aberystwyth Grits, Clarach Bay.

Return to Aberystwyth along the cliff path.

Morfa Bychan

5 miles: approximately 3 hours

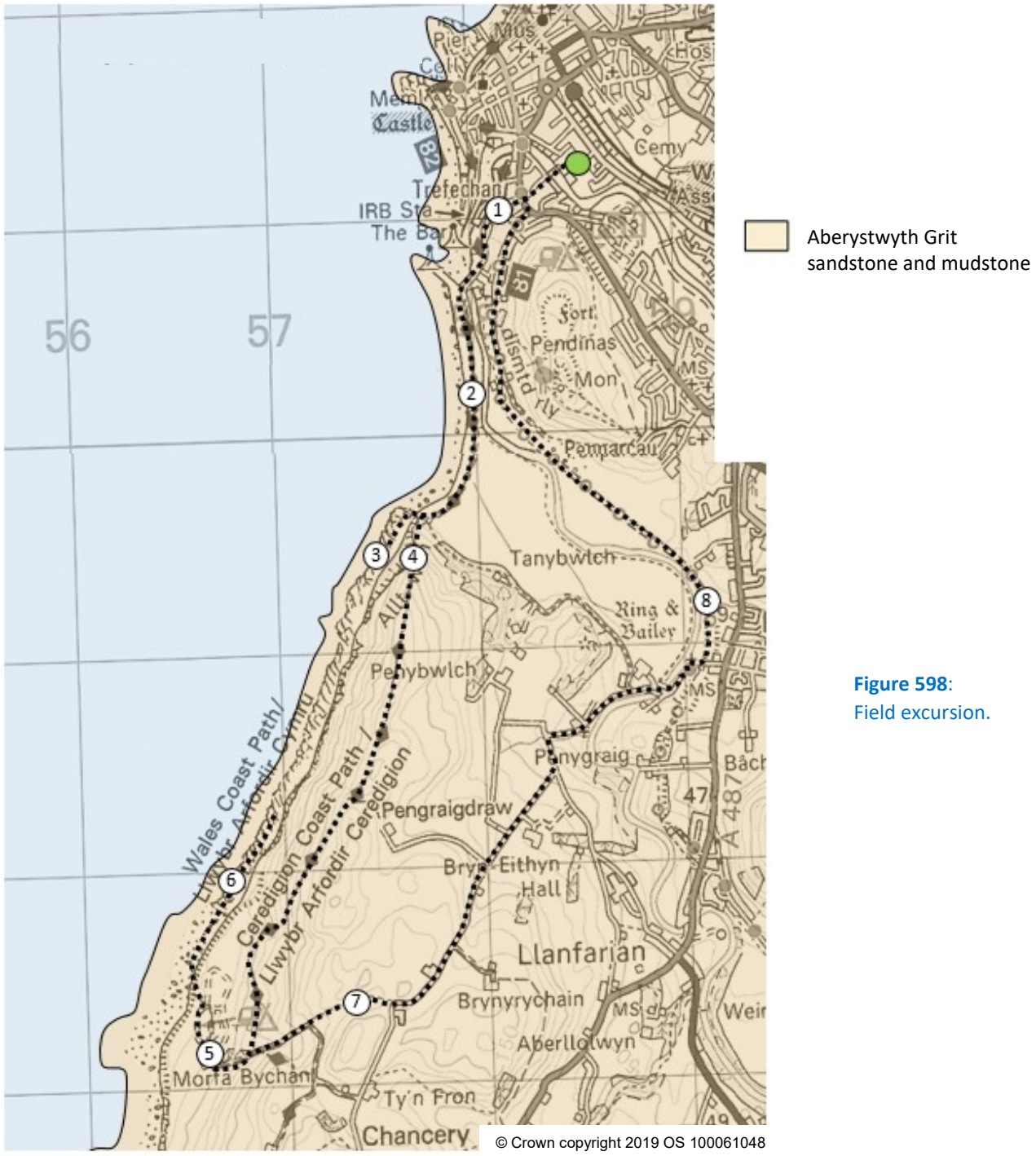


Figure 598: Field excursion.

Start: Park in Aberystwyth. A convenient car park is located near the railway station on Park Avenue [SN585813]. A foot bridge over the Afon Rheidol leads to the bottom of Penparcau Road near the fire station.

1: Walk along the minor road Pen-yr-Angor immediately south of the fire station. Continue past the harbour and cross the bridge at the mouth of the River Ystwyth to reach the shingle beach at Tan y Bwlch.

2: Follow the coastal path southwards along the gravel storm beach to reach the cliffs at Allt Wen.

3: Descend to the beach and examine the cliffs, where a sequence of turbidites outcrop, composed

of Bouma B, C and D units. The proportion of mudstone present is less than at localities further north along the coast. Folding is evident, with strata becoming vertical or overturned along the base of the cliffs.

4: Return along the shore and take the cliff path which ascends to the summit of Allt Wen. After a short climb, we pass an old quarry where a sequence of near-horizontal turbidites has a very low proportion of finer mudstone horizons (fig.599).

5: Continue along the path to Morfa Bychan, then descend along the minor road to the Holiday Village.

6: Walk through the village to reach a pathway and steps down to the beach. Walk northwards along the beach to examine the cliff outcrops.

We see a high proportion of coarser C unit sandstones, with little interbedded mudstone. Convolute and current bedding are present, and the sandstones show rippled surfaces. The current bedding suggests that the rate of deposition was reduced with distance from the source. Traction currents below the turbidite flow were able to erode and redistribute the sediment. A further indicator of reducing flow strength is the presence of a mud lens within a C unit sandstone bed (fig.600).

7: Take minor roads back to the village of Rhydyfelin.

Figure 599: Old quarry at Allt Wen.

Figure 600: Morfa Bychan:
(left) Cliffs near the Holiday village.
(right) Turbidites with C units showing convolute bedding. The upper bed is split by a mud lens towards the left of the picture.

Return to the Holiday Village, then to Aberystwyth along the coastal path. Alternatively:

8: After crossing the bridge over the Afon Ystwyth, turn left onto a footpath which follows the old railway track back to Aberystwyth.