
Braich y pwll to Parwyd

[SH 135 258]–[SH 154 244] and [SH 155 243]

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Introduction

This 2.5 km long cliff section is situated at the south-western tip of Llŷn and provides continuous exposure of a remarkably varied sequence of rocks that include: *mélange*, schist, and gneiss and overlying Ordovician strata and intrusions (Figure 7.25). The exposures have been described as including some of the best examples of *mélange* in the world (Gibbons and McCarroll, 1993): *mélanges* are peculiar mixtures of rocks that form in various tectonic settings and are especially typical of destructive plate margins. In this site, sedimentary and igneous rocks, notably basaltic pillow lavas, are mixed together in a slaty matrix to produce chaotic and colourful cliff exposures.

These classic exposures are comparable to famous *mélange* localities elsewhere such as western California, Timor, Turkey and Iran. They form part of the outcrop of the Gwna Group, which extends from Bardsey Island to the north coast of Anglesey. They are especially instructive because they illustrate how an originally bedded sequence of sediments has become progressively disrupted, leaving only traces of the original strata in the form of a 'ghost' stratigraphy.

The stratigraphical interpretation of this Gwna *mélange* and its contact with adjacent schists has been the subject of considerable controversy. This interest has focused on this site because it is the only place where these relationships can be viewed in one continuous outcrop (Matley, 1928; Shackleton, 1956; Barber and Max, 1979; Gibbons, 1983; Gibbons and Ball, 1991). Furthermore, the gneisses, which lie immediately east of the schists, represent the only exposure of high-grade metamorphic rocks on the mainland of North Wales. The relationships between the younger Ordovician sedimentary cover and the older, more metamorphosed (Monian) rocks is also of special interest: on the west side of the bay known as Parwyd, the schists are thrust over the cover strata, whereas on the east side of Parwyd these strata lie unconformably upon gneisses. It is rare to see any exposed contact between the geological basement to Wales and its cover of Welsh Basin sedimentary rocks, let alone relationships that demonstrate both unconformity and thrusting within the same site.

Description

The site can be subdivided into four sectors running down the coastline south-eastwards, from Braich y Pwll to Pared Llech-y-menyn, Trwyn Bychestyn, and Parwyd (Figure 7.25). The first two of these sectors expose different facies of the Gwna *mélange*, the third sector preserves the contact between the *mélange* and adjacent phyllitic schists, and the final part of the traverse includes the geologically complex cove of Parwyd, which exposes schists, gneisses and Ordovician sedimentary rocks.

Braich y Pwll to Porth Felen

This traverse provides the best-known and most photogenic exposures of Gwna Group *mélange*; the spectacular clasts of white quartzite in the cliffs of Trwyn Maen Melyn (Figure 7.26) are figured in several publications (e.g. Gibbons and McCarroll, 1993). The exposures are especially striking because they include not only large, distinctive masses of white quartzite, but also clasts of basaltic pillow lava and associated manganiferous limestone, plus various sandstones, red shales, and a peculiar sequence of fine-grained siliceous bedded rocks known as the Gwyddel Beds (Maley, 1928). Furthermore, the sector has excellent structural interest because one can trace a series of upright to south-easterly verging folds across the area, these structures folding an earlier foliation with associated recumbent folds (Figure 7.27).

The cliffs around Braich y Pwll expose typical Gwna Group *mélange*, comprising clasts of limestone, basic lava, red shales, various sandstones and Gwyddel Beds in a grey-green slaty matrix. This *mélange* is overlain by one of several

giant masses of bedded Gwyddel sediments, with a notable marker horizon of bedded red shales occurring at the boundary. The bedded, fine-grained sediments can be traced 500 m southwards; not only do they reveal many examples of upright (F_2) folds, but also rare examples of recumbent (F_1) structures (Gibbons, 1980). Farther south are further exposures of the underlying *mélange*, which continues for 400 m south-east to Trywn Maen Melyn, across superb exposures of *mélange* containing white quartzite (the Great Quartzite of Matley, 1928) and basaltic pillow lava. Farther south-east, the site follows the coast around the prominent hill of Mynydd y Gwyddel, type locality of the Gwyddel Beds (Figure 7.28). This part of the site is notable for preserving well-developed F_2 folds with prominent steep NW-dipping S_2 foliation. Porth Felen, which indents the coastline immediately east of Mynydd y Gwyddel, once again exposes the red shales that originally lay stratigraphically beneath the Gwyddel Beds.

Porth Felen to Pared Llech-y-menyn

The 400 m of extensive cliff exposures southeast of Porth Felen preserve some of the best examples of jaspery pillow lava-and-limestone *mélange* in the Gwna Group. Most of the exposures show large masses of purple basaltic pillow lavas, commonly with red jasper occurring between pillows. Despite the fact that the lavas are chaotically disrupted, the pillows within the larger masses of lava are so well preserved that they can easily be seen to be right way up. This illustrates how great slabs of rock were not overturned, but merely slid into position during the disruption that created the Gwna *mélange*. These exposures are also of interest because large slabs of brown, pyritic limestone occur mixed with the pillow lavas. One particularly large limestone slab is overlain by a well-exposed and accessible NW-dipping thrust, interpreted as a post-Ordovician (Acadian) compressive structure. A similar structure forms the cliff-base at Pared Llech-y-menyn, and separates gently dipping *mélange* on the shallow limb of a SE-verging F_2 fold from steeply dipping *mélange* in the footwall to the south-east.

Pared Llech-y-menyn to Parwyd

This cliff section provides good continuous exposure of the relationship between the Gwna Group *mélange* and a narrow belt of low-grade schists. These schists have been referred to by several authors (see interpretation below) as the 'Penmynydd Zone of Metamorphism', after the work of Greenly (1919) on similar rocks exposed on Anglesey. Although the same metamorphic zone is seen on the Penrhyn Nefyn foreshore, here is the only place where its relationship with the *mélange* is well exposed. Matley (1928) described the section as grading southeastwards from highly crumpled and disrupted metasedimentary rocks and lavas, passing rapidly into mica-schists and basic schists belonging to the Penmynydd Zone of Metamorphism. Shackleton (1956) ascribed this imperceptible transition to increasing recrystallization in which original textures are obliterated. The section immediately south-east from Pared Llech-y-menyn shows deformed, metamorphosed, upturned *mélange* containing clasts of red shales, basaltic lavas, limestone, white quartzite (Matley's Great Quartzite) and various other clastic sedimentary rocks immersed in a grey-green, semi-pelitic, foliated matrix. These exposures of deformed *mélange* grade south-east into fine-grained, highly foliated phyllites and, ultimately, into semi-pelitic (micaceous) and basic (actinolitic) schists, well exposed on the headland of Trwyn Bychestyn. These observations provide key evidence that the *mélange* is older than the 'Penmynydd' mylonitic schists of the Llŷn Shear Zone

Parwyd

The precipitous cove of Parwyd exposes remarkably varied geology: schists, gneisses, and Ordovician sedimentary rocks. The western side of the bay shows the 'Penmynydd' schists, of Trwyn Bychestyn, thrust south-eastwards over bedded Arenig rocks. The schists in the hanging wall show a sub-vertical foliation intensely corrugated by recumbent, thrust-related, F_3 folds. The central and eastern sides of the bay show Arenig strata faulted against, and locally unconformable on, retrogressed garnetiferous and felsic metamorphic basement known as the 'Parwyd Gneiss' (Greenly in Matley, 1928; Baker, 1969; Gibbons, 1980, 1983). This unit has been considered a component of the Sarn Complex by Gibbons (1980), Gibbons and Horák (1990, 1996) and Horák (1993). As this is regarded as part of the Cymru Terrane, rather than the Monian Composite Terrane to which the Gwna Group belongs, a summary of its lithological characteristics, geochemistry and age is given in the introduction to Chapter 6.

Interpretation

The Gwna mélange has been variously interpreted as having been produced by tectonic (endogenic) processes (Greenly, 1919) or large-scale sedimentary sliding and disruption. The latter idea was introduced to North Wales geology by Shackleton (1956) and later championed by Wood (1969). The outstanding exposures along the coast of south-west Llyn, especially those between Trwyn Maen Melyn and Braich y Pwll, have been cited by Wood and others as being typical of the olistostromic mélange. Both Shackleton (1969) and Wood (1969) have interpreted the undisrupted masses of Gwyddel Beds in this site as representing the stratigraphical top of the Gwna mélange, thus supporting the olistostrome model whereby a chaotic unit would be sandwiched between stratigraphically coherent, bedded sequences. Gibbons and Ball (1991) and Gibbons and McCarroll (1993) disputed this conclusion, arguing instead that the Gwyddel Beds were disrupted clasts within the mélange, the top of which was therefore not seen.

The transition between mélange and schist has also proven controversial. Most workers (Matley, 1928; Shackleton, 1956; Baker, 1969; Gibbons, 1983) have recognized a gradation from one to the other, with increasing metamorphic grade south-eastwards. Barber and Max (1979), on the other hand, believed that an unconformity existed between the higher-grade metamorphic rocks and the lower-grade mélange, a conclusion that created considerable debate. The idea of such an unconformity has not borne the test of detailed mapping (Gibbons and McCarroll, 1993). Another controversy concerns the relationships between schist and gneiss. Shackleton originally believed that the schists graded into the Parwyd gneisses by pro-grade metamorphic transition. Subsequently, Baker (1969) recognized that the schists occurred within a zone of intense shearing deformation and introduced the term 'blastomylonite' to describe the schists. Gibbons (1983) recorded how the gneisses have been retrogressed by shearing. He further recognized that the Penmynydd Zone of Metamorphism on Llyn represents a shear zone that is a continuation of that seen farther north at the Penrhyn Nefyn GCR site. This separates two quite different rock units: the Gwna Group mélange to the north-west, and the Sarn Complex, to which the Parwyd gneisses probably belong, to the southeast. It follows from the discussion in Chapter 1, that the Penmynydd Zone is also a terrane boundary along which the Monian Composite Terrane (Gwna Group) is juxtaposed with the Cymru Terrane (Parwyd Gneiss–Sarn Complex).

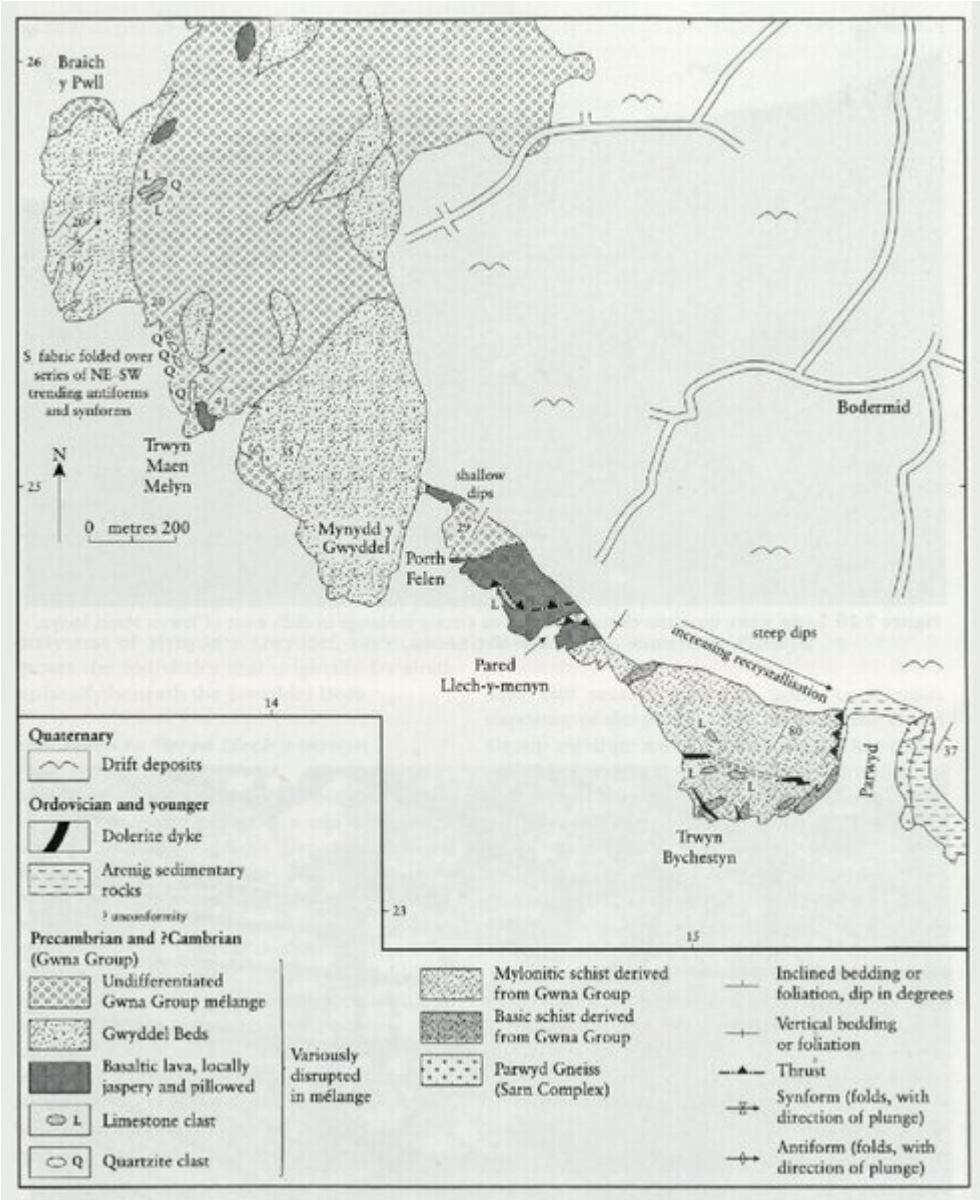
To summarize why the interpretations of this site are so important it is firstly necessary to state that the exposures of Gwna mélange are truly world class and are certainly internationally famous. Any interpretation of this spectacular but enigmatic unit (and mélanges in general) is likely to focus on the exposures within this site. Secondly, one of the major revolutions in geological understanding in the second half of the 20th century was the recognition of the kinematic significance of shear zone lithologies. The Shackleton–Baker debate over the schist-gneiss relationships was a necessary precursor to the general recognition of mylonitic rocks in the basement to southern Britain and an understanding of their importance to the Precambrian plate tectonic framework of north-west Wales and Anglesey (this is discussed further in the account of the Penrhyn Nefyn GCR site). Finally, exposures from this site demonstrate clearly the presence of a pre-Arenig tectono-metamorphic episode and the overprinting of a post-Arenig (Acadian) compressional deformation.

Conclusions

The rocks exposed in this site are of special interest because of their exceptional variety (many different types, including superbly graphic examples of jaspery pillow lavas) and because their interpretation has provided a hotbed of controversy that has helped evolve our present understanding of the geology of North Wales. Mélanges are unusual, chaotic rock units that are found worldwide and are commonly associated with subduction zones at destructive plate boundaries. Many such mélanges have been described, but that within the Gwna Group remains the first ever recorded (by Greenly in Anglesey, 1919). The mélange exposures within this site are the best in Anglesey and Llyn, and have justifiably gained the reputation of world class. The gradation between this mélange and the more highly metamorphosed rocks to the south-east illustrates how shearing deformation and metamorphism can transform such a mélange into mylonitic schist. The Parwyd Gneiss, though poorly exposed, represents the only outcrop of high-grade metamorphic basement in mainland North Wales. Furthermore the unconformity with overlying Arenig strata is one of only three such occurrences in Llyn, its significance being that it constrains the deformation in the mélange to a pre-Arenig age. Finally, not only does this site preserve a rare sub-Ordovician unconformity, it also exposes several examples of post-Ordovician thrusts

produced when the Welsh Basin was subjected to Acadian deformation in late Silurian and early Devonian times.

References



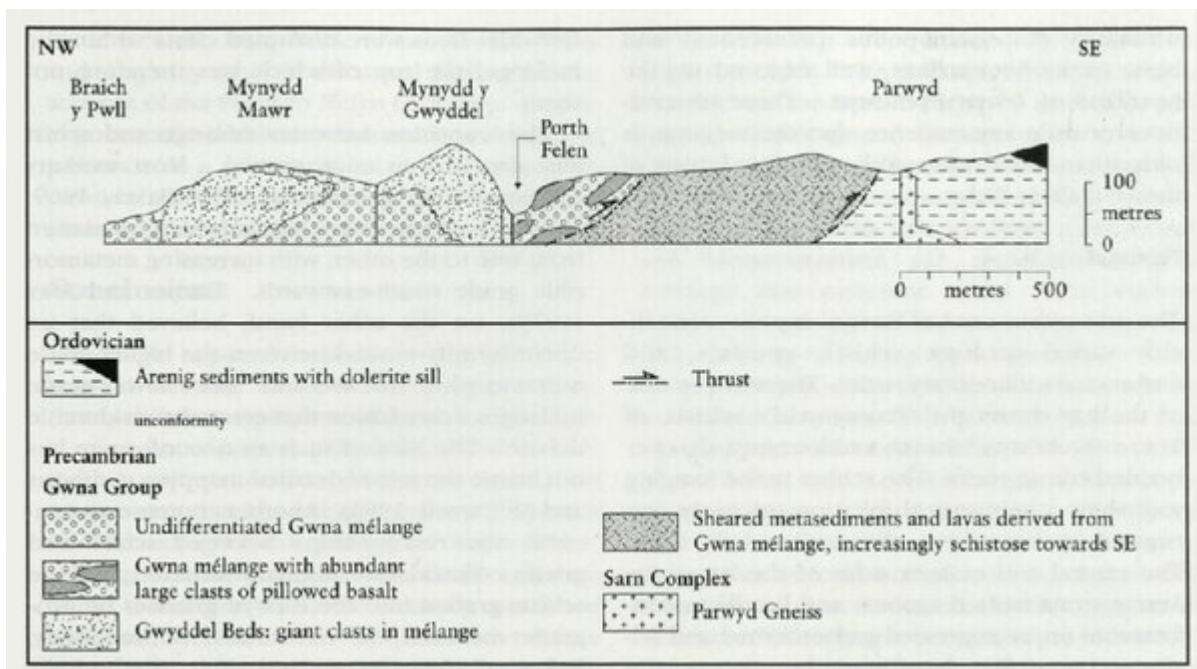
(Figure 7.25) Geological map of the south-west Llyn, Braich y Pwll to Parwyd site. For cross section, see (Figure 7.28)



(Figure 7.26) Large white quartzite clasts within Gwna Group *mélange* in cliffs west of Trwyn Maen Melyn.



(Figure 7.27) Early recumbent folds in 'Gwyddel Beds' south of Braich y Pwll. (Photo: W. Gibbons.)



(Figure 7.28) Geological cross-section (see (Figure 7.25)): Braich y Pwll to Parwyd (looking north-east).