Chapter 7 Anglesey and the Lleyn Peninsula (Ll■n)

Introduction

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The sites covered in this chapter lie within, or to the north-west of, the Menai Strait Fault System (Figure 7.1) and represent the most lithologically varied suites of Precambrian rocks in southern Britain. Exposures cover the island of Anglesey (Ynys Mon) and extend to the south-west along the north-western side of the Lleyn Peninsula (Ll■n), on the mainland, as far as Bardsey Island (Ynys Enlli). Greenly (1919) referred to these rocks as the Mona Complex, a term now superseded by the concept of several Monian fault-bounded blocks or 'terranes', each with a distinct tectono-metamorphic history (Bassett *et al.,* 1986). These have been collectively termed the Monian Composite Terrane, as discussed further in Chapter 1. The more complex histories of these terranes, which include polydeformed blueschists, distinguishes them from the 'British Avalonian Terranes' located to the south-east of the Menai Strait Fault System, thus making the latter a major terrane boundary (Gibbons, 1987).

Three rock masses of this region can be further classified as individual terranes in their own right. Such nomenclature forms the basis of the GCR network systems (Figure 1.5), and is compared with the equivalent lithostratigraphical names of the units as follows:

- Coedana Complex — Coedana Terrane of Chapter 1
- Eastern Schist Belt — Aethwy Terrane
- Monian Supergroup — 'Monian Supergroup Terrane'

The following sections provide introductory details of each of these terranes and where available include evidence for their age. In recent years, palaeontological and stratigraphical evidence has been presented to suggest that all or part of the Monian Supergroup may have an early Cambrian age (Barber and Max, 1979; Muir *et al.,*1979; Peat, 1984b; Tietzsch-Tyler and Phillips, 1989; Bennett *et al.,* 1989; Gibbons *et at,* 1994). In view of the considerable uncertainty still surrounding the precise age of this sedimentary sequence, the GCR sites relating to the Moinian Supergroup have been retained within this chapter to maintain continuity and context with the regional geology

Greenly (1919, 1920) published the first detailed work on the Monian rocks of Anglesey, producing a memoir and the linework and colour on the accompanying, still current, BGS map. He divided the Monian rocks into granite and hornfels, gneisses, low-grade predominantly metasedimentary rocks, and a belt of schist outcropping in central and eastern Anglesey. Originally interpreting the granite (Coedana Granite) to post-date the metasedimentary rocks, he later reconsidered this and interpreted the gneisses, granite and hornfels as forming their ancient basement. This model stood unopposed until Shackleton (1954, 1956) introduced a key revision of Monian stratigraphy by recognizing the use of way-up criteria within the metasediments. Shackleton (1954, 1956, 1969) also attempted to revise Greenly's interpretation of the metamorphic history of the Monian rocks. He presented a model whereby the granite was interpreted as the anatectic product of metamorphism of the low-grade sediments, with the schists and gneisses representing intermediary stages. Studies of the Monian rocks on USTI reinterpreted the schist belts as ductile fault zones (Gibbons, 1983) and this led the way both to an abandonment of Shackleton's *prograde metamorphic transition'* and the development of a terrane model for the Monian rocks. Bassett *et al.* (1986) defined three terranes; the Coedana Complex, the Monian Supergroup and the Eastern Schist Belt, separated from each other by brittle faults, or by ductile shear zones such as the Central Anglesey Shear Zone of (Figure 7.1). Each terrane has by definition had a separate history and unproven relationships to the other terranes.

Coedana Complex

The Coedana Complex, described in the Tyddyn Gyrfer, Maengwyn Farm and Gwalchmai site reports, has three components: low-grade hornfels, high-grade metamorphic rocks (the Central Anglesey Gneisses), and the Coedana

Granite, which crops out over an area of 30 km^2 and volumetrically forms the most important component. The mapping and petrological work of Greenly (1919), supplemented by the work of Horák (1993), shows both porphyritic and non-porphyritic varieties with a variation in mineralogy from biotite- and minor garnet-bearing, to highly leucocratic, muscovite and garnet-bearing granite and aplite. Garnet compositions have been confirmed as spessartine-rich from the leucocratic facies (Horik, 1993). All facies are pervasively affected by ductile deformation, such that the intrusion can be classified more accurately as a protomylonitic, or locally mylonitic, metagranite (Horák, 1993). Both the mineralogy and the whole-rock geochemistry confirm the calc-alkaline, subduction zone affinity of the intrusion. A U-Pb zircon age date of 614 ± 4 Ma (Tucker and Pharaoh, 1991) supports *c.* 600 Ma ages obtained by previous workers (e.g. Fitch *et al.*,1964, 1969; Moorbath and Shackleton, 1966; Beckinsale and Thorpe, 1979), and the upper intercept of 1443 Ma for the discordia is consistent with the $\in$Nd model ages of 1300–1430 Ma (Davies *et al.,* 1985), indicating derivation of the granite from an older crustal source.

In comparison with the Coedana Granite, since the initial work of Greenly (1919), little work has been undertaken on the gneisses; specifically, their relationship with the granite and hornfels remains unproven as contacts between these units are either faulted or unexposed. Like the granite, the gneisses have suffered considerable retrogression and are overprinted by much brittle deformation. This is most likely Palaeozoic in age, as the most highly deformed outcrops of gneiss lie as slivers within the Carmel Head Thrust System (Gibbons *et al.,* 1994), a structure attributed to movements during the Acadian Orogeny. Paragneisses, ranging from pelite to semi-pelite, but also including minor outcrops of calc-silicates, are associated with amphibolite. The local presence of sillimanite and migmatitic textures provides evidence for upper amphibolite facies conditions of metamorphism, as seen at the Tyddyn Gyrfer GCR site. The gneisses are especially important to our understanding of the Avalonian of southern Britain as they are the only examples of high-grade metamorphic rocks. They also allow correlations to be made with the Rosslare Complex of south-east Ireland, providing some indication of the original extent of these late Precambrian terranes.

Eastern schist belt

A narrow (< 5 km), NE–SW oriented, and fault-bounded belt of blueschists and associated rocks, defining the Aethwy Terrane (Chapter 1), crops out in south-east Anglesey. Greenly (1919) referred to this metamorphic belt as the Aethwy unit of the 'Penmynydd Zone of Metamorphism', a term that has fallen into disuse as it includes several, apparently unrelated schistose units. The metamorphic rocks of south-east Anglesey, though small and poorly exposed, are famous worldwide for preserving some of the oldest, and yet still mineralogically fresh, blueschists on Earth (Marquis of Anglesey's Column and Penrhyn Nefyn sites). The rocks are dominantly metasedimentary phengitic mica schist and metabasaltic glaucophane schist, although lawsonite schist and spessartine-rich metasediments have also been recorded (Gibbons and Mann, 1983; Gibbons and Horik, 1990). Blueschist metamorphism was accompanied by intense deformation, producing a mostly flat-lying foliation, isoclinal folds and a north–south trending mineral lineation.

The geochemistry of the basic rocks within the Anglesey blueschist reveals a strong MORB (mid-ocean-ridge basalt) signature (Thorpe, 1972c; Phillips, 1989) and suggests that these rocks represent a slice of Precambrian oceanic crust. ^{40}Ar–^{39}Ar cooling ages derived from amphiboles in the blueschist indicate a latest Precambrian age (560–550 Ma; Dallmeyer and Gibbons, 1987). Such ages are interpreted as having been produced during rapid uplift of the blueschists through their mineral blocking temperatures (*c.* 500°C) during oblique movements on the Menai Strait Fault System (Figure 1.4). Slightly older ages (580–590 Ma; Dallmeyer and Gibbons, 1987) have been obtained from a metagabbroic protolith to one of the blueschist metabasites, and are interpreted as recording an earlier sub-seafloor-metamorphism (Gibbons and Gyopari, 1986).

The north-western margin of the Anglesey blueschist belt is characterized by a steep, schistose, high strain zone referred to as the Berw Shear Zone. High-level brittle movements along this lineament have juxtaposed Carboniferous sedimentary rocks against Precambrian blueschists (Greenly, 1919). Most of the southeastern margin of the blueschist belt is covered by an unconformable Carboniferous sequence, but north of the Menai Bridge the schists are in tectonic contact with the Gwna Group mélange (Gyopari, 1984). All contacts between the Anglesey blueschists and other rocks therefore are either unconformable or tectonic. The blueschists are interpreted as having originally belonged within a Precambrian accretionary prism (Figure 1.4), one small slice of which has been preserved within the Menai Strait Fault System. The latter structure is interpreted as just one of a family of such terrane boundaries, running sub-parallel to the

former Avalonian subduction-related faults, that dispersed slivers of the subduction system as plate convergence became progressively more oblique through latest Precambrian times (Gibbons and Horák, 1996). One consequence of this was the tectonic incorporation of Arfon-type' volcanic-arc lithologies, such as the Bwlch Gwyn Tuff, within the Berw Shear Zone (Figure 7.1), as discussed further in the introduction to Chapter 6. It follows from this model (Figure 1.4) that all the Precambrian rocks of southern Britain, along with those of Nova Scotia and Newfoundland, Canada, could belong to the same Avalonian subduction system.

Monian Supergroup

The Monian Supergroup, originally described by Greenly (1919) as the 'Bedded Succession', is a thick (up to 7.5 km) tripartite sequence of low-grade metamorphic rocks dominated by metasediments. The base of the supergroup is not seen, and the highest unit is overlain unconformably by Arenig strata. The three units that together comprise the supergroup are as follows.

- Gwna Group, spectacular mélange with no coherent internal stratigraphy (Ogof Gynfor, Penrhyn Nefyn and Braich y Pwll and Parwyd sites).
- New Harbour Group, mostly semi-pelites but locally containing basalt, gabbro and serpentinite (Cae'r Sais site).
- South Stack Group, which mostly consists of psammitic meta-turbidites; it is the oldest component of the Monian Supergroup (South Stack and Rhoscolyn sites).

Shackleton (1954, 1969) used sedimentary structures preserved within the South Stack Group to prove this meta-turbiditic sequence to be right-way up, thus revising Greenly's (1919) initial interpretation. A later controversy was provoked by Barber and Max (1979), who argued for a tectonic contact between a supposedly older New Harbour Group and underlying South Stack Group. This was similarly disproved by various authors, notably Cosgrove (1980). The Gwna Group incorporates various other lithostratigraphical units, previously named as the Skerries and Fydlyn groups (Greenly, 1919; Shackleton, 1969), but these names have become disused as all of these rocks are essentially part of the same chaotic mélange (Gibbons and Ball, 1991). An alternative view of Phillips (1989, 1991), however, was that the Skerries unit is part of the New Harbour Group.

The age of the Monian Supergroup is poorly constrained, and has been variously referred to as Precambrian and Cambrian (Gibbons *et al.,* 1994). A minimum age is provided by the overlying late Arenig (Fennian) sediments, and a maximum age is provided by clasts of granite within the Gwna Group (Horák *et al.,* 1996) that resemble, and are correlated with, the Coedana Granite (614 Ma). Less definitive is the presence of (?Precambrian) stromatolites in Gwna mélange limestone clasts, the possible presence of ?Cambrian microfossils in cherts associated with pillow-lava clasts in the mélange, and supposedly Cambrian *Skolithos* burrows in the South Stack Group (Barber and Max, 1979;Muir *et al.,* 1979; Peat, 1984b). Lithostratigraphical correlations with the Cullenstown Formation, exposed in south-east Ireland, suggest that the Monian Supergroup could be Cambrian rather than Precambrian (Bennett *et al.,* 1989; Tietzsch-Tyler and Phillips, 1989; Gibbons *et al.,* 1994).

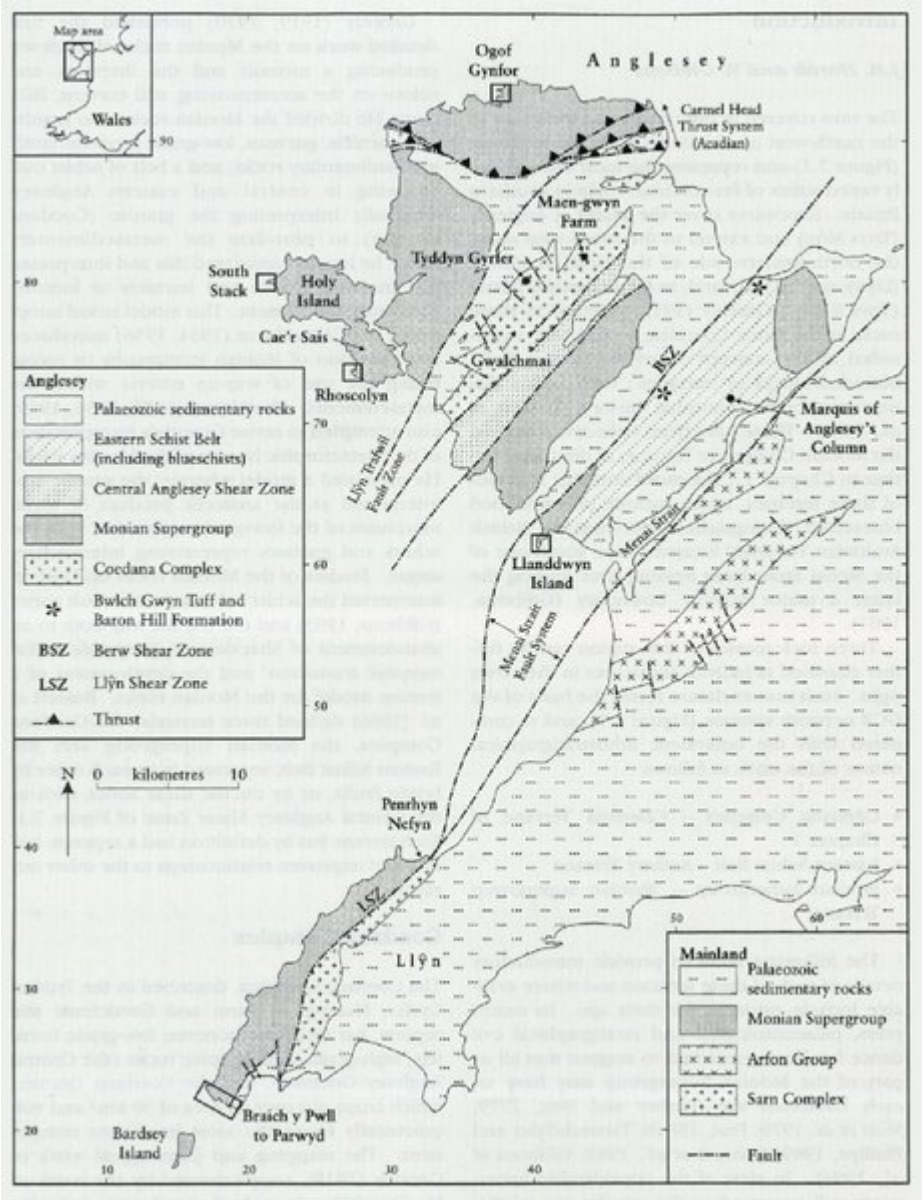
The presence of calc-alkaline igneous detritus in some parts of the New Harbour Group, combined with the geochemistry of the basalt contained within this group, suggests a subduction-related tectonic setting (Thorpe *et al.,* 1984; Phillips, 1989; Gibbons *et al.,* 1994). Its sedimentary rocks contain detritus indicative of their derivation by the progressive unroofing of an andesitic volcanic arc, although Phillips (1991a) notes that the arc was probably extinct by this time. The South Stack Group, on the other hand, contains detritus indicative of a quartzose to mixed recycled orogenic provenance (Phillips, 1991a). It may represent part of a submarine fan complex within a forearc or backarc basin, or may have been deposited within a later (Cambrian) basin that received detritus from a Precambrian arc being degraded during strike-slip dispersal of an extinct Avalonian subduction system (Phillips, 1991a). The Gwna Group mélange contains oceanic pillow basalt associated with deep-water cherts and limestone, and may represent the higher levels of a subduction-related accretionary prism, or some collision-related olistostrome.

The Monian Supergroup commonly exhibits polyphase deformation, especially on Holy Island in western Anglesey, and along the west and south-west coast of Ll■n. The exposures around Rhoscolyn and South Stack on Holy Island are spectacular, revealing several generations of folds and related cleavages: these are the best exposures of polydeformed

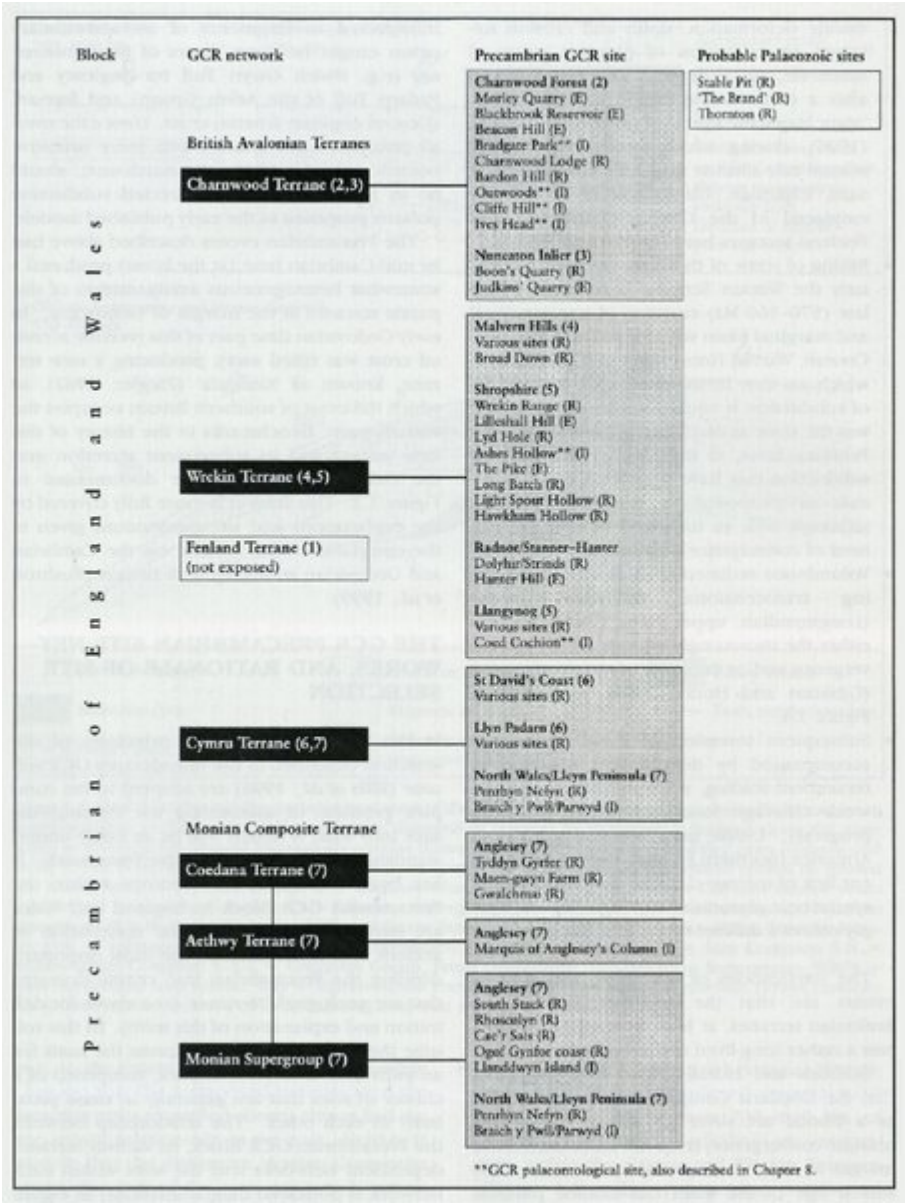
rocks in southern Britain. The ages of these deformations are, however, poorly known. It is unclear how many of the fold generations owe their origin to late Caledonian (Acadian', i.e. ?late Silurian to early Devonian) compression, and whether some of the early phases relate either to Precambrian or Cambrian–Tremadoc deformation events, or both.

It should be noted that two of the following GCR sites (Penrhyn Nefyn and Braich y Pwll to Parwyd) contain the boundary between the Monian and Cymru terranes (Chapter 1), and as a result they expose lithologies more appropriate to the latter. These constitute the Parwyd Gneiss and the Sarn Complex, which are for convenience described here but whose origins, age and geochemistry are discussed in the introduction to Chapter 6, along with the other rocks of the Cymru Terrane.

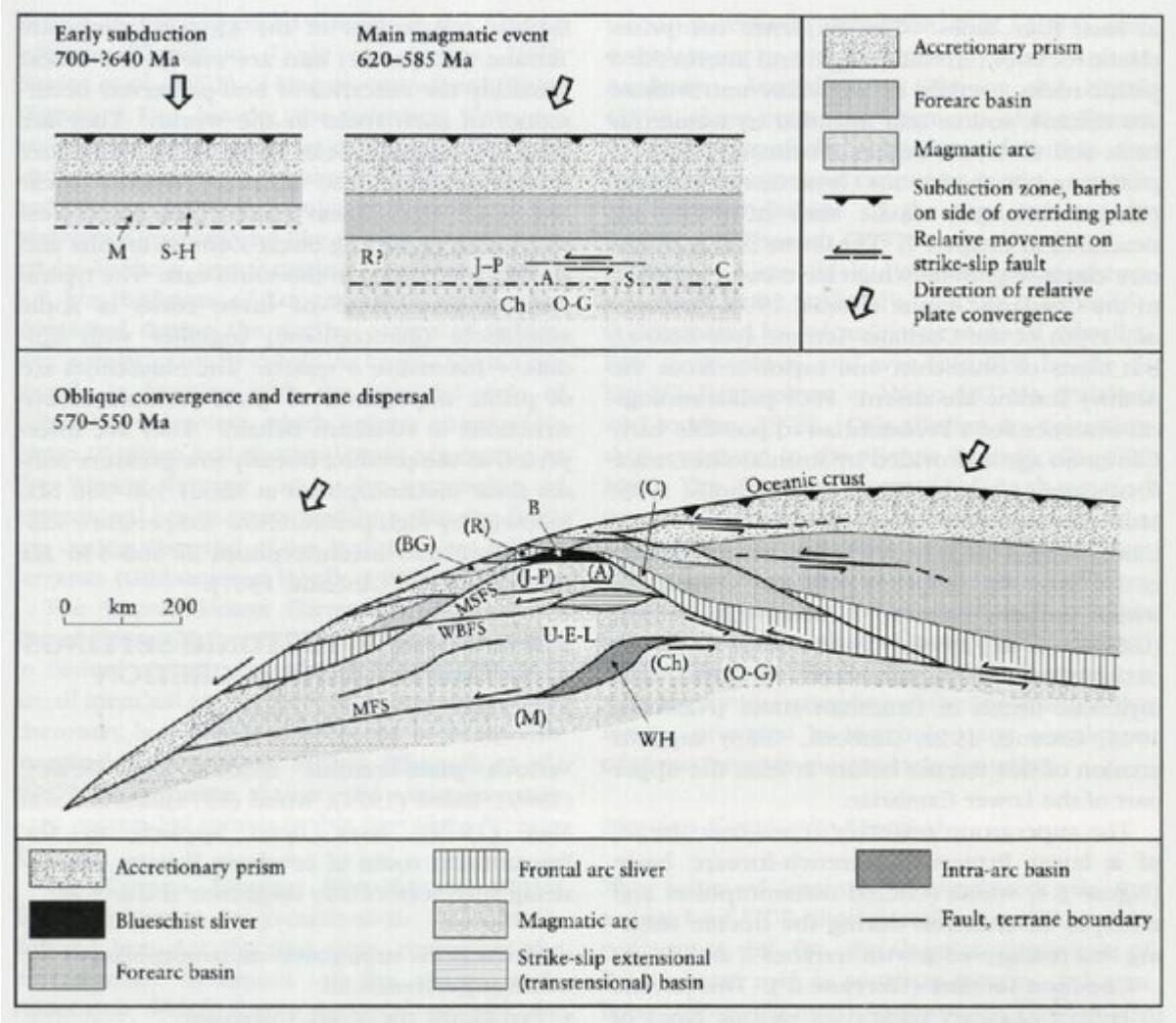
References



(Figure 7.1) Geological map showing simplified geology and location of GCR sites (bold lettering) in the Anglesey–Llŷn region.



(Figure 1.5) Diagram showing the relationship between Precambrian terranes, GCR networks and site clusters. Figures in brackets refer to the relevant chapters in which the descriptions occur. Letters in brackets indicate the JNCC scientific 'ranking' of each site (see text for explanation). Note that sites with probable Palaeozoic rocks are treated outwith the main GCR site networks.



(Figure 1.4) Model for the late Precambrian evolution of the Avalonian subduction system: episodic Precambrian magmatism (top two cartoons) followed by the dispersal of terranes by transcurrent faulting along the plate margin as convergence became increasingly oblique during the latest Precambrian (modified from Gibbons and Horik, 1996). Note that the presence of the Monian Composite Terrane within this system cannot be proved until Arenig time. A = Arfon Group; B = Anglesey blueschists; BG = Bwlch Gwyn Tuff and related strata (Anglesey); C = Coedana Complex; Ch = Charnian Supergroup; J-P = Johnston Plutonic Complex and Pebidian Supergroup; M = Malverns Complex; MFS = Malverns lineament or fault system; MSFS = Menai Strait fault system; O-G = volcanics in Orton and Glinton boreholes; R = Rosslare Complex; S = Sam Complex; S-H = Stanner-Hanter Complex; U-E-L = Uriconian Group, Ercall Granophyre, Longmyndian Supergroup; WBFS = Welsh Borderland fault system; WH = Warren House Formation. The same letters in brackets (lower cartoon) refer to the relative positions of those volcanic belts that were by then extinct.