Chapter 6 Introduction to Ordovician stratigraphy

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History

The Ordovician System was proposed by Lapworth (1879a) for the strata 'between the base of the Lower Llandovery Formation and that of the Lower Arenig', and he referred particularly to the rock successions in North Wales. His object was not only to still the controversy over the limits of the Cambrian and Silurian systems, as outlined in Chapter 2, but also to give expression to what he perceived to be the three natural divisions of the Lower Palaeozoic, as characterized by three 'Silurian' faunas distinguished in Bohemia by Barrande (1852) — the First or Primordial Silurian fauna (i.e. the Cambrian), the Second or Lower Silurian fauna (i.e. the Ordovician) and the Third or Upper Silurian fauna (i.e. the Silurian). The development of the Ordovician concept is traced by Holland (1974), Bassett (1979) and Webby (1998). In Britain, the Geological Survey, which was at that time directed by Murchison's protege Geikie, resisted official acceptance of Lapworth's Ordovician System for the next 20 years. However, use of the Ordovician was one of many changes adopted at the time of the reorganization of the Geological Survey, when Teall replaced Geikie as Director in 1901 (Oldroyd, 1990, chapter 10). In 1903 the US Geological Survey likewise adopted the Ordovician System (Yochelson, 1997), and this was doubtless influential in its wider acceptance. The principal change from Lapworth's original proposal is the international agreement to include strata of Tremadoc age at the base of the system.

Distribution

Ordovician stratigraphy in Britain is much more complicated than that of the Cambrian. This is mainly because of the changes from settings at passive plate margins to subduction-related active margins, with their associated volcanic rocks and tectonism. Chapters 7–11 discuss the Anglo-Welsh area south of the Iapetus suture, the Scottish Ordovician, which is no less complicated, being discussed in Chapters 12–15.

Two widespread unconformities within the Ordovician of England and Wales were used by Woodcock (1990) to mark the boundaries separating three megasequences, which he traced throughout the region. In the Welsh Basin the lower unconformity lies below the Rhobell Volcanic Group just below the base of the Arenig and is related to the onset of subduction. It separates the Tremadoc rocks at the top of the Dyfed Supergroup, which follow the Cambrian conformably or paraconformably, from the base of the Gwynedd Supergroup. Tremadoc rocks are thus separated from the remainder of the Ordovician and are treated as a unit in Chapter 7. In North Wales there are outcrops of Tremadoc rocks important both historically and in relation to the Cambrian—Ordovician boundary (Figure 3.2). In South Wales there are few outcrops of the Tremadoc and the strata are more akin to the thick successions of the Welsh Borderlands (see (Figure 7.2)) that extend across central England, where, however, they are poorly exposed and are known mainly from boreholes.

The upper of Woodcock's (1990) 'basin-wide' unconformities lies close to the base of the Ashgill Series and in Wales separates the Gwynedd from the Powys Supergroup. It marks the closing down of major volcanic activity and the cessation of active subduction and is much less conspicuous than the unconformity below the Arenig. In both Wales and England, therefore, the sequences of Arenig to Ashgill are taken together, being discussed in Chapters 8–11, each dealing with a main area.

The most complete sedimentary successions are seen along the Tywi lineament in South Wales (Chapter 8). In this region (see (Figure 8.1)) the Arenig is particularly well developed, and the Llanvirn and Llandeilo series were originally proposed to encompass strata there. There are lateral and vertical transitions from neritic shelly facies to graptolitic shales but only relatively local intercalations of volcanic rocks, as in the Builth Inlier, which is appended to this chapter (see (Figure 8.25)).

In North Wales, Arenig to Ashgill stratigraphy, dominated by successions reflecting a series of volcanic episodes, is complicated by the interfingering of sedimentary and volcanic units. In Snowdonia and L15'n alone, Rushton and Howells (1998) catalogued nearly 100 named divisions of the Gwynedd Supergroup, with over 20 more that are synonyms or of doubtful value. Of these, the volcanic rocks are considered in a companion volume (Stephenson *et al.,* 1999) and a modest number of the sedimentary divisions, including parts of the historic Arenig and Bala series (see (Figure 9.1)), are described here in Chapter 9. The Gwynedd Supergroup extends in attenuated form onto Anglesey, which lies on the Monian Terranes (see (Figure 9.13)). The Ashgill strata at the base of the Powys Supergroup include Hirnantian rocks that show the effect of the end-Ordovician glacio-eustatic drop in sea level.

The Ordovician appears in two main areas in the county of Shropshire and adjoining parts of Wales (see (Figure 10.1)). To the west of the Long Mynd horst, the lower half of the Ordovician is thickly developed in the Shelve area on the downthrown side of the Linley–Pontesford Fault. To the east, on the east side of the Church Stretton Fault, the classical Caradoc area exposes almost the whole of the Caradoc Series (Chapter 10). Apart from the Tremadoc, the Ordovician is little known over most of central England. The Lickey Quartzite south-west of Birmingham, formerly doubtfully assigned to the Cambrian, is now referred to the Ordovician (Old *et al.,* 1991), and Molyneux (1991) reviewed borehole records, for example of Llanvirn strata near Eyam (Derbyshire) and Huntingdon (Rushton and Hughes, 1981), and of Caradoc strata in Kent (Lister *et al.,* 1969).

In the ocean-facing setting of northern England (Chapter 11), Ordovician rocks crop out in the main Lake District Inlier and in the smaller Cross Fell, Cautley and Craven inliers (Figure 6.1), which are brought up along the Pennine, Dent and Craven fault systems. There are places where the unconformities that bound Woodcock's (1990) Megasequence II are not apparent. The Lake District has a thick sedimentary succession (Skiddaw Group) extending from the upper Tremadoc continuously to the Llanvirn, and comparable sequences make up much of the Isle of Man. In both the Lake District and Cross Fell the Skiddaw Group successions are followed unconformably by thick are volcanics, notably the Borrowdale Volcanic Group of possible late Llanvirn to early Caradoc age (Molyneux, 1988). These are overlain, again unconformably, by marine sediments of mid-Caradoc age, and the fullest knowledge of the succession from the mid-Caradoc to the top of the Ashgill has been derived in this area by piecing together sections from various of the inliers, especially those at Cross Fell and Cautley (see (Figure 11.6)), where the successions show no hiatus equivalent to the sub-Powys unconformity.

Unconnected with any other outcrop of the British Ordovician is the tiny exposure in southwest England at Gorran Haven in Cornwall. Blocks of shallow-water feldspathic quartzites embedded in a slaty matrix, known as the Gorran Quartzites, contain trilobites (Sadler, 1974) and brachiopods (Bassett, 1981) of approximately Llandeilian age. The trilobites are most comparable with those of such Armorican quartzite formations as the Gres de May of Normandy. The Gorran Quartzites are thought to be fragments of an Armorican quartzite shed into an olistostrome deposit formed during the mid- or late Devonian, during the last stages of the closure of the Rheic Ocean (Cope *et al.,* 1992).

The Ordovician of northern Scotland (Chapter 12) is present as part of the foreland sequence of the Hebridean Terrane, where it forms outliers on the Cambrian at Durness and Balnakeil (see (Figure 12.1)), and also on the Island of Skye. The question of whether the Dalradian Supergroup contains rocks of Lower Palaeozoic age, discounted by Brasier *et al.* (1992b), has been reopened by Molyneux (1998), who recognized the presence of an undoubted acritarch of early Ordovician type reportedly from the Macduff Slates of Banff, at the top of the Dalradian succession in the Banff Nappe. Nearly 200 km south-west of Macduff, at the northern edge of the Midland Valley Terrane, there are small outcrops of Ordovician rocks along the Highland Boundary Fault Complex from Arran to Stonehaven, but only the Dounans Limestone at Lime Craig Quarry is well dated (Chapter 13). At the southern edge of the Midland Valley Terrane the celebrated Ordovician of the Girvan district (Chapter 14) is a thick sequence deposited against and over scams created by steeply dipping south-facing growth faults. In the Southern Uplands Terrane the Ordovician is mainly developed as a thick imbricated succession in the 'Northern Belt', but there are important faulted inliers in the 'Central Belt' to the south (Chapter 15).

Boundaries of the Ordovician system

Lower boundary

The differing views on the most appropriate level for the base of the Ordovician were touched on in Chapter 2 (Introduction to the Cambrian). An international working group set up to resolve the problem agreed that a level at or close to the base of the Tremadoc should be adopted for the Cambrian–Ordovician boundary (Norford, 1988). Subsequently the working group recommended that the stratotype should be defined in the section at Green Point, northwest Newfoundland, and at present (1999) ratification is pending (Webby, 1998). The level is to be taken at the appearance of a species of the conodont *Iapetognathus,* and as it lies just below the appearance of subspecies of the graptolite *Rhabdinopora flabelliformis,* it is very close to the base of the Tremadoc Series at Bryn-llin-fawr in Wales recommended by Rushton (1982). A volcaniclastic sandstone high in the Merioneth Series has been dated at 491 ± 1 Ma (Davidek *et al.,* 1998), showing that the age of the Cambrian—Ordovician boundary is close to 490 Ma (see the site report for Ogof Ddû, in chapter 3).

Upper boundary

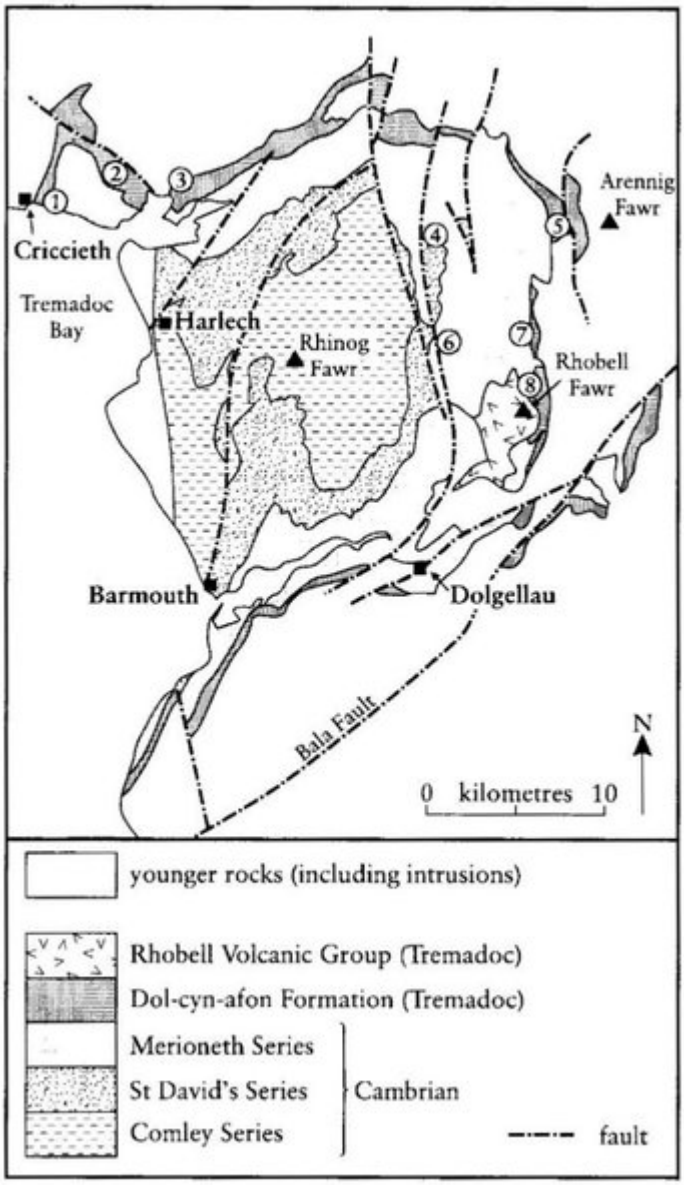
The top of the Ordovician is defined by the stratotype base of the overlying Silurian. In Britain this had for many years been taken at the base of the *persculptus* graptolite zone, both in the Welsh Basin and at Dob's Linn in Scotland. As recounted by Cocks (1988), when an international working group was formed to discuss the matter, agreement was better served by taking the base of the overlying *acuminatus* Zone (Cocks and Rickards, 1988, p. 6), and a stratotype base was defined at this level at Dob's Linn in southern Scotland. Tucker *et al.* (1990) derived ages of 446 ± 2 Ma for metabentonites in the upper part of the upper Ordovician *anceps* Zone and of 439 ± 2 Ma for the lower Silurian *cyphus* Zone, from which they interpolated an age of about 441 Ma for the Ordovician—Silurian boundary; this was revised to 443 Ma by Tucker and McKerrow (1995), from which it is inferred that the duration of the Ordovician was nearly 50 Ma.

Divisions of the British Ordovician

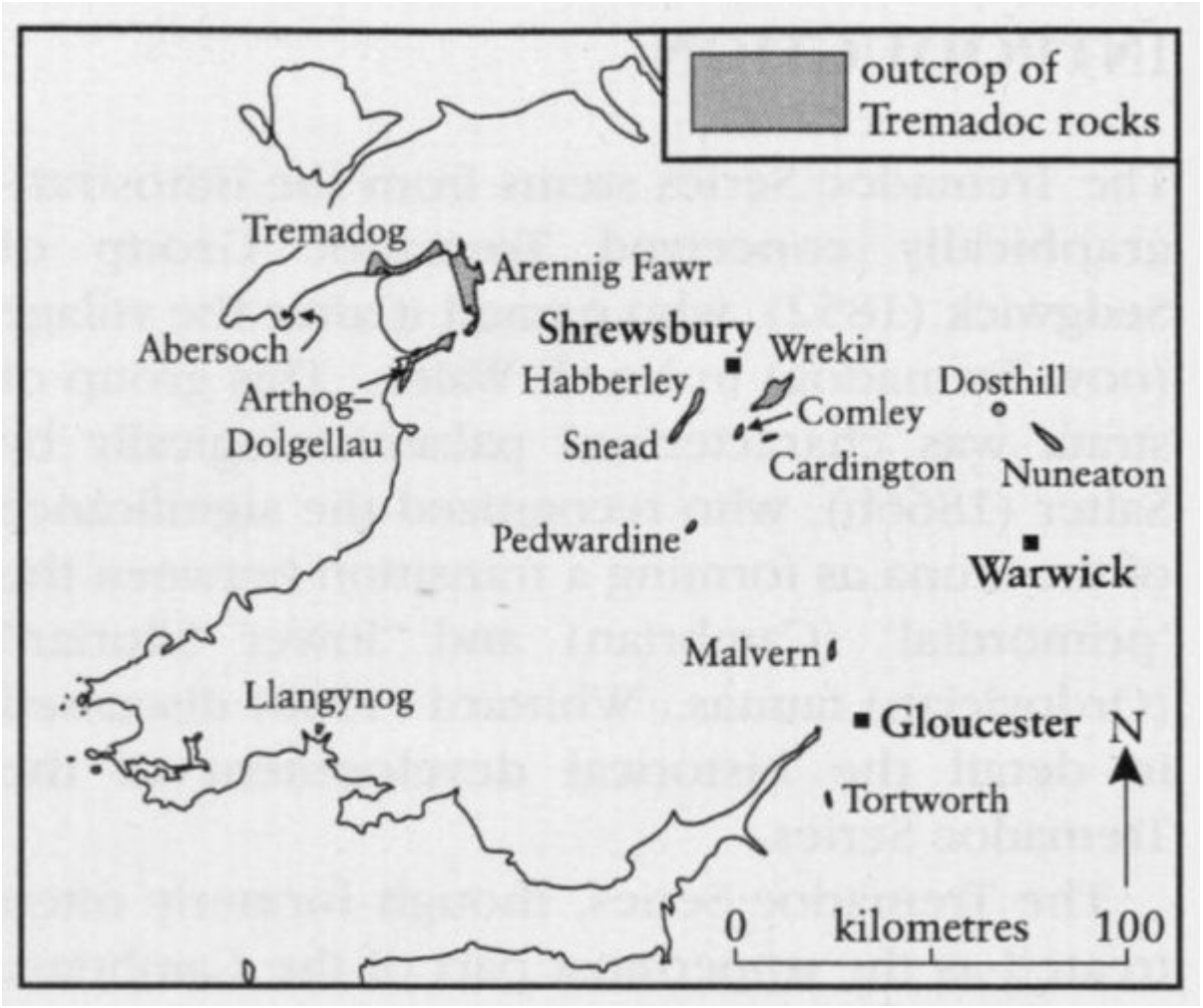
The synthesis by Williams *et al.* (1972) used the traditional series of the Ordovician: Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill. Of these, only the Caradoc and Ashgill were at that time divided into named stages. Subsequent reviews by Whittington *et al.* (1984) and Fortey *et al.* (1991) also considered the Tremadoc and sought to clarify the status of all the series and make them more useful for international correlation. Most recently, Fortey *et al.* (1995) revised the series by reducing the Llandeilo to the status of a stage within the Llanvirn and extending the base of the Caradoc down to the base of the *gracilis* graptolite zone, a level at which some earlier workers had already placed it. They introduced two new stages for the Tremadoc Series and employed the three Arenig stages introduced by Fortey and Owens (1987), though recognizing that the base of the lowest stage, the Moridunian, has yet to be defined. The Llanvirn comprised the new Abereiddian overlain by the newly formulated Llandeilian. Fortey *et al.* (1995) reorganized the Caradoc by reducing to substages the eight existing stages, grouping them into four larger stages of wider correlative potential. Webby's (1998) review of international Ordovician stratigraphy gave the chronostratigraphical classification proposed by Fortey *et al.* (1995), and their scheme is adopted here (Figure 6.2).

Several fossil groups, such as acritarchs, brachiopods, conodonts and trilobites, have been used to set up zonal schemes for parts of the Ordovician succession, some of them only for local use. The principal zonal scheme used, however, is based on graptolites (Figure 6.2). This scheme, and some of the problems in its use, were reviewed by Rushton (1990). Changes to some of the Arenig zones follow the suggestions of Cooper *et al.* (1995), and the division of the *clingani* Zone into two subiones follows Zalasiewicz *et al.* (1995). Rather than use the name '*foliaceus* Zone' (Fortey *et al,* 1995), the name '*multidens* Zone' is retained here, pending revision of the zone itself, following Rushton's (1990) recommendation.

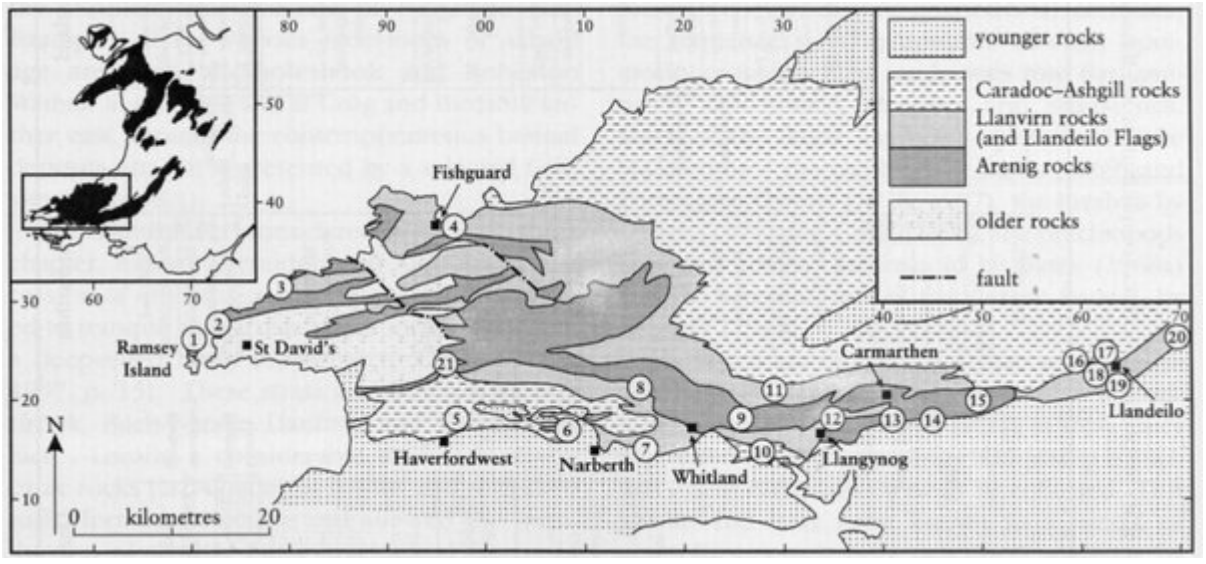
References



(Figure 3.2) Geological sketch-map of the Harlech Dome, after the British Geological Survey (1994b). Cambrian and Tremadoc GCR sites are as follows: 1, Ogof Ddû; 2, Tyn-llan and Wern; 3, Y Garth; 4, Afon Llafar; 5, Amnodd Bwll; 6, Nant-y-graean; 7, Bryn-llin-fawr; 8, Rhobell-y-big and Dol-cyn-afon.



(Figure 7.1) Generalized sequences of Tremadoc rocks in North Wales and Shropshire, showing stratigraphical ranges of individual GCR sites. For locations of sites see (Figure 3.2), (Figure 7.9), (Figure 9.1) and (Figure 10.1).



(Figure 8.1) Distribution of Ordovician (Arenig to Ashgill) rocks in south-west Wales, after British Geological Survey (1994c). Locations of GCR localities as follows: 1, Ogof Hên and Road Uchaf; 2, Pwlluog; 3, Abereiddi Bay; 4, Abergwaun; 5, Sholeshook; 6, Robeston Wathen; 7, Bryn-banc; 8, Llanfallteg; 9, Pontyfenni; 10, Mylet Road; 11, Meidrim; 12, Dan-lan-y-castell; 13, Glan Pibwr; 14, Allt Pen-y-coed; 15, Cwm yr Abbey; 16, Birdshill; 17, Crag; 18, Dynevor Park; 19, Ffairfâch; 20, Talar Wen. Also 21, Treffgarne Bridge (Upper Cambrian, see Chapter 4).

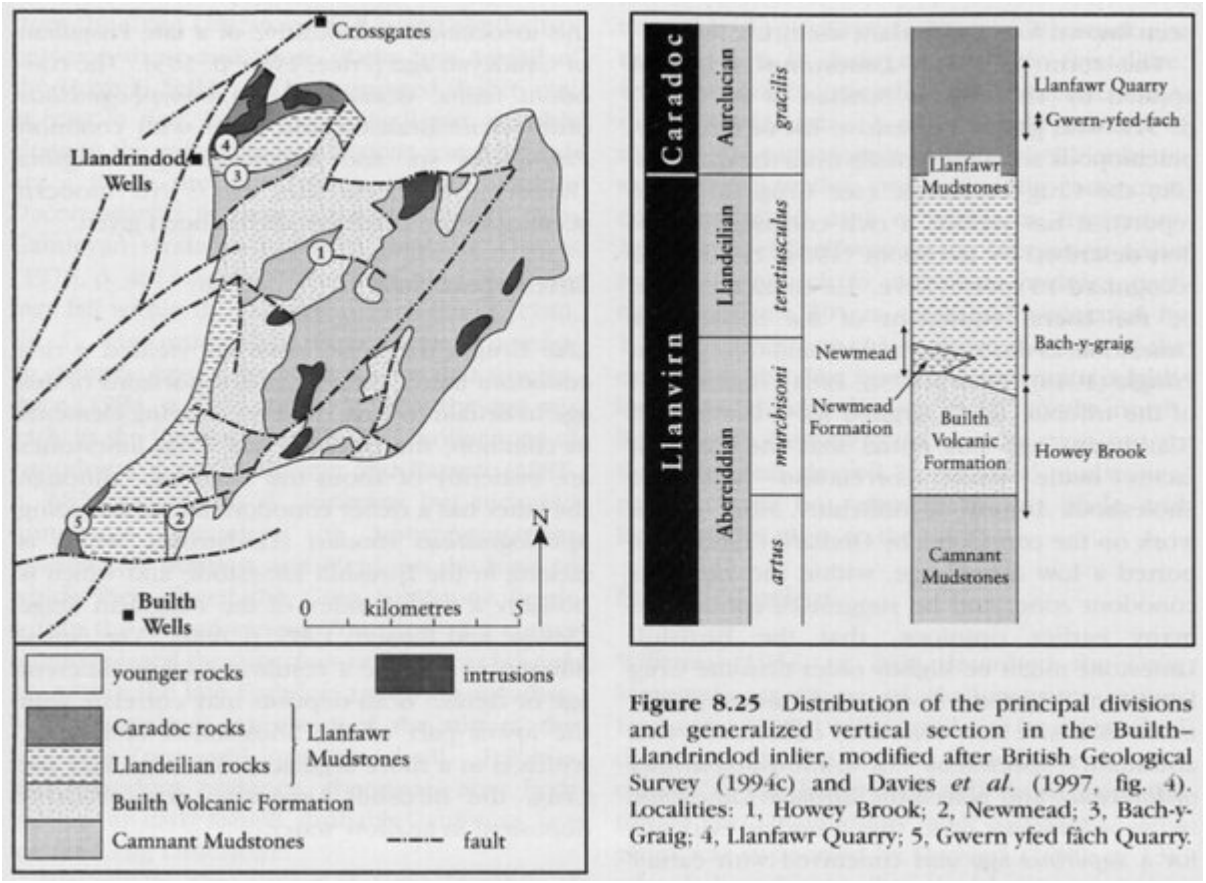


Figure 8.25 Distribution of the principal divisions and generalized vertical section in the Builth–Llandrindod inlier, modified after British Geological Survey (1994c) and Davies *et al.* (1997, fig. 4). Localities: 1, Howey Brook; 2, Newmead; 3, Bach-y-Graig; 4, Llanfawr Quarry; 5, Gwern yfed fâch Quarry.

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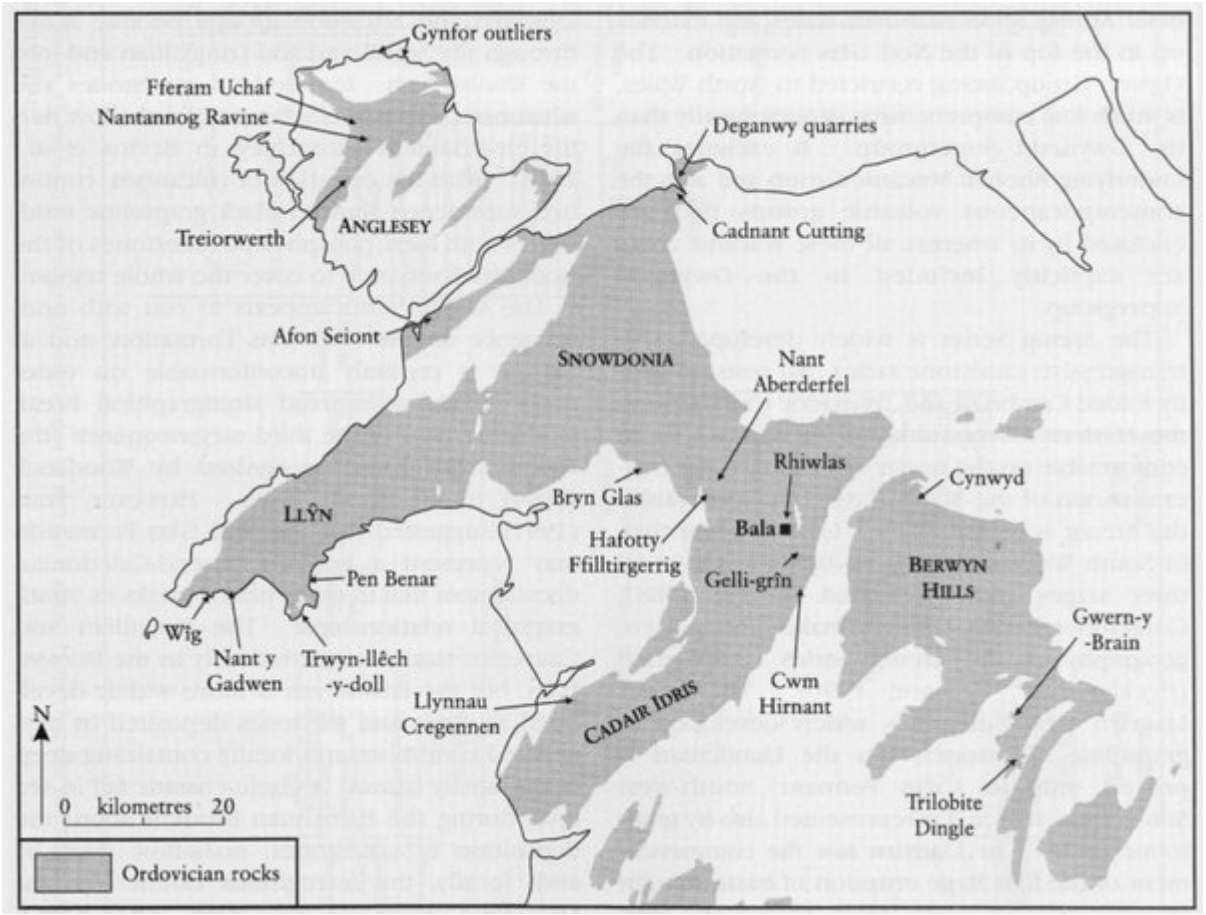
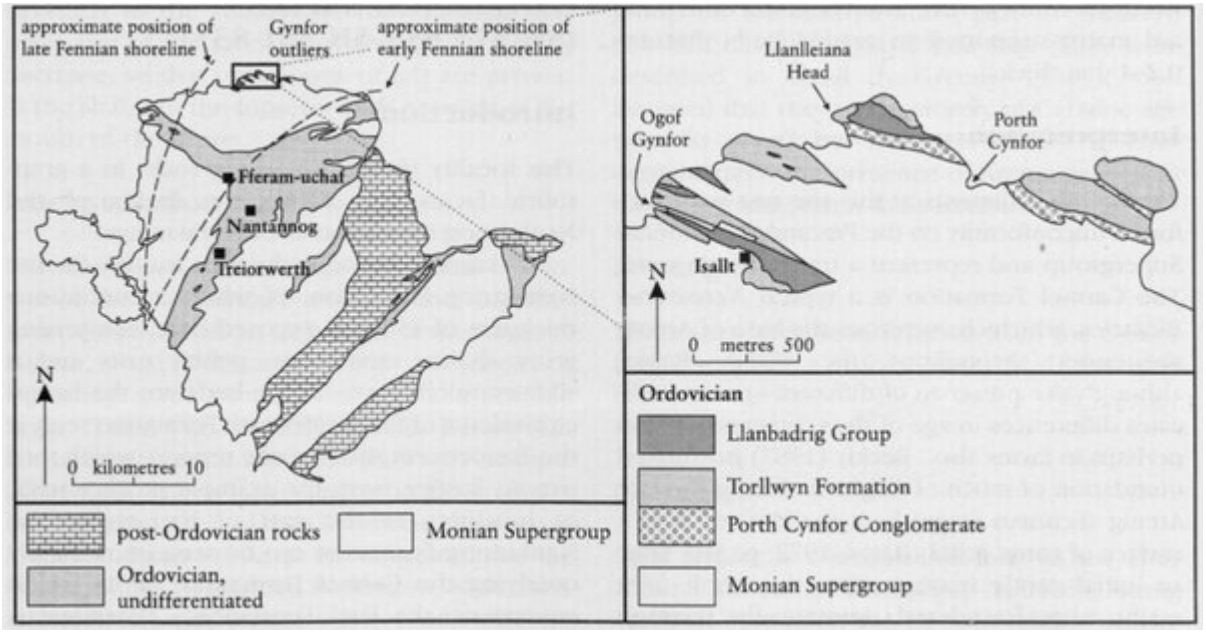
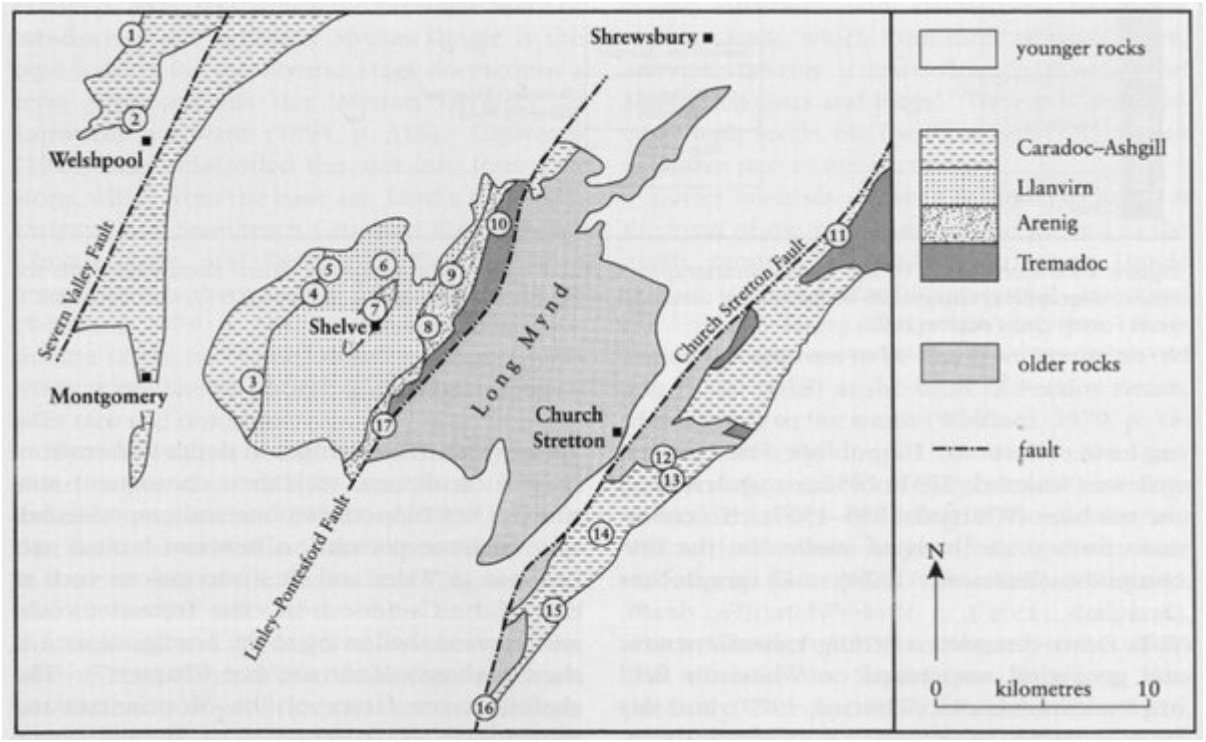


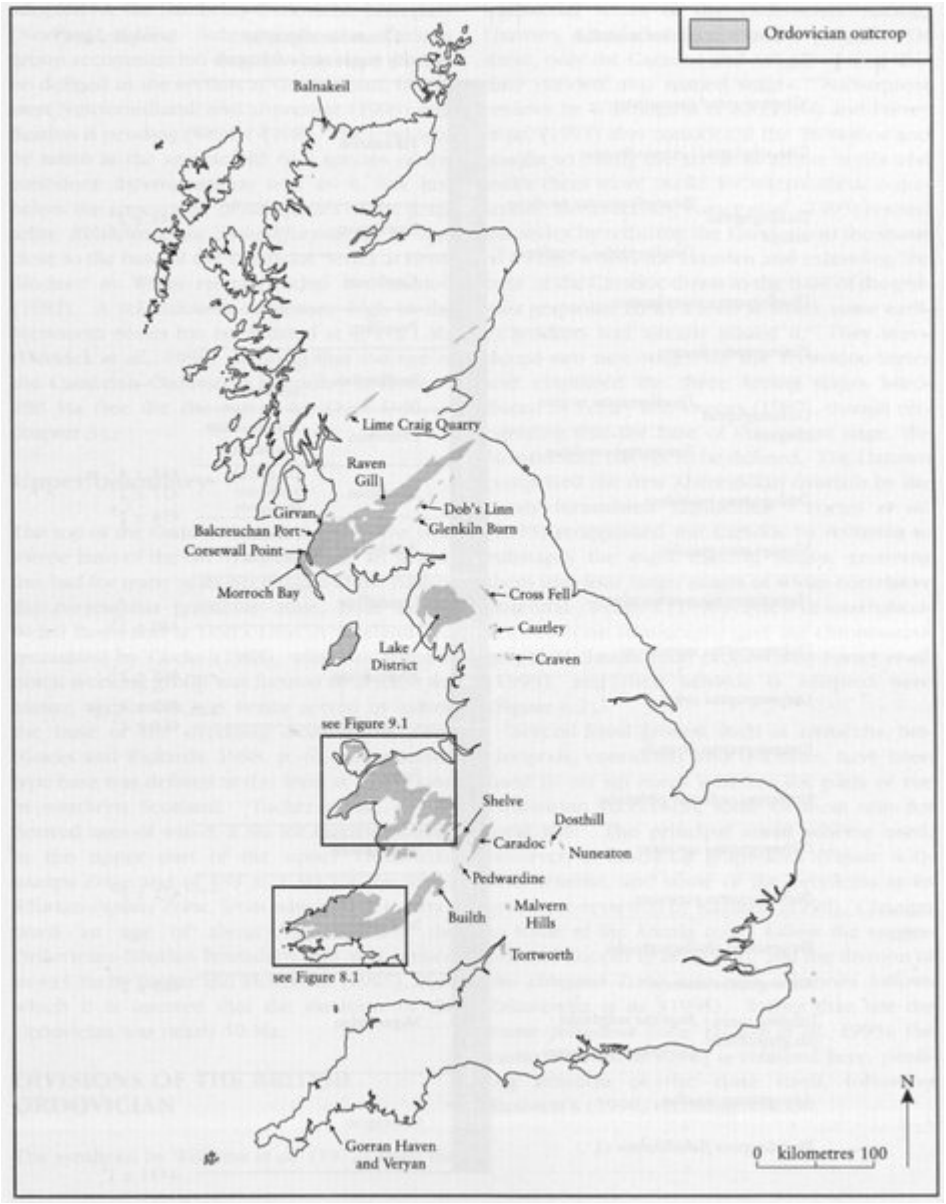
(Figure 9.1) Distribution of Ordovician (Arenig to Ashgill) rocks in North Wales, after British Geological Survey (1994c), showing the location of GCR sites. For the Tremadoc site at Pen Benar, see Chapter 7.



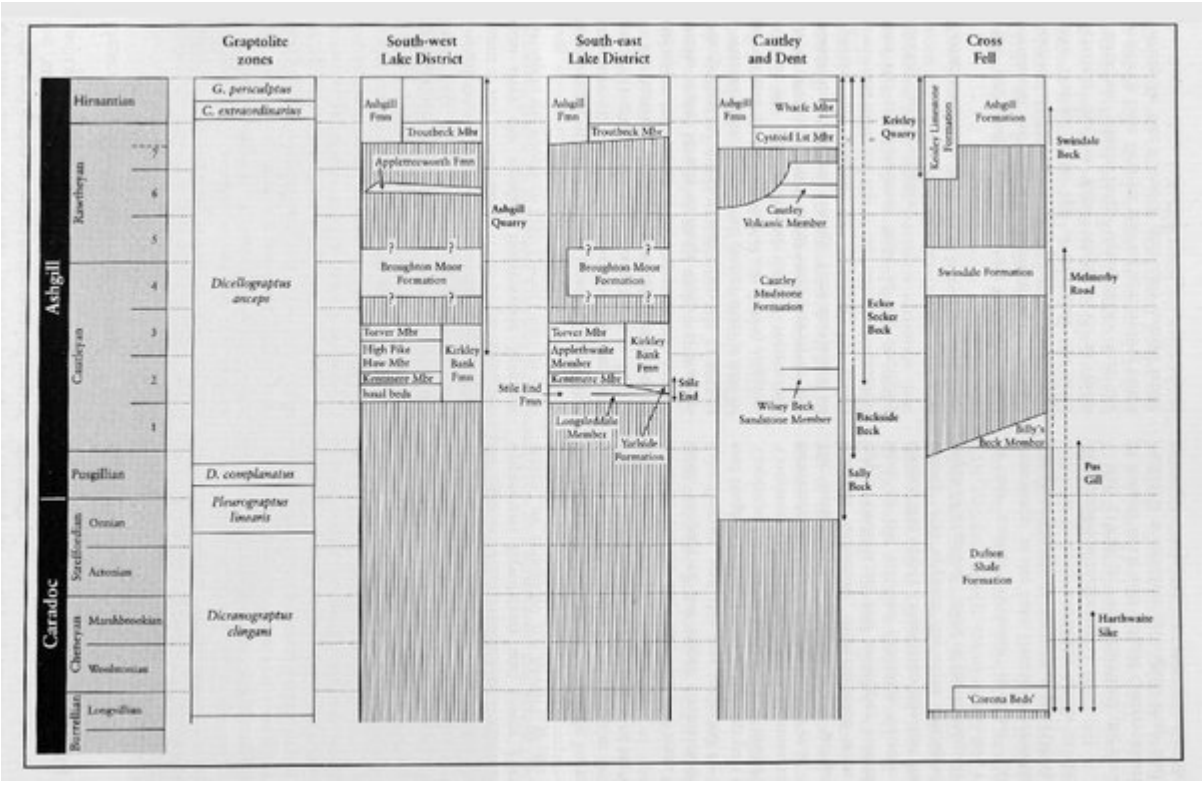
(Figure 9.13) Distribution of Ordovician rocks on Anglesey, from British Geological Survey (1994b), with details of the Gynfor inliers from Bates (1972).



(Figure 10.1) Map showing the distribution of Ordovician rocks in south Shropshire and eastern central Wales, from British Geological Survey (1994c). GCR sites as follows: 1, Gwern-y-brain; 2, Trilobite Dingle; 3, Spy Wood and Aldress dingles; 4, Meadowtown; 5, Betton Dingle; 6, Hope Valley; 7, Shelve Church; 8, Bergam Quarry; 9, Mytton Dingle; 10, Granham's Moor (Tremadoc, see Chapter 7); 11, Coundmoor Brook (Harnage); 12, Hope Bowdler; 13, Soudley Quarry; 14, Marshwood; 15, Onny River; 16, Coston Farm; 17, Linley Big Wood (Tremadoc, see Chapter 7).



(Figure 6.1) Distribution of Ordovician outcrops in Wales, England and Scotland.



(Figure 11.6) Correlation chart of the upper Ordovician (Dent Group) in the main crop of the Lake District, the Cautley and Dent inliers and the Cross Fell Inlier, and the stratigraphical range shown by the GCR site described herein, based on Kneller et al. (1994, fig. 5). In all areas the Dent Group lies unconformably on the Borrowdale Volcanic Group. The correlation of the graptolite zones with the stages of the Ashgill Series is subject to revision (R. B. Rickards pers. comm. 1999).

(Figure 12.1) Distribution of Cambrian and Ordovician rocks in Scotland, showing the general location of key sites.

(Figure 6.2) Chronostratigraphy of the Ordovician of England and Wales, correlated with the graptolite zonation. Selected ages (in millions of years) from the study of radioactive isotopes are shown to the right. Sources: 1, Tucker et al. (1990); 2, Compston and Williams (1992); 3, Landing et al. (1997); 4, Davidek et al. (1998); 5, Tucker and McKerrow (1995).