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Crychan Forest Network of GCR Sites: a critical appraisal with recommendations

Jeremy R Davies MBE

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Summary of key findings and recommendations (in order of priority)

The study of the track cuttings in Crychan Forest and the fossils they contain was critical to the acceptance of the local rock succession as the *international standard* for early Silurian successions – the Llandovery Series. The criteria and terminology devised in the Llandovery area informs the subdivision of rocks of this age wherever they occur in the world; and the area hosts the type sections for two of the series' three constituent stages – the Aeronian and Telychian.

The Geological Conservation Review (GCR) of Silurian sections identified the Crychan Forest track exposures, and the features they display as, of international significance and included them in a network of GCR sites. However, a majority of the Crychan Forest sections are currently overgrown and fail to display the features for which they were selected. For them to do so requires extensive clearance work.

In addition, one site (Scrach Track GCR) fails to include adjacent exposures now know to be of regional significance. The GCR descriptions for all the sites fail to reflect recent scientific discoveries in the Llandovery area.

Annotated plans of the Crychan Forests GCR sites investigated as part of this study are included as Appendix 1 and the GCR accounts as Appendix 2. The following recommendations follow a field visit to these sites undertaken on 5th March 2019:

1. Critical parts of the Trefawr Track GCR site that expose the current Aeronian Stage international stratotype need to be cleared of surface vegetation as a matter of urgency. The stratotype's location is under review and there is little prospect of the Trefawr Track being retained in its current condition.

2. The stratotype location needs to be cleared by hand and its precise position located and marked. Adjacent parts of the site also need to be cleared.

3. The Scrach Track GCR site should be extended to include the adjacent disused forestry quarry to the east [SN 8415 3942]. The latter exposes stratigraphical contacts in late Ordovician rocks that have been critical to a revised interpretation of the regional geological succession.

4. Extensive remedial work is needed to restore the quarry exposures which are currently obscured by surface vegetation and fallen trees. Critical parts of the section (base Cwm Clyd Sandstone Formation) should be cleared by hand.

5. The Scrach Track site previously provided one of the best, accessible exposures though the base of the Bronydd Formation in the Llandovery area. The boundary is now completely obscured by surface vegetation and difficult to locate. Recent re-interpretation of its significance underlines the scientific importance of the Scrach Track exposures and the urgent need for this key part of the section to be restored. Someone familiar with site will need to be on hand to locate the boundary and supervise the clearance work.

6. The account provided for the Scrach Track section in the Silurian GCR volume needs to be up-dated both to reflect the inclusion of the adjacent quarry (see 3 above) and to take account of recent advances in our scientific understanding of other parts of the section.

7. New discoveries at the Coed Glyn-moch Track GCR site, including fossil assemblages and the margin of a major slide complex, add to the scientific importance of this section. Exposures that were critical to these new findings are now largely obscured by vegetation and require targeted restoration work.

8. Limited restoration is needed for the Coed-cwm-Aeron GCR site.

9. Consideration should be given to the inclusion of additional sections in the Llandovery area networks of GCR sites or to other means of conservation such as RIGS registration. These are listed in the report.

10. In light of advances made to our understanding of the late Ordovician-Silurian succession of the Llandovery area, significant new fossil discoveries and nomenclature changes, consideration should be given to up-grading the GCR site descriptions and interpretations that are currently in place.

11. Consider the installation of coloured marker posts alongside key features of the GCR sites. This would aid with management, facilitate access to web-based descriptions of the sites and maximise their educational opportunities.

Proposed strategy for restoration of the Crychan Forest GCR sites

Given the length of the Crychan Forest GCR sites, a targeted approach to their restoration is warranted. Annotated plans (Appendix 1) show in red and green those parts of the GCR sites that should be prioritised for restoration. These reflect the recommendations given above.

Areas marked in red need to be regularly maintained, possibly on a yearly basis. **The clearance of these areas will require use of the least damaging clearance methods. It is vital that someone familiar with these sites locates the key sections of the cuttings and supervises the clearance work.**

Green areas should be regularly assessed with a view to clearance work being undertaken at least every 2 to 3 years. The frequency that other parts of the sites are restored should be determined by regular monitoring.

In the longer term, following the next scheduled period of tree felling, consideration should be given to the creation of a tree-free buffer zone along the top of each of the GCR track sections; an area to be excluded from future planting so that conifer needle fall and shading becomes less of an issue.

Crychan Forest Network of GCR Sites: a critical appraisal with recommendations

A report by Jeremy R Davies MBE, BSc, PhD, FGS, CGeol
on behalf of Natural Resources Wales

1. Background

The outcrop of early Silurian rocks east of the town of Llandovery in south central Wales constitutes the type area, or 'global standard', for the Llandovery Series. The seminal studies of Jones (1925 and 1949) and Williams (1951, 1953) established the succession as the UK standard for early Silurian rocks. The need for international correlation and Global Boundary Stratotype Sections and Points (GSSPs) (see review by Holland, 1989) initiated a phase of further detailed study and the landmark publication of Cocks *et al.* (1984). Critical to this work was the creation in the 1970s of extensive new track cuttings in Crychan Forest. The extensive fossil collections obtained from these and other exposures in the region underpinned new biostratigraphical and lithostratigraphical syntheses for the Llandovery area succession and led ultimately to the Llandovery succession being accepted as the *international series standard* (Cocks, 1989; Melchin *et al*., 2012). The criteria and terminology devised in the Llandovery area continues to inform the subdivision of rocks of this age wherever they occur in the world. The constituent Rhuddanian, Aeronian and Telychian stages all take their names from sections near Llandovery documented by Cocks *et al.* (1984). Though the adoption of Dob's Linn in Scotland as the basal Silurian stratotype made this the *de facto* base of the Rhuddanian Stage, both the other stages have their GSSPs in the area (Table 1).

Period	Series	Stage	Graptolite biozone
Silurian (part)	Llandovery (part)	Telychian (part)	*turriculatus* s.l.
		Aeronian	*sedgwickii-halli*
			convolutus
			leptotheca
			magnus
			triangulatus
		Rhuddanian	*cyphus*
			acinaces
			atavus
			acuminatus
Ordovician (part)	Ashgill	Hirnantian	*persculptus*
			extraordinarius
		Rawtheyan	*anceps*
		Cautleyan	
		Pusgillian	*complanatus*
			linearis
	Caradoc (part)		*clingani*

Table 1. Chronostratigraphical and biostratrigraphical nomenclature used for Late Ordovician and Silurian rocks in Wales

Many of the most important sections in the Llandovery area have been described by Cocks (1971) and Siveter *et al.* (1989); and their significance is reflected in the selection of many for inclusion in the Geological Conservation Review for Silurian sites produced by Aldridge (2000). These sites were selected to ensure that exposures containing key fossil localities and displaying important stratigraphical boundaries were protected from potentially damaging activities and would continue to be accessible for future research. They also comprise representative sections though the principal rock units established and mapped by Cocks *et al.* (1984). The GCR sites established in the Llandovery area comprise two separate networks. The important forestry track sections in Crychan Forest constitute a northern network of sites. More widely separated sections form a southern Llandovery network. It is the Crychan Forest Network (Figs 1 & 2) that is the focus of this report.

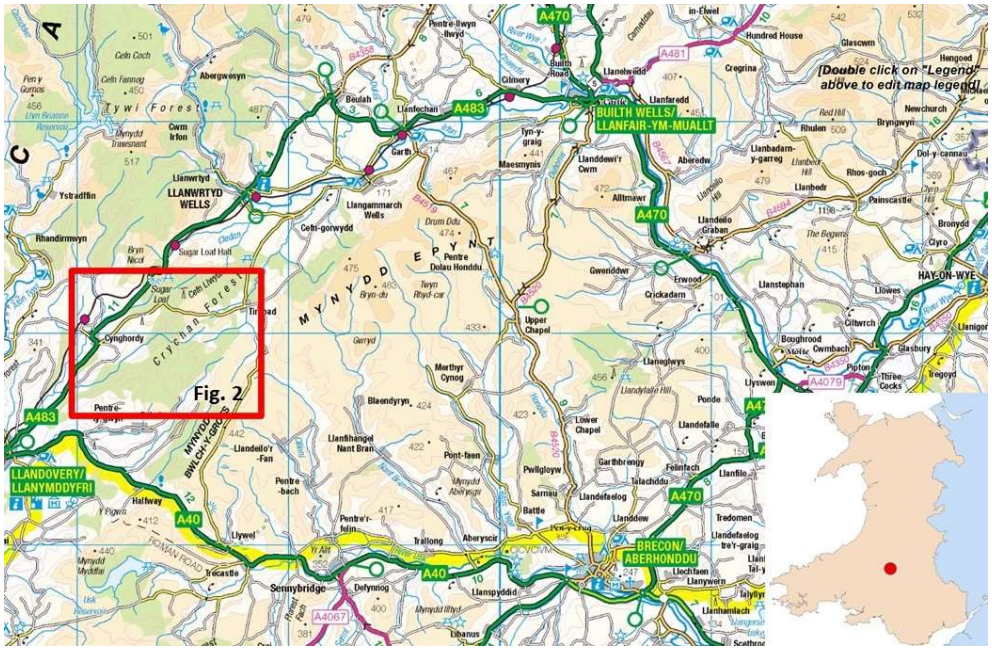


Figure 1. General location map for the Crychan Forest Network of GCR sites showing the location of Fig. 2

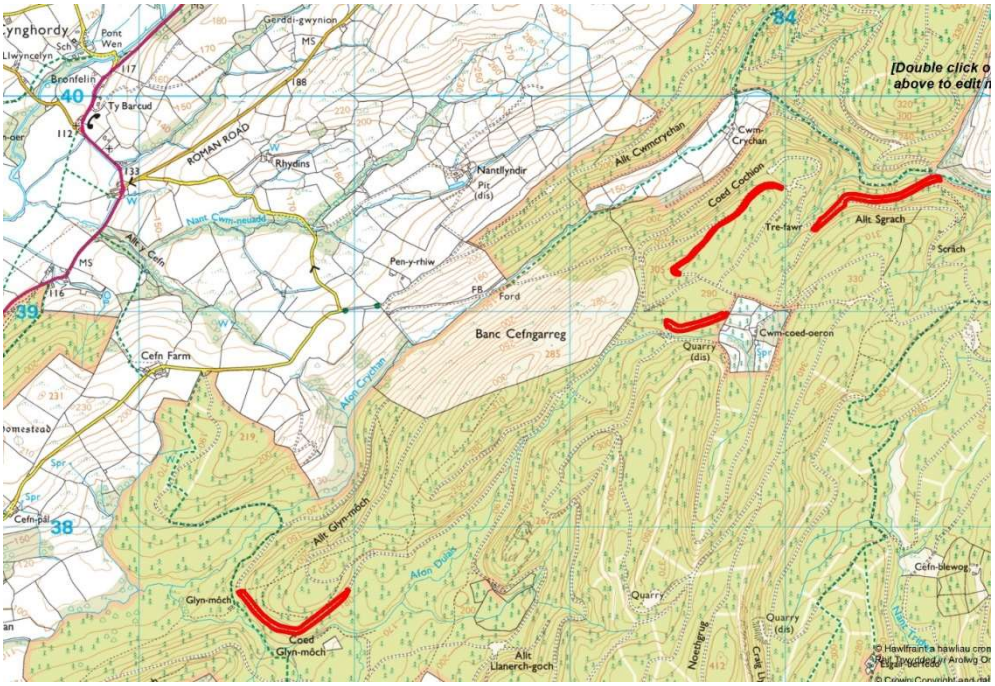


Figure 2. Crychan Forest showing the location of GCR sites assessed in the report

Over the last 25 years the British Geological Survey (BGS) and its collaborators have undertaken detailed mapping and interpretation of the deep water Llandovery facies of the Lower Palaeozoic Welsh Basin in central Wales. This has contributed to a detailed understanding of basinal depositional events and processes (e.g. Woodcock *et al.*, 1996; Davies *et al.*, 1997; Schofield *et al.*, 2009a). In the last decade this work has been extended into the shelf succession of the Llandovery areas where the establishment of an event stratigraphy common to both the basin and shelf successions has been a central aim (Schofield *et al.*, 2004, 2009b; Barclay *et al.*, 2005; BGS, 2005a and b; 2008). The major revisions to the stratigraphical and structural understanding of Llandovery area succession arising from this work, and their scientific significance, are presented by Davies *et al*. (2009, 2013, 2016) (Fig. 3). Upgraded descriptions of some of the key sections are provided in field guides by Davies *et al.* (2010; 2011).

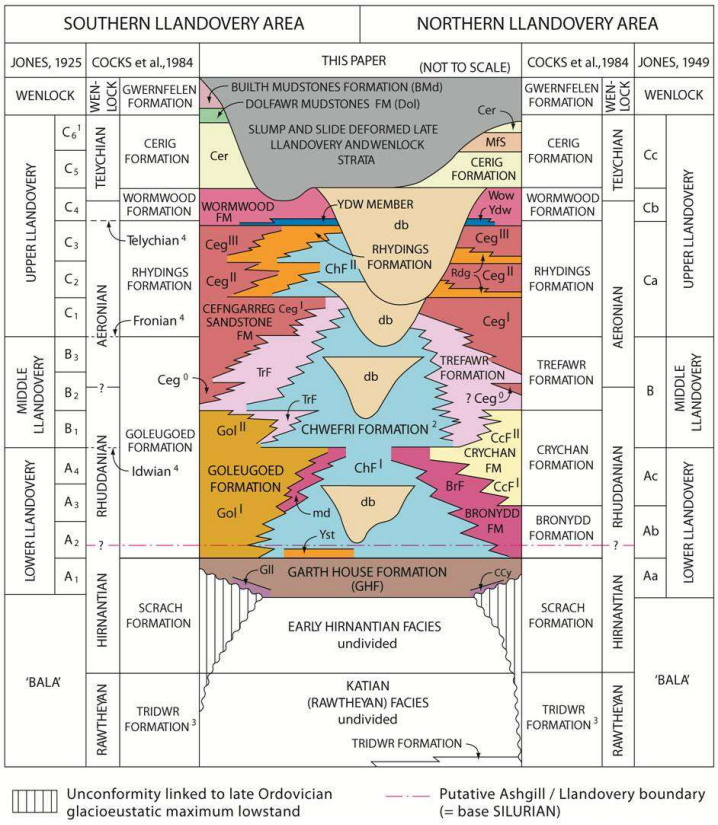


Figure 3. Past & current stratigraphical nomenclature for the Llandovery area (after Schofield *et al*., 2009b; Davies *et al*., 2013) (N.B. Crychan Forest is in the northern Llandovery area)

Consequently, NRW is aware that some of the extant GCR sites fail adequately to encompass, and ensure the protection of, newly recognised critical levels in the local stratigraphy. It is also acknowledged that many of the exiting site descriptions now fail to reflect more recent advances in sedimentological understanding and stratigraphical nomenclature for the Llandovery area succession. Advice on the current condition of the Crychan Forest Network of sections, including recommendations for their restoration, is also sought. NRW is additionally anxious to learn whether the current network of GCR sites in the Llandovery area are fit for purpose and to learn of additional sections that should be considered for protection in the future. Hence, this report seeks to undertake the following:

1. A detailed re-assessment of the Scrach Track GCR including recommendations for its expansion to include additional significant exposures; and an evaluation of the current condition of the existing GCR section.

2. An evaluation of the current condition of the remaining Crychan Forest GCR sites namely the Trefawr Track, Coed-cwm-Aeron Track and Glyn-moch Track sections.

3. Make recommendations for the targeted restoration of the above sites.

4. Identify additional sections in the Crychan Forest area to be considered for future conservation.

5. List other important geological sites in the Llandovery area are not currently included in the GCR networks for the region that might be considered for future conservation.

A visit to examine the Crychan Forest Network of GCR sites was undertaken on 5th March 2019. JRD was accompanied by Raymond Roberts and Ali Baird of NRW and the forestry manager James Tinney also attended an initial briefing session. The comments below re the condition of the sites and possible restorative actions are based in part on the findings and discussions held that day.

Locality details given in square brackets refer to the UK National Grid. Annotated plans of the Crychan Forest GCR sites are included as Appendix 1 and the current GCR accounts are replicated in Appendix 2.

2. Scrach Track GCR

The Scrach Track cutting provides an important section through some of the latest Ordovician (Hirnantian) and earliest Llandovery (Rhuddanian) rocks preserved in the Llandovery area. Cocks *et al*. (1984) recognised the westwards-dipping succession as a key reference section through their Scrach Formation, its contact with the succeeding Bronydd Formation and the latter's upwards passage in to the Crychan Formation. Though its exact position has yet to be determined, sparse graptolites recovered from the Scrach Track succession confirm that it spans the Ordovician-Silurian boundary. Shelly fossils, including stratigraphically important brachiopod species, are locally common in the Bronydd and Crychan formations.

Critically, Cocks *et al*. (1984) viewed the Scrach Formation as resting conformably on older Ordovician rocks (Tridwr Formation) and as recording deposition in the Llandovery area that occurred during the end-Ordovician glaciation and sea-level low stand (see also Woodcock & Smallwood, 1987). Fossil brachiopods recovered from exposures of the Scrach Formation elsewhere in the Llandovery area belong to the distinctive 'Hirnantia Fauna'. In addition to confirming their Hirnantian age, such assemblages are widely present in deposits that formed during the cold climate, low-stand event. Further evidence to Cocks *et al.* (1984) that the Scrach Formation was deposited during this worldwide marine regression.

Cocks *et al*. (1984) consequently viewed the base of the overlying Bronydd Formation as marking the onset of the post-glacial marine transgression. And they explain the upwards passage from the muddy Bronydd Formation into the more sandy Crychan Formation as the product of pro-delta progradation.

Recent work: base of the 'Scrach Formation'

Davies *et a*l. (2009) present a radically different interpretation of the strata assigned to the Scrach Formation both in the Scrach Track and throughout the Llandovery area. A disused forestry quarry [SN 8415 3942] immediately to the east of the Scrach Track GCR section provides one of the key exposures they cite in support of their revisions (Appendix 1, Fig. 1). Here they observed a gently dipping, boulder conglomerate at the base of the Cwm Clyd Sandstone Formation (Fig. 4 & 5). Critically, this overlies a pronounced angular unconformity with the steeply dipping mudstones and sandstones of the underlying Tridwr Formation. The latter must have been deformed, uplifted and deeply eroded prior to the deposition of the Cwm Clyd Sandstone and, moreover, the conglomeratic sandstone unit records a significant marine transgression.

The overlying succession of smooth mudstones and lenticular sandstones that Cocks *et al*. (1984) recognise as their Scrach Formation, Davies *et al*. (2009) reassign to the Garth House Formation, a distinctive rock unit present in successions to the north and west (e.g. Schofield *et al.*, 2004; Barclay *et al.*, 2005). Here, these strata and their basal sandstone are recognised as a transgressive succession that provides evidence, not of syn-glacial shoaling, but the onset and progress of the late Hirnantian, post-glacial maximum rise in sea level. In contrast to the overlying rocks, graptolites and shelly fossils are absent from the Garth House Formation and it displays very low levels of bioturbation.

Figure 4. Forestry quarry adjacent to Scrach Track GCR site as exposed in 2006 following extensive clearance work by hand. Upper left: angular unconformity (at hand level) at base Cwm Clyd Sandstone Formation. Lower left: close-up of overlying boulder conglomerate. Above: sedimentary log of the quarry section (from Davies *et al*. 2009, 2011).

Elsewhere, this transgressive stratigraphy overlies and oversteps the regressive Cwmcringlyn Formation and, where it is preserved, it is this division that appears to record glacial low-stand deposition. Many of the 'Hirnantia Fauna' assemblages found in the Llandovery area are now recognised as coming from exposures in this regressive unit. However, it is also now widely acknowledged that the key taxa also occur in transgressive Hirnantian facies that postdate the glacial low-stand event.

Based on these findings, Davies *et al.* (2009) argue that the Scrach Formation should be abandoned as a formal lithostratigraphical division in the Llandovery area.

Recent work: base of the Bronydd Formation

Graptolite discoveries reported by Davies *et al*. (2009) from elsewhere in the Llandovery area (see below) show that the bioturbated mudstones that immediately succeed the Garth House Formation (former Scrach Formation) are of late Hirnantian *persculptus* Biozone age. Moreover, the morphology of the key taxon (*Normalograptus? parvulus*) allows precise correlation with a bioturbated level in the deep water basin succession to the west (Mottled Mudstone Member, Cwmere Formation). In all these areas, rocks displaying little or no evidence of bioturbation and preserving no body fossils are succeeded by units displaying bioturbation and that contain either graptolites or shelly fossils of both. The base of the Bronydd Formation exposed in the Scrach Track GCR represents such a contact (Fig. 3).

These findings discredit long standing and widely cited regional correlations (e.g. Jones, 1925, 1949; Cave & Hains, 1986; Davies *et al*. l997; Barclay *et al*., 2005). They show that the Cwm Clyd Sandstone and Garth House formations of the Llandovery region pre-date these bioturbated levels and, since it is the former divisions that appear to mark the onset of post-glacial deepening (see above), it follows that the entry of the overlying biologically distinctive units mark an important subsequent event.

Davies *et al*. (2009, 2011) argue that at the time of the late Ordovician glacial low-stand the Welsh Basin was isolated from oceanic influences. They suggest that the base of the Bronydd Formation and its correlative levels throughout the Welsh Basin records the point in the post glacial transgression when connections to the open ocean were restored. This allowed bioturbating organisms and shelly benthos to recolonise the basin floor and graptolites to repopulate its water column.

Figure 5. Base of Bronydd Formation, Scrach Track GCR site. Following clearance of the site in 2009 (left hand image) and as it is now (March 2019) (right hand image) with hammer showing approximate location of contact

Recent work: biostratigraphic & isotopic

Davies *et al*. (2013) summarise the results of biostratigraphical investigations undertaken at the Scrach Track section since the work of Cocks *et al*. (1984). New chitinozoan findings are presented by Challands *et al*. (2014) and chitinozoan samples from the Bronydd Formation are in preparation by Thijs Vandenbroucke (Ghent University).

Brad Cramer (Iowa University) is overseeing the analysis of a clay bentonite sample recovered from the near the base of the Bronydd Formation.

Implications for the Scrach Track GCR

These recent discoveries and the re-evaluation of the Scrach Track section that they permit highlight shortcomings with the boundary and scientific description provided for the current GCR (see Appendix 2). The principal issues are as follows:

1. The quarry exposing the angular unconformity at the base of the Cwm Clyd Sandstone and contact with the succeeding Garth House Formation (former Scrach Formation) requires protection and should be included in the GCR site boundaries (Appendix 1, Fig.1).
2. The account given for the GCR then needs to be upgraded to include a description of these critical exposures.
3. A broader concern – something that applies to all the current Crychan GCR sites - is that the current account given in the Silurian GCR volume (Aldridge, 2000) is now significantly out of date. It fails to document the new work undertaken in the Llandovery area and the revised interpretations now available for the section and the key contacts it exposes.

Current condition of the section

The Scrach Track GCR section is currently extensively masked by moss and fallen branches from the overhanging trees (Fig. 6). Critical contacts including the contact between the Garth House and Bronydd formations, and the upward passage from the Bronydd Formation into the Crychan Formation are obscured and very difficult to locate without extensive clearance work (Fig. 3).

The disused quarry to the east of the GCR site that exposes the Cwm Clyd Sandstone Formation, its basal boulder conglomerate and angular unconformity with the underlying, deformed Tridwr Formation is heavily overgrown and obscured by fallen trees (Figs 4 & 5). The critical contacts observed and photographed by Davies *et al*. (2009) are currently not visible without remediation of the rock face.

Both the current GCR section and its proposed extension to include the adjacent quarry exposures are at the moment not fit for purpose. They fail to allow meaningful scientific observation of these sites, the regionally important geological contacts to be easily located and the rock units present to be studied. **Targeted restorative work is urgently required (Appendix 1, Fig. 1).**

Figure 6. Disused forestry quarry adjacent to the Scrach Track GCR site as seen on 5th March 2019 showing level of the unconformity (ruler) exposed after clearance of sphagnum moss cover by hand (compare with Fig. 4)

Figure 7. Views of the disused forestry quarry adjacent to the Scrach Track GCR site as seen on 5th March 2019 and (lower image) showing the location of the proposed new eastern boundary for the site and the area in need of restoration (see text)

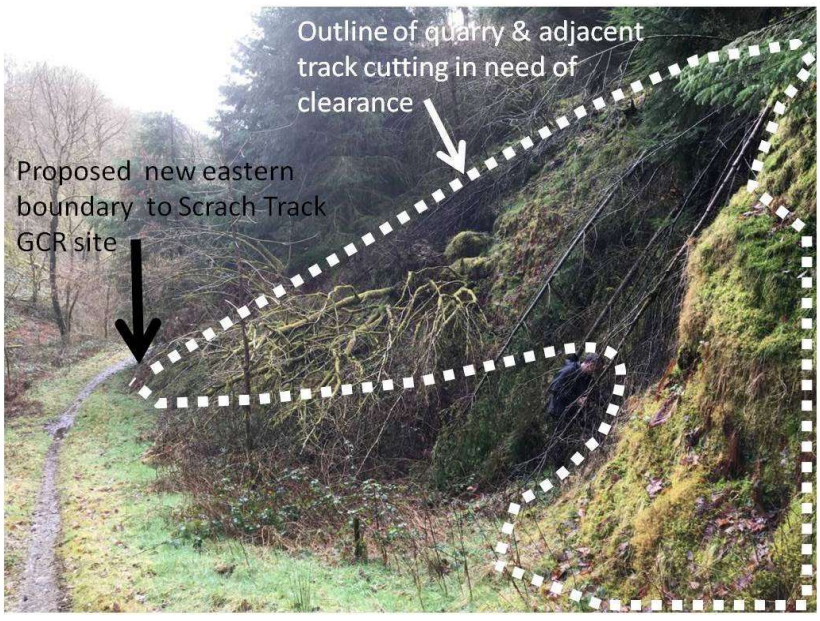


Figure 8. General views of the Scrach Track GCR site to the east (left) and west (right) of the Garth House Formation and Bronydd Formation contact (circled hammer) showing the current overgrown state of the section

3. Other Crychan Forest GCR sites

Trefawr Track Section

This section includes the stratotype for the Aeronian Stage (Cocks *et al*., 1984; Cocks, 1989; Melchin *et al*., 2012), the so called GSSP (Global Standard Section and Point) and is, therefore, of international significance. It includes several fossil localities that were critical in the erection stage and the positioning of its GSSP, which is located beneath the lowest level at which Cocks *et al*. (1984) recovered *triangulatus* Biozone graptolites (Figs 9 & 10). It additionally provides representative sections through the Trefawr and Cefngarreg Sandstone formations. In light of the site's re-evaluation by Davies *et al*. (2010, 2011, 2013), its suitability as the stratotype for the Aeronian Stage is under review and the account of the section given in the Silurian GCR volume (Aldridge, 2000) (see Appendix 2) needs updating.

The section is heavily obscured by moss, fallen braches and leaf litter. All the critical fossil levels including the level of the GSSP itself are currently concealed (Fig. 10). The present condition of the section precludes any possibility that it could be retained as the stratotype. **The key part of the section, between the points that Cocks *et al*. (1984) recovered their highest *cyphus* (*revolutus*) Biozone graptolites and their lowest record of *magnus* Biozone graptolites, spanning the stratotype level, requires restorative work to be undertaken as a matter of urgency (see Appendix 1, Fig. 2).**

Moreover, since the GSSP is a unique point on the track cutting rock face that can only be located with reference to the photographs published by Cocks *et al*. (1984), the remedial action needed in this area of the section should be undertaken extremely carefully and preferably by hand. Once the location of the GSSP has been verified, its location should be clearly marked by a painted metal nail driven into the rock face – the so called 'golden spike' as GSSPs are commonly referred to.

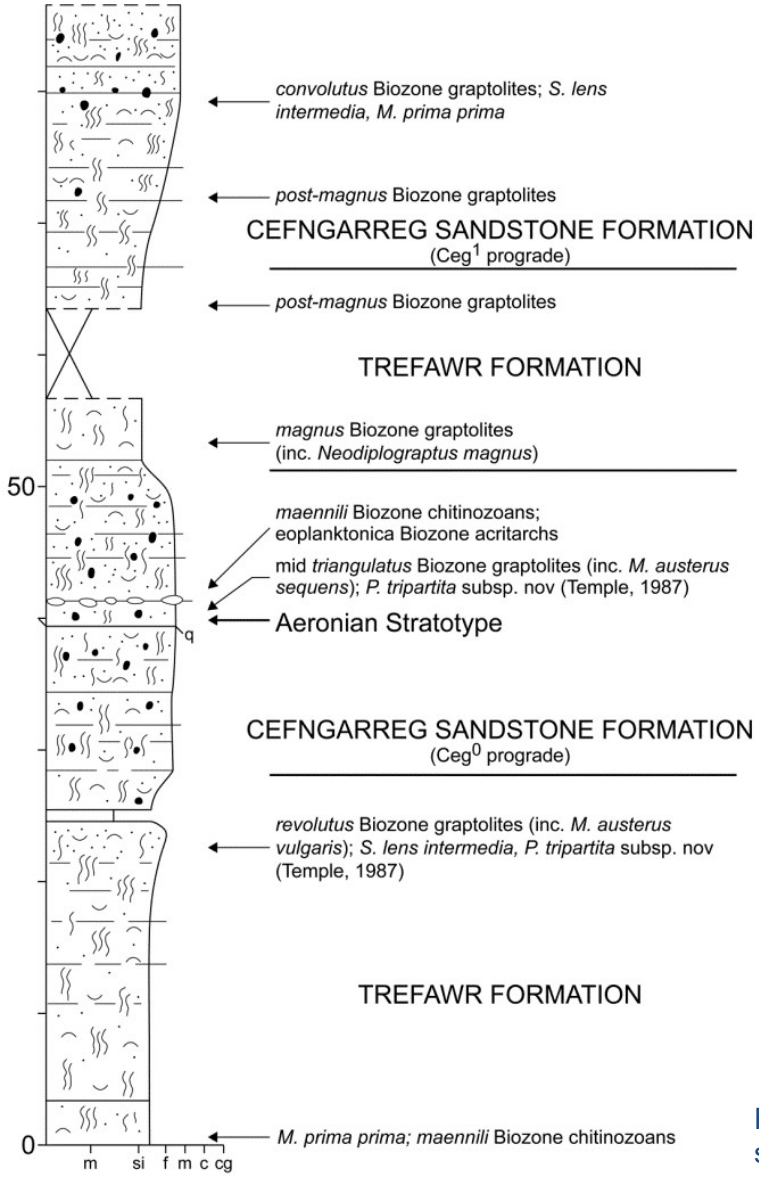


Figure 9. Log of Trefawr Track GCR site (from Davies *et al*., 2011)

Figure 10. Base Aeronian Stratotype, Trefawr Track GCR site. Arrow in left hand image shows precise location of the GSSP following site clearing in 2009 (from Davies *et al*., 2010). Right hand image shows the vegetated rock face as it appears is now (March 2019); hammer (circled) shows approximate location of the GSSP

Cwm-coed-Aeron Track Section

On the whole, this section though the Cefngarreg Sandstone Formation is in far better condition that the other Crychan Forest sites examined. Minimal restorative work is required for the bulk of the section at the moment (Fig. 11). However, exposures at the northern end of the site that were reported to expose a contact with the underlying Trefawr Formation and to have yielded graptolites (Cocks *et al*. 1984) are now obscured. This part of the section is in need of clearance work (Appendix 1, Fig. 3).

Figure 11. Coed-cwm-Aeron Track GCR site. The weather-resistant nature of the Cefngarreg Sandstone Formation that occupies the bulk of the track cutting is reflected in the better condition of this site, which currently requires little remedial work (see text)

Coed Glyn-moch Track Section

According to the GCR account, this site provides representative exposures and fossil localities in Rhydings, Wormwood and Cerig formations of Cocks *et al*. (1984). It's re-examination by Davies *et al*. (2010, 2011, 2013), in addition to allowing new graptolite discoveries and a revision of the stratigraphical nomenclature, revealed the presence in the section of major synsedimentary slide feature – the Glyn-moch Slide Complex complex; findings that re-enforce the significance of the site (Figs 12 to15).

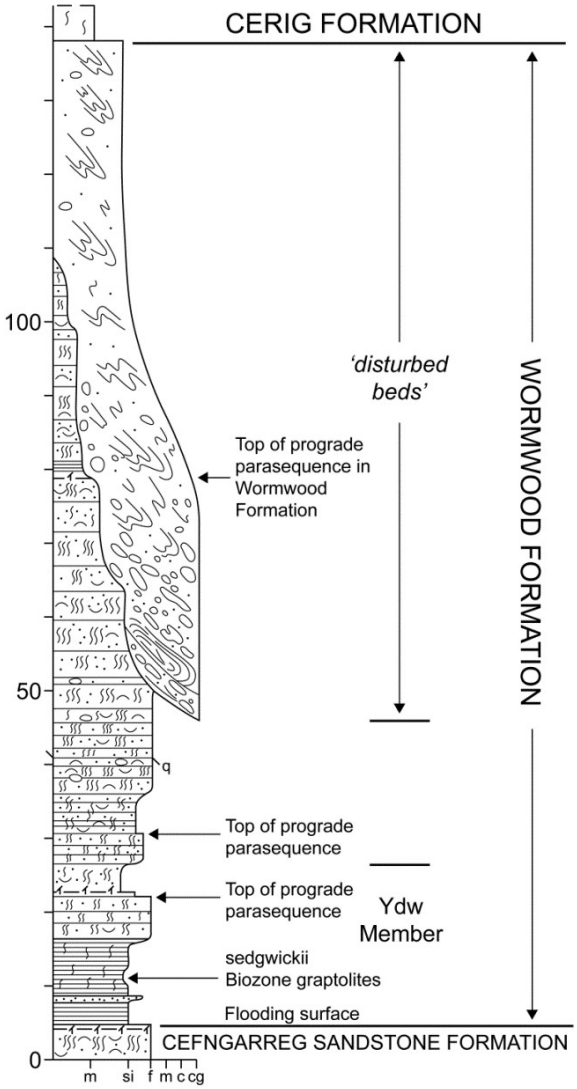


Figure 12. Log of Coed Glyn-moch Track GCR site (from Davies *et al*., 2011).

The rock succession youngs to the south-east, but throughout much of the section the rocks are inverted. The Cefngarrg Sandstone Formation, seen in the western part of the site, is overlain by the recently erected Ydw Member (Wormwood Formation). The discovery of lower *sedgwickii* Biozone graptolites from this unit was a key factor in the major revision of the Llandovery area stratigraphy presented by Davies *et al*. (2013). The succeeding, more strongly inverted Wormwood Formation sandstones occupy much of the remaining track section. However, clearance work undertaken some years ago, to the east of the sharp bend in the forestry track, exposed a highly disturbed rock unit comprising blocks and pillows of sandstone set in a mudstone matrix. Davies *et al*. (2010, 2011) recognise this as a synsedimentary mélange and its contact with the Wormwood Formation sandstones, at the time clearly visible in the cutting, as a major slide plane (Figs 12 & 13). Undisturbed Cerig Formation mudstones of *guerichi* graptolite Biozone age overlie the disturbed unit at the eastern end of the section.

Figure 13. Cutting in the Ydw Member. Davies *et a*l. (2011, 2013) report *sedgwickii* Biozone graptolites from this section of the Coed Glyn-moch Track GCR site following its clearance in 2008 (see Fig. 11)

Clearly the account of the section given in the GCR volume fails to document these recent findings (see Appendix 2). However, a greater concern is that the section is now badly degraded. An extensive covering of moss and leaf litter obscure many of the important features recognised by Davies *et al*. (2010, 2011). The graptolite-bearing levels in the Ydw Member are no longer visible (Fig. 13) and the slide complex mélange and its contact with the Wormwood Formation are difficult to discern (Fig. 13). The need for restorative work is clear (see Appendix 1, Fig. 4).

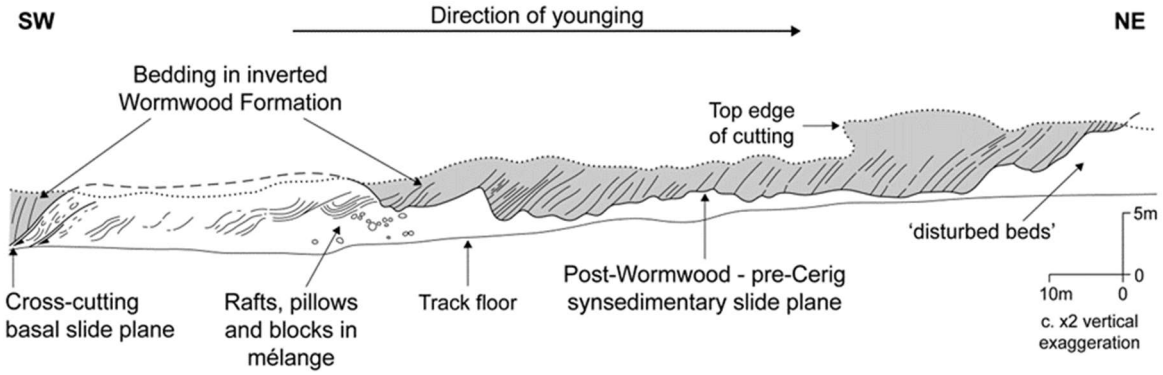


Figure 14. Sketch of the Glyn-moch Slide Complex exposed in the Coed Glyn-moch Track GCR site (from Davies *et al*., 2011)

4. Strategy for restoration of the Crychan Forest GCR sites

A majority of the Crychan sections currently fail to display the geological features they were selected for, and their descriptions provide details of. For them to do so requires clearance work to be undertaken. However, the length of the sections means that such restoration poses logistical difficulties in terms of the equipment and man power needed and implies significant cost implications. A targeted approach is warranted.

The annotated plans of the Crychan Forest GCR sites included in Appendix 1 show in red and green those parts of the GCR sites that should be prioritised for restoration. Areas marked in red are particularly sensitive and require clearance by hand tools. It is also these areas that need to be more regularly maintained, possibly on a yearly basis. Green areas should be regularly assessed, possibly at the time the red areas are being cleared, but with a view to clearance work being undertaken at least every 2 to 3 years. Other parts of the GCR sites all require clearance work, but arguably less frequently. These too should be assessed when work on the red and green areas to being undertaken.

Methods of restoration

In the past mechanical scrapping of the track cutting faces has proven to be an efficient and effective means of restoration (see Fig. 8). However, sections of some sites that encompass critical stratigraphical contacts and/or where significant features might be irreparably damaged by mechanical excavation require a more careful method of restoration. These are the areas shown in red on the accompanying plans. They comprise the quarry face exposing the Cwm Clyd Formation unconformity in the

proposed extension to the Scrach Track GCR, the Aeronian Stratotype in the Trefawr Track GCR and the base of the Glyn-moch Slide Complex in the Coed Glyn-moch Track GCR (Fig 15). Informed supervision of the clearance work at these sites may be required.

The vegetation cover that currently obscures many of the track cutting facies in Crychan Forest principally comprises sphagnum moss that can be easily peeled away from the rock surfaces beneath (see Fig. 6). Loose leaf litter and brambles are a significant factor in some sites, notably along parts of the Coed-cwm-aeron and Coed Glyn-moch tracks. An option for parts of the sections that require the least damaging form of restoration is to restore the exposures by hand, or by using a plastic grass/leaf rake. Alternatively, consideration could be given the use of high pressure water hoses. Such a method has been deployed to clean geologically important track cutting in Hafren Forest. Brambles may need to be removed using secateurs. Branches that overhang many of the sections should also be cut back.

Figure 15. Coed Coed Glyn-moch Track GCR site showing the clearly visible base of the Glyn-moch Slide Complex and melange (right of dashed line) as seen following the clearance of the site in 2008 (top) (after Davies *et al*., 2010) and, below, the same section as it currently appears (March 2019). Note these strata are structurally inverted and young from left to right)

The coloured sectors shown on the enclosed plans (Appendix 1) should be viewed as providing a guide only. It is important that someone familiar with the sites, and the geological features they were selected to display, marks the sections that require more careful clearance work beforehand. Coloured posts located along the sides of the track cuttings or painted marks on the cutting surfaces could be used to do this.

Consideration should be given to making these permanent features that enable critical parts of the sites to be more readily identified and maintained in the future. Such markers would also facilitate the description of the sites via web-based information sheets that allow visiting scientists and both university and amateur field groups more easily to locate and appreciate the key scientific features of the Crychan Forest Network of GCR sites. Such an initiative should form part of a strategy to encourage such visits and thereby maximise the educational opportunities the sites offer.

In the longer term, following the next scheduled period of tree felling in the areas of the GCR sites, consideration should be given to the creation of a tree-free buffer zone along the top of each track section; an area to be excluded from future planting so that conifer needle fall and shading becomes less of an issue. Forestry managers need to be consulted re the feasibility and practicalities of this recommendation.

5. Other sites in the Crychan Forest and Llandovery area to be considered for conservation

Fire Tower Hill Tracks [SN 8535 3848 to 8545 3843]

Track cuttings along the southern flank of Fire Tower Hill, described and interpreted by Davies *et al*. (2010, 2013), expose geological units and stratigraphical relationships not represented in the current network of Crychan Forest GCR sites (Fig. 16). In the western part of the section and in track floor exposed above, highly fossiliferous Derwyddon Formation sandstones rest unconformably on the Tridwr Formation. The presence of cross bedding and coquinas of pentamerid brachiopod valves (Fig. 17) testify to deposition under much shallower water conditions than the units seen to the west.

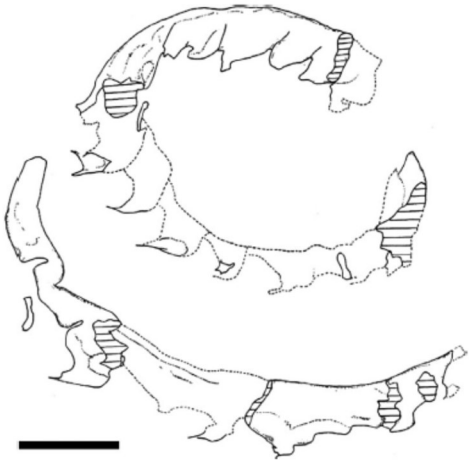
At the base of the succeeding Cerig Formation, Davies *et al*. (2010, 2013) report their discovery, for the first time in the Llandovery area, of the graptolite *Spirograptus guerichi*, the eponymous taxon of the Telychian *guerichi* Biozone (Fig. 18). In addition, in light of problems with the Cerig Formation's former type section (Fron Road GCR site), Davies *et al*. (2013) argue that the Fire Tower Hill track provides a more appropriate and better dated type locality for the formation (Fig. 14).

Figure 16. Main Fire Tower Hill track cutting exposing Derwyddon Formation sandstones (left); and the new type section for the Cerig Formation (right) (see text) - this part of the section need significant clearance work to be undertaken

The succession exposed in the cuttings shows that many of the geological units seen in the current Crychan Forest GCR Network further west have been overstepped and much younger Llandovery strata accumulated in a shallower, structurally positive setting linked to an active Pen-y-waun Fault Belt (Davies *et al*., 2013).Given the significance of these findings there is a compelling argument for the Fire Tower Hill Track sections to be conserved and included in the Crychan Forest Network of GCR sites.

Figure 17. Coquina of pentamerid brachiopod valves, Derwyddon Formation, Fire Tower Hill track cuttings (from Davies *et al*., 2013)

Figure 18. *Spirograptus guerichi*, base Cerig Formation, Fire ower Hill (from Davies *et al*., 2013) (scale bar = 1 mm)



Nantllyndir Cutting [SN 8245 3967 to 8256 3970]

The rock cutting seen to the north of Nantllyndir farm house exposes geological divisions, including the Cwmcringlyn and Ciliau formations that were deposited during late Ordovician glaciation and global low-stand in sea level. The section also exposes the sharp, but conformable contact between the sandy Cwmcringlyn Formation and the transgressive Garth House Formation.

The low-stand divisions are absent from the Crychan sections further east. It is their overstep that the Cwm Clyd Sandstone unconformity seen in the proposed Scrach Track extension demonstrates (Davies et al., 2009) (Fig. 19).

All the strata exposed in the Nantllyndir cutting are of late Ordovician age, but the section is not included in the relevant GCR volume (Rushton *et a*l. 2000) and it would have been inappropriate to include them in the Silurian GCR volume (Aldridge, 2000). Nevertheless, the cutting provides an accessible reference section through formations and stratigraphical contacts that are key to the better understanding of the Crychan Forest Network of sites. Though the section lies outside the boundaries of the forest, consideration should be given to its inclusion in that network or to other means of conservation such as RIGS registration.

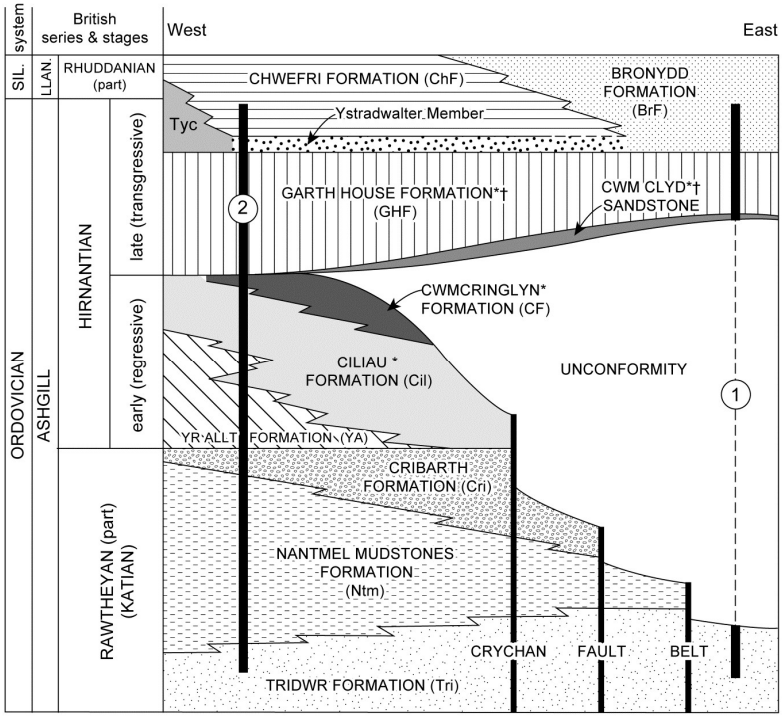


Figure 19. Chronostratigraphical illustration of the Hirnantian successions in the Crychan Forest area (from Davies *et al*., 2011). Succession 1 is as seen in the Scrach Track forestry quarry (see Fig. 4). Succession 2 shows the expanded stratigraphy present in the Nantllyndir region

List of other sites in the Llandovery region to be considered for conservation

The following sites are not currently recognised as GCR or RIGS. Their significance is documented in the cited publications. Consideration should be given to their conservation.

1. Ystradwalter Quarry (Ystradwalter Member, Chwefri Formation, fossil locality; Davies *et al*., 2009).

2. A40 road cutting (Ciliau, Cwmcringlyn and Garth House formations; microfossil locality; Challands *et al*., 2014).

3. Allt Troedrhiwfelen stream (Chwefri, Trefawr, Cefngarreg, Rhydings, Wormwood formations; multiple fossil localities; Davies et al., 2013).

4. Trackside quarry, Mandinam (Wormwood Formation; fossil locality; Davies *et al*., 2010, 2013).

5. Farm cutting, Mandinam (Cerig Formation-Builth Mudstones Formation contact; fossil locality; Davies *et al*., 2010).

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Appendix 1: Plans of the Crychan Forest Network GCR sites (supplied by NRW) showing sections to be targeted for restorative work (see text).

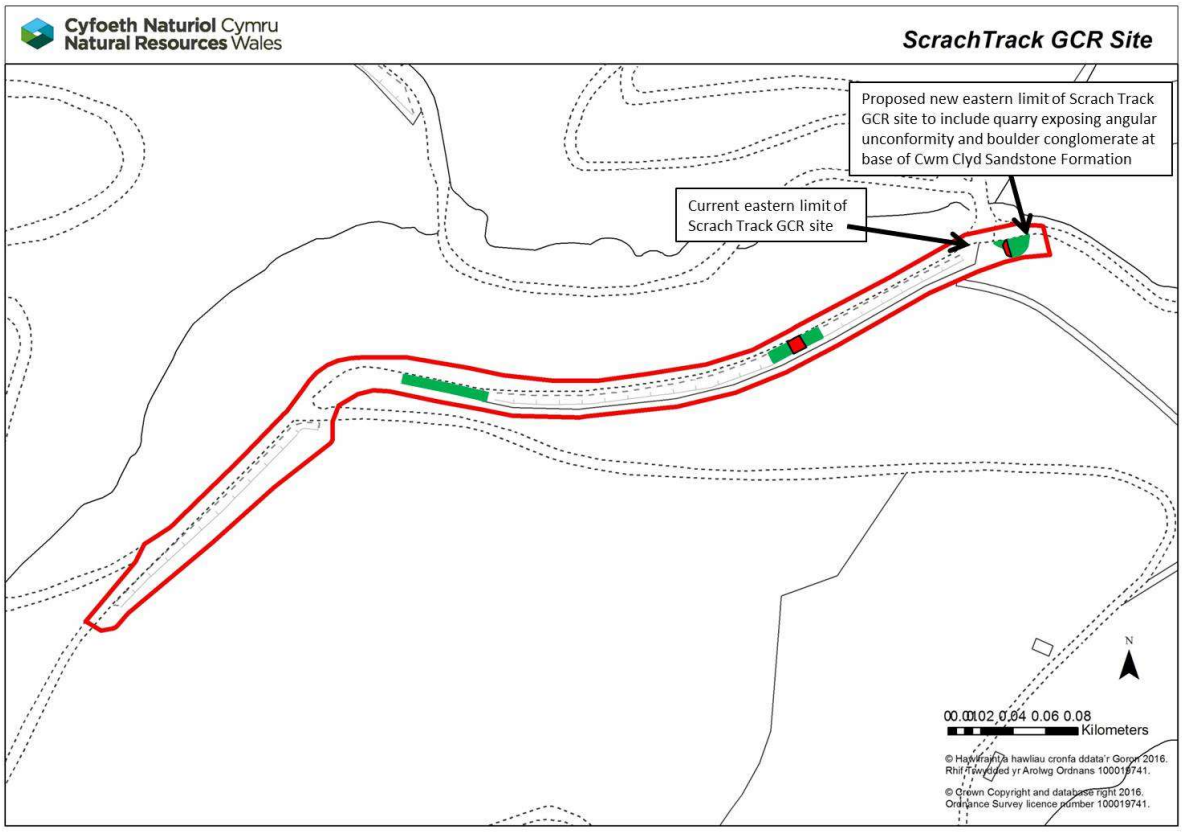

Figure 1. Scrach Track GCR site

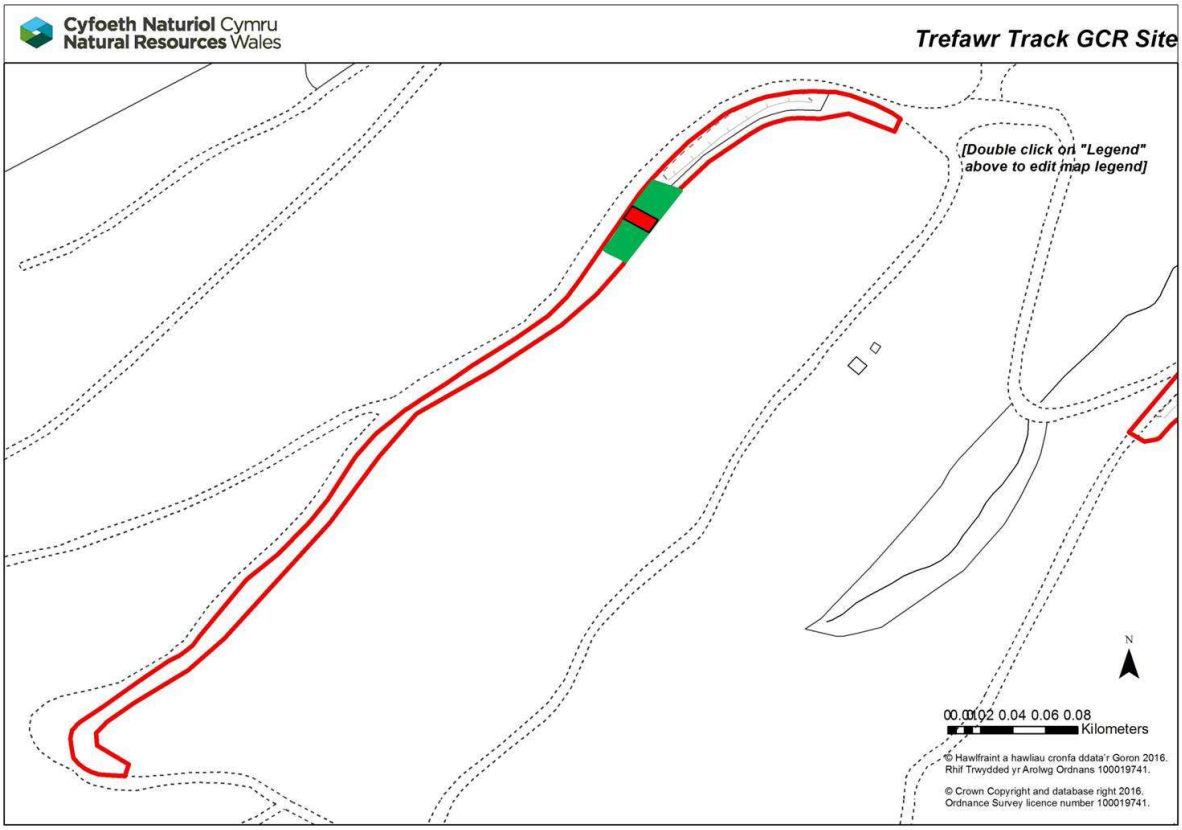

Figure 2. Trefawr Track GCR site

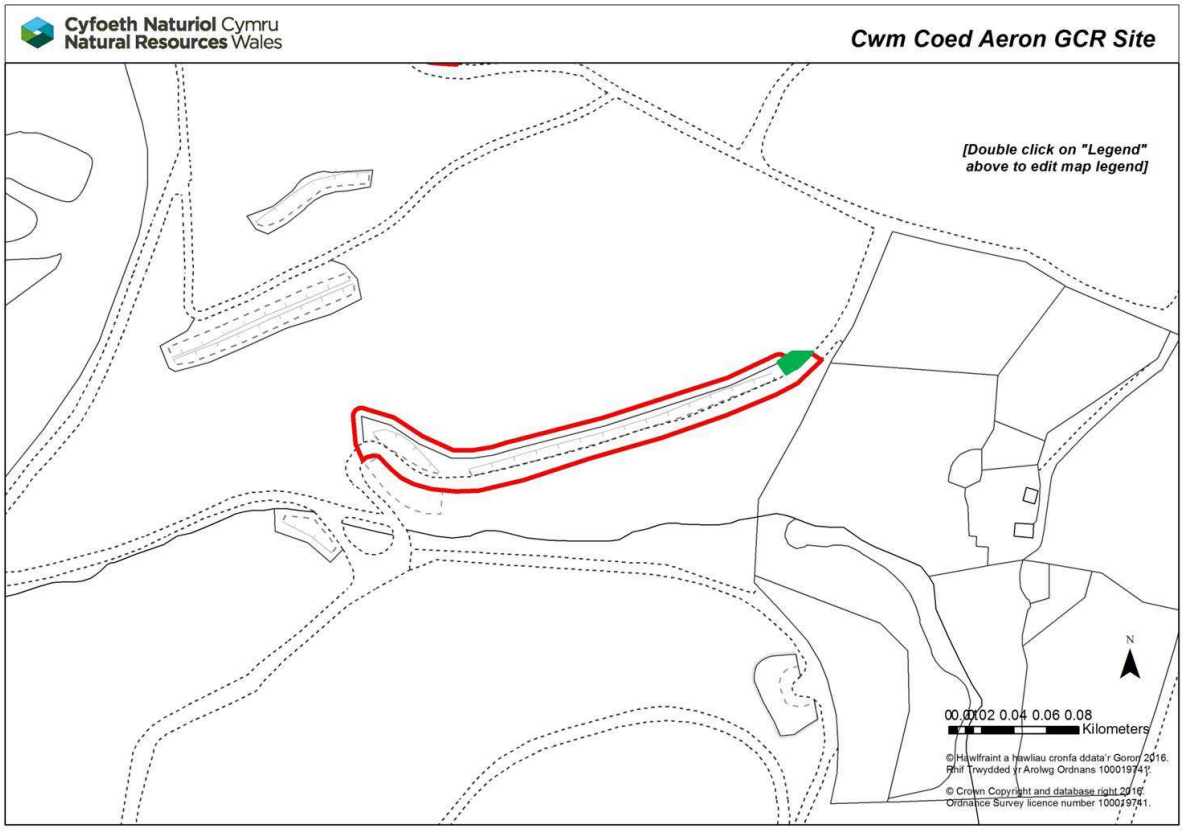

Figure 3. Coed-cwm-Aeron Track GCR site

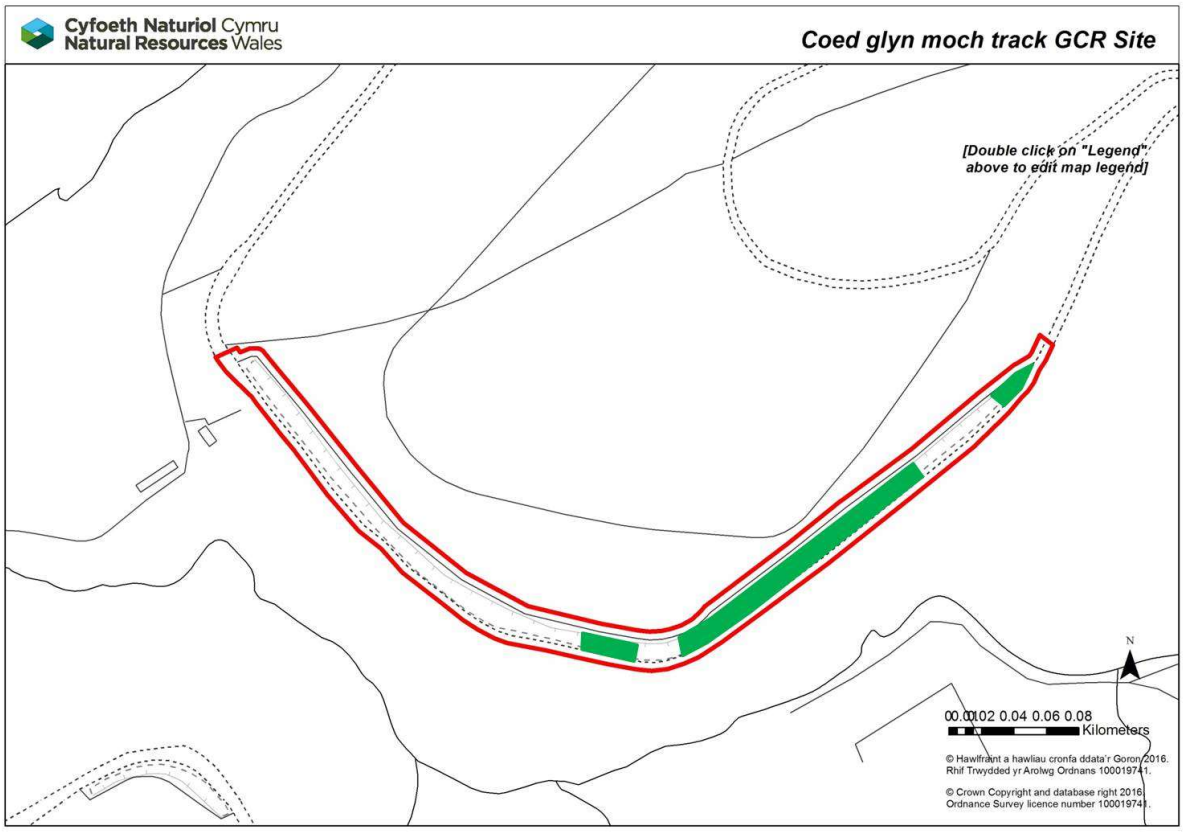

Figure 4. Coed Glyn-moch Track GCR site

Appendix 2. Current GCR accounts for the Crychan Forest Network sites

SCRACH TRACK
OS Grid Reference: SN84153942–SN84653959

Volume 19: British Silurian Stratigraphy
Chapter 3: The Llandovery Series
Site: SCRACH TRACK (GCR ID: 1763)

The Llandovery district has long acted as a national and international reference area for strata now assigned to the lowest series of the Silurian System. The initial work by Murchison (1839) was followed by Geological Survey mapping in 1855–1856, and a major study of the geology was undertaken by Jones (1925, 1949). Jones applied a set of informal lithostratigraphical terms to the succession, using the letters A (Lower Llandovery), B (Middle Llandovery) and C (Upper Llandovery) for his major divisions. In the southern part of the Llandovery area these were subdivided into A_1–A_4, B_1 –B_3 and C_1–C_6(Jones, 1925), whereas in the northern part, where there are differences in facies, the subdivisions used were Aa–Ac, B and Ca–Cc (Jones, 1949). More recently, Cocks et al. (1984) remapped the area, revised the lithostratigraphy and completed new biostratigraphical investigations. They renamed the 'basal Llandovery sandstones' (A_1, Aa) of Jones (1925, 1949) as the Scrâch Formation, and suggested that it is of latest Ordovician (Hirnantian) age rather than earliest Silurian. They also established new formation names for the Llandovery strata of the southern and northern parts of the area, replacing Jones' informal system of letters and numbers (Figures 3.23, 3.24).The Scrâch section lies on the eastern limb of the Cefn-y-gareg Syncline in the northern Llandovery area (Jones, 1949; Cocks et al., 1984). Jones (1949) showed the eastern edge of this limb as faulted, with his Aa unit absent, but the map provided by Cocks et al. (1984, fig. 3; Figure 3.23) shows an unfaulted contact in this area with the Scrâch Formation present. The Scrâch track section exposes the Scrâch Formation, overlain by the Bronydd and Crychan formations, of Rhuddanian age; the section was logged, as section i2, by Cocks et al. (1984, fig 4).

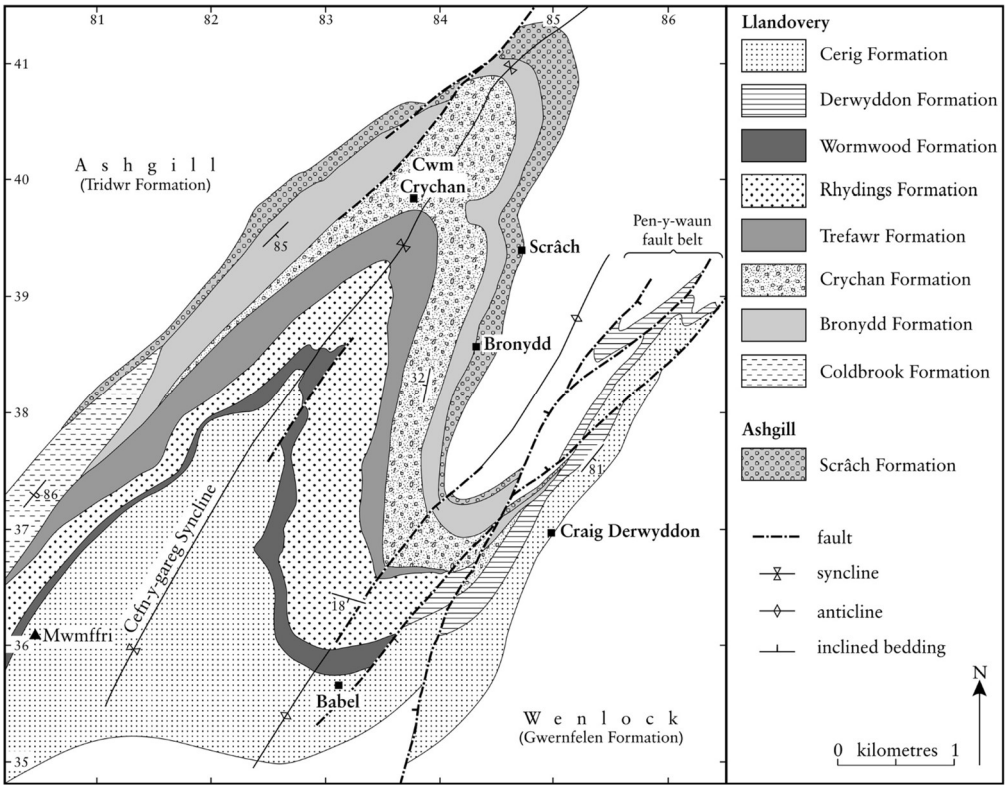

Figure 3.23: Geological map of the northern part of the type Llandovery area (after Cocks et al., 1984).

This is an important site as it exposes an almost continuous section of strata across the Ordovician–Silurian boundary, from the top of the Scrâch Formation, through the Bronydd and Crychan formations. The base of the Silurian System is defined outside this area, at Dob's Linn in Scotland, but it is important to identify its position in the type area for the Llandovery Series. According to Cocks et al. (1984), the boundary lies at or near the base of the Bronydd Formation, low in which are graptolites of the acuminatus Biozone.

Description

The Scrâch section is situated on the south side of the forestry trackway north to WNW of Scrâch. In this section, the beds dip 33–35° to the west (Jones, 1949; Siveter et al., 1989); the Scrâch Formation is 70 m thick, the Bronydd Formation is 120 m thick, and the Crychan Formation is 250 m thick (Cocks et al., 1984). Site clearance has shown that the Scrâch Formation commences with thick conglomerates, passing upwards into crosslaminated sandstones and cleaved shales. The contact with the Bronydd Formation is complicated by faulting (J. Davies pers. comm.), above which the formation is dominated by mudstones, with interbedded sandstones increasing upwards. The Crychan Formation consists of massive, bioturbated sandy mudstones and muddy sandstones, commonly with coarser bases; occasional thin shelly sandstones occur. The top of the Crychan Formation is not seen in this section.

Cocks et al. (1984) recorded a Hirnantia fauna in the Scrâch Formation, demonstrating a Hirnantian age. Close to the base of the Bronydd Formation in the Scrâch section, the graptolite Climacograptus normalis occurs, indicating the perscultus or acuminatus biozone (Rickards in Cocks et al., 1984, p. 144). Other

graptolites from higher in the formation include C. cf. normalis and C. rectangularis, assignable approximately to the atavus and acinaces biozones (Cocks et al. 1984). The Crychan Formation has yielded several graptolites, including Rhaphidograptus toernquisti, and a locality in the very top of the formation beyond the Scrâch section at SN 8397 3907 has produced Atavograptus? strachani and some possible triangulate monograptid thecae; thecae of this type first appear in the cyphus Biozone (Cocks et al., 1984). Cocks et al. (1984, table 1) provided full lists of brachiopods and other fossils in the Bronydd and Crychan formations. Brachiopods are relatively common, with Eoplectodonta duplicata, Leangella scissa, Mendacella mullochiensis (= 'Resserella'sp.) and Dolerorthis sowerbyana present throughout; the Bronydd Formation also includes Hyattidina? angustifrons and Skenidioides sp., with Clorinda undata, Cryptothyrella crassa and Meifodia prima prima in the upper beds; the Crychan Formation also has Stricklandia lens lens and diverse less common forms. Among the other fossils, pelmatozoan columnals and bryozoans are most common, but occasional corals, trilobites and gastropods also occur.

Interpretation

Environmental interpretations of the sedimentological features were given by Cocks et al. (1984), who considered the flaser-bedded sands of the Scrâch Formation to be characteristic of intertidal or shallow subtidal conditions, with coarser sand bodies representing tidal bars or channels. The environment is shallower than that represented by underlying Ordovician sediments and probably reflects late Ordovician glacio-eustatic lowering of sea level. Subsequent deepening is indicated by the marine shelf mudstones of the Bronydd Formation, in which the discrete sand beds may represent occasional storm events; the general coarsening upwards in this formation indicates prograding sedimentation, perhaps prodeltaic. The further coarsening in the Crychan Formation is probably the result of deposition on a more proximal part of a pro-delta lobe, although, as the fauna shows, this is still in a fully marine regime. The diverse brachiopods, including S. lens lens, show that a Stricklandia benthic community was developed. Palaeocurrent directions indicate a sediment source from the south-east, with evidence for storm events from winnowed sand beds. This is a key site in the type Llandovery area that demonstrates the environmental development in the early Silurian of this part of the Welsh Basin and provides a representative section through the Scrâch, Bronydd and Crychan formations. Together with the local sites in the Ydw Valley and the sites at Gasworks Lane and Meifod, it provides evidence of the marine fauna that succeeded the characteristic late Ordovician Hirnantia fauna in the Welsh Basin.

Conclusions

These trackside exposures are of major importance as they display the local base of the Silurian System in the international type area for the Llandovery Series. They also provide representative sections in the Scrâch, Bronydd and Crychan formations, and present lithological evidence for the development of early Silurian marine environments in this part of the Welsh Basin. The strata contain characteristic latest Ordovician and earliest Silurian faunas. The international importance of this site as a reference section in the Llandovery type area renders it of high conservation value.

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TREFAWR TRACK
OS Grid Reference: SN83473916–SN83983960

Volume 19: British Silurian Stratigraphy
Chapter 3: The Llandovery Series
Site: TREFAWR TRACK (GCR ID: 1762)

This reference section in the Llandovery type area exposes much of the Trefawr Formation, which comprises sandy mudstones with a fauna of graptolites, brachiopods and other fossils. It is a long trackside section extending from 500 m south-west to 150 m north of the farm of Trefawr, to the north of the Crychan Forest in the northern area of the Llandovery district. Geologically, the section is situated almost directly on the axial planar trace of the Cefn-ygareg Syncline (Cocks et al., 1984, fig. 3; Figure 3.23), and traverses the Trefawr Formation from north-east to south-west (Figure 3.25). The Trefawr Formation was named and defined by Cocks et al. (1984) to replace the informal unit B (Middle Llandovery) of Jones (1949). These exposures have been opened up since the work of Jones (1949), who recorded that the formation was not well exposed around the nose of the Cefn-y-gareg Syncline.

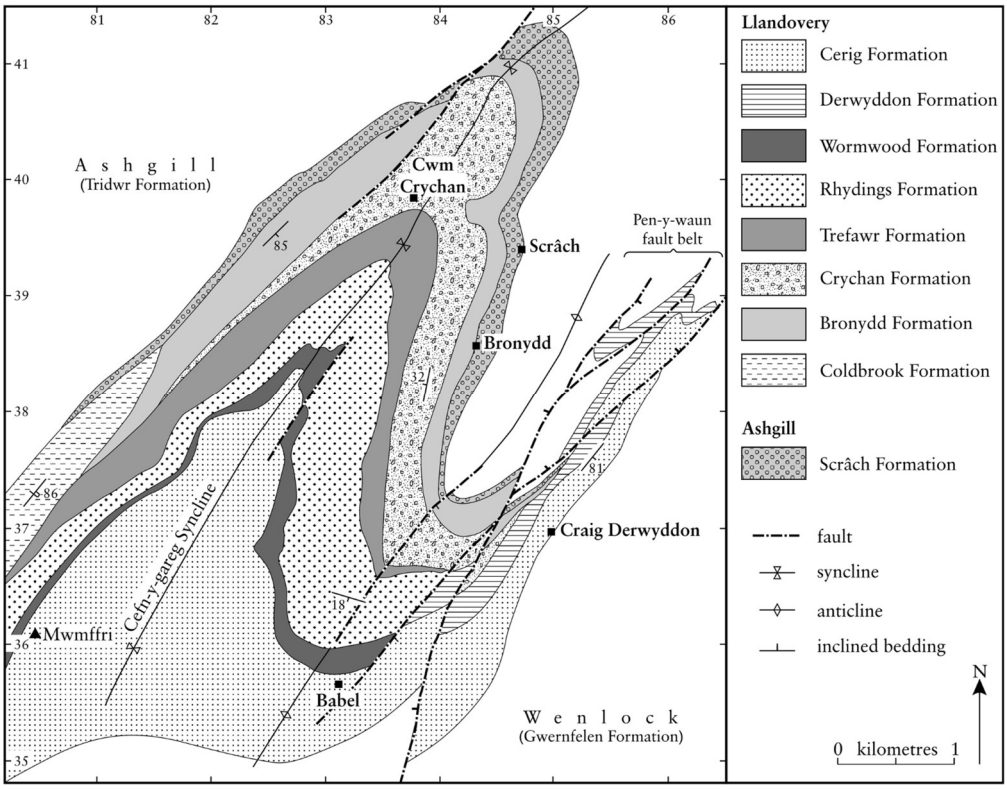

Figure 3.23: Geological map of the northern part of the type Llandovery area (after Cocks et al., 1984).

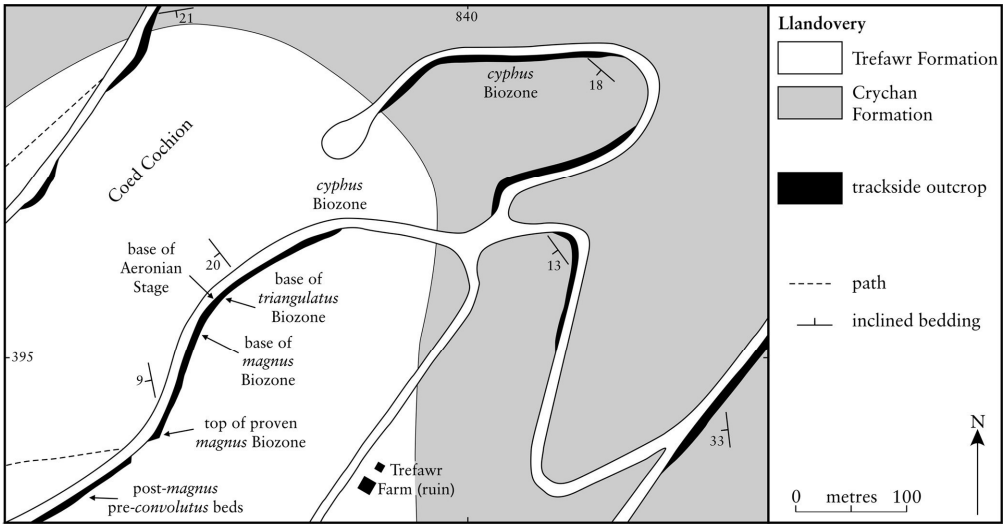

Figure 3.25: Exposures along and around the Trefawr Track, including the stratotype section for the base of the Aeronian Stage (modified after Cocks et al., 1984).

The Aeronian Stage is named after Cwm-coed-Aeron Farm, 500 m south of the Trefawr track (Cocks et al., 1984), and was proposed to replace the Idwian and Fronian stages of Cocks et al. (1970; see report on the network site at Cilgwyn–Ydw Valley). The base of the Aeronian Stage is defined in the Trefawr Track section, within gently dipping mudstones at SN 8380 3953, 92 m above the base of the Trefawr Formation, at the first appearance of the graptolite Monograptus austerus sequens; this was taken by Cocks et al. (1984) to be equivalent to the base of the triangulatus Biozone. This biozone, or the broader gregarius Biozone which has a similarly defined base, is recognized in many areas globally; the incoming of triangulate monograptids and of the genera Rastrites and Petalograptus is generally indicative of this level (Cocks et al., 1984). The base of the Aeronian Stage is somewhat higher than the base of its precursor, the Idwian Stage, which was defined at the locality at SN 757 309 in the Ydw Valley GCR site in the southern Llandovery area. The Aeronian Stage encompasses the majority of the Trefawr Formation plus the Rhydings and Wormwood formations in the Llandovery type area (Cocks et al., 1992).

Description

The Trefawr Formation is 240 m thick (Cocks et al., 1992), and comprises unlaminated silty mudstones with beds of micaceous sandstone. Strata from the upper part of the underlying Crychan Formation are exposed in a trackside section 160 m north-east of the Trefawr track site, at SN 8410 3963; these muddy sandstones yield a brachiopod fauna that includes Stricklandia lens intermedia (Siveter et al., 1989). The lowest exposed beds of the Trefawr Formation are generally finer-grained, and there is a general coarsening up-sequence. The beds dip south-westwards at 10–20°.

The Trefawr track section has yielded a large fauna of brachiopods, together with smaller numbers of graptolites, corals, trilobites, ostracods, gastropods, cephalopods, echinoderm fragments and bryozoans (Cocks et al., 1984, table 2; Siveter et al., 1989). The distribution of brachiopods and graptolites across the Rhuddanian–Aeronian boundary is shown in Figure 3.26. Fossils reported from the lower part of the section, referable to the upper part of the Rhuddanian Stage, include the

brachiopods Eoplectodonta duplicata,Plectatrypa tripartita, Aegiria garthensis, Mendacella mullochiensis, Leangella scissa, Anisopleurella gracilis and Skenidioides sp., and the graptolites Rhaphidograptus toernquisti, Monograptus austerus vulgaris, Diplograptus aff. elongatus, cf. Lagarograptus acinaces, Climacograptus sp. and Dictyonema corrugatellum. Immediately above the base of the Aeronian Stage, Clorinda undata, Plectatrypa tripartita and Skenidioides sp. occur, as well as Monograptus austerus sequens. Four metres above the boundary the presence of the magnus Biozone is demonstrated by the occurrence of the graptolites Glyptograptus (Pseudoglyptograptus) vas, Orthograptus insectiformis and Glyptograptus tamariscus cf. linearis. Graptolites of the magnus Biozone, including Diplograptus magnus and similar forms, are present through the section up to beds at SN 8371 3943, and a change to the convolutus Biozone probably takes place near SN 8363 3937, although it has not been demonstrated in this particular section (Cocks et al., 1984). Brachiopods associated with the magnus Biozone graptolites include Meifodia prima, Anisopleurella gracilis, Leangella scissa, Aegiria garthensis and Glossoleptaena? bella.

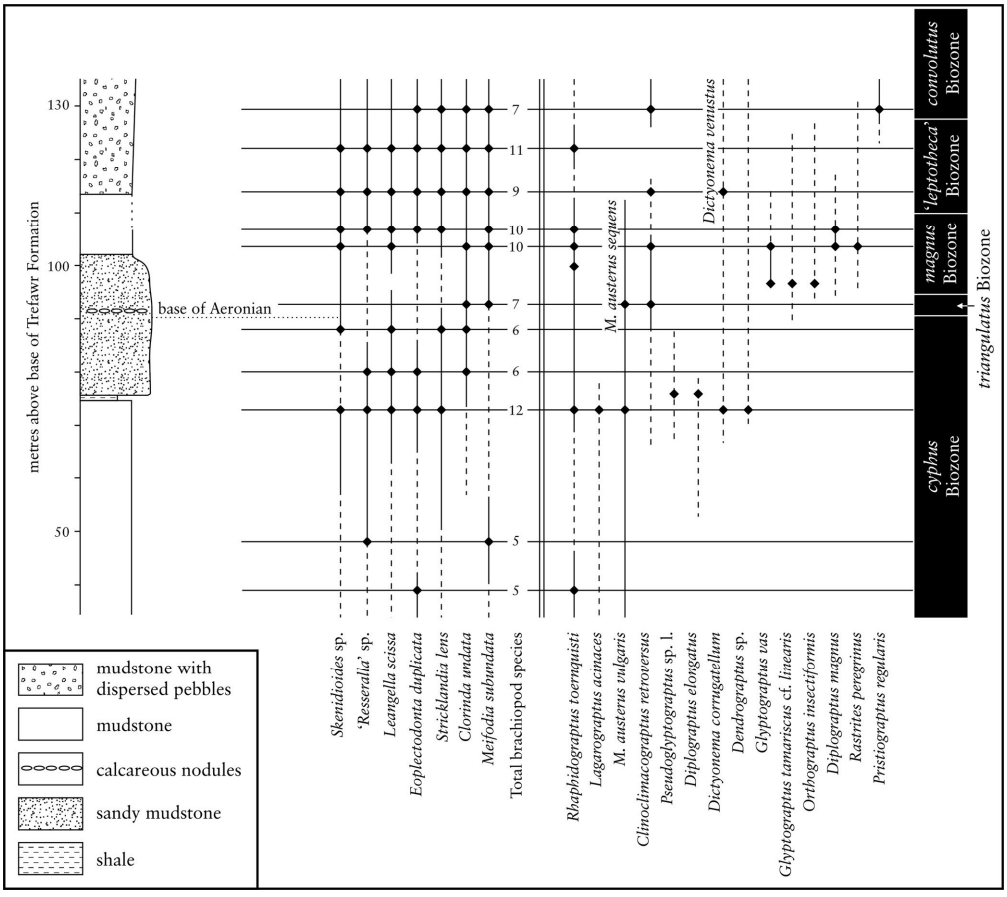

Figure 3.26: Range chart of brachiopod and graptolite taxa across the Rhuddanian –Aeronian boundary in the Trefawr Track section (after Cocks et al., 1984).

The highest exposed beds in the Trefawr Formation (SN 8347 3925) contain Clorinda undata, Plectatrypa tripartita, Meifodia prima and other brachiopods. At the bend in the track, sandy mudstones near the base of the Rhydings Formation contain Monograptus cf. sedgwickii, indicative of the sedgwickii graptolite biozone (Cocks et al., 1984).

Interpretation

The Trefawr Formation is generally finer-grained than the underlying Crychan Formation, as seen at the GCR site at Scrâch Track. Cocks et al. (1984) interpreted the lithology to indicate deposition of the Trefawr Formation in a pro-delta marine setting, but more distal than the Crychan Formation. The sandier beds were probably introduced by storm events. The brachiopod faunas do not fit well into well-defined communities, but the Meifodia and Plectatrypa assemblages typical of the Trefawr Formation are more diverse than the Stricklandia community of the Crychan Formation and this would be consistent with a more offshore marine environment. In combination with others in the type Llandovery area, this site serves to illustrate the early Silurian stratigraphical and sedimentological succession in this part of the Welsh Basin. Together with the upper beds of the Skomer Volcanic Group at the network site of Marloes Sands, this locality provides evidence of the early Aeronian fauna of the southern part of the basin, and is particularly important for the relative abundance of graptolite specimens that have been recovered.

Conclusions

This is a site of international stratigraphical importance in the Llandovery type area, as it includes the international reference section for the base of the Aeronian Stage of the Llandovery Series. An almost complete section through the Trefawr Formation is displayed, delimited by exposures of the upper beds of the Crychan Formation below and the lower beds of the Rhydings Formation above. Graptolites are more abundant in the Trefawr Formation than in any other part of the Llandovery succession in the type area; these graptolite faunas have allowed recognition of several graptolite biozones and have been used to define the base of the Aeronian Stage. Other fossils, particularly brachiopods, are also common. This site is of major conservation value as an international reference section.

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CWM-COED-AERON
OS Grid Reference: SN83383889–SN83753903

Volume 19: British Silurian Stratigraphy
Chapter 3: The Llandovery Series
Site: CWM-COED-AERON (GCR ID: 1760)

This is a key stratigraphical site in the international type area for the Llandovery Series. It comprises a well-exposed trackside section, extending from 150 m to 400 m west of CwmCoed-Aeron, in the Crychan Forest. It is situated in the northern part of the Llandovery type area, on the eastern limb of the Cefn-y-gareg Syncline, close to the axial plane trace (Figure 3.23). The section, which displays strata of the upper part of the Trefawr Formation and the lower Rhydings Formation, of Aeronian age, was logged by Cocks et al. (1984) as their transect i3. The sandy mudstones of the Trefawr Formation pass gradually and conformably into laminated muddy sandstones and sandstones of the Rhydings Formation. This formational boundary is coincident with the boundary between the Middle Llandovery (B) and Upper Llandovery (C), as used by Jones (1949). Jones considered this boundary to be unconformable, and an angular unconformity is indeed developed at this level towards the Pen-y-waun fault belt to the south of Cwm-Coed-Aeron (Cocks et al., 1984). However, the transitional relationship seen at this GCR site confirms the conclusion of Cocks et al. (1970) that the period represented by this unconformity was not long.

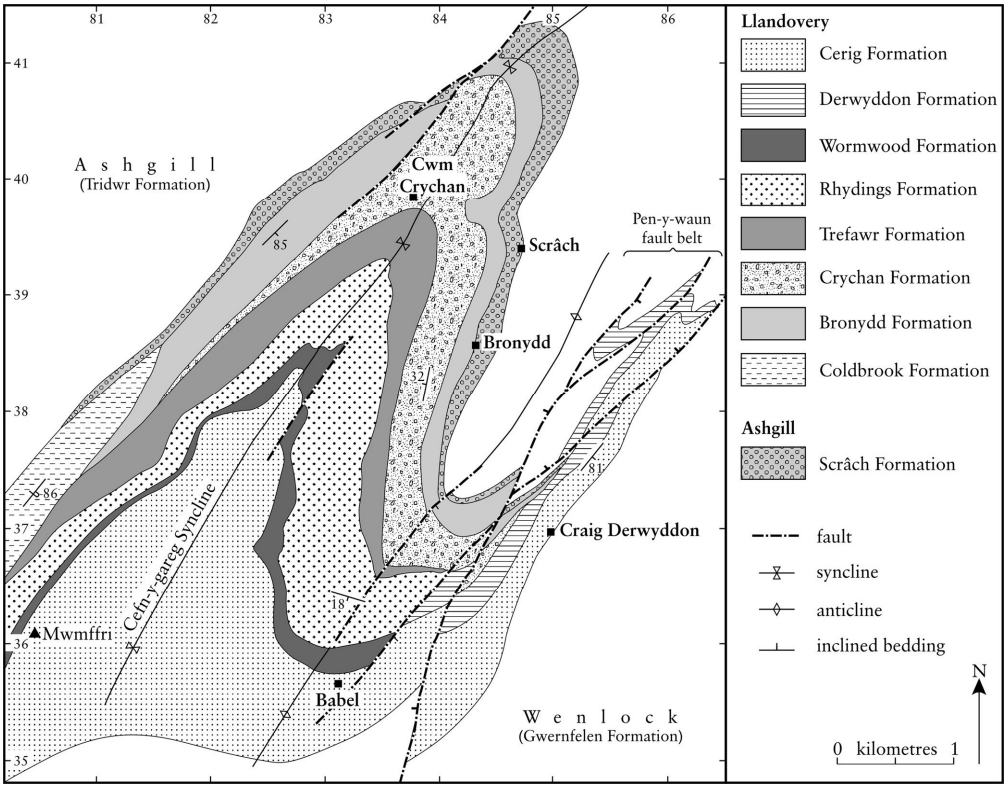

Figure 3.23: Geological map of the northern part of the type Llandovery area (after Cocks et al., 1984).

Description

Grey sandy mudstones of the upper 25 m of the Trefawr Formation are exposed at this locality and have yielded the graptolite Orthograptus amplexicaulis. Cocks et al. (1984) also reported the sandstones of the Rhydings Formation to contain Orthograptus cf. bellulus, Rastrites aff. linnaei, and specimens of Glyptograptus and Monograptus. These graptolites, together with those found low in the Rhydings Formation at other localities including Trefawr Track, suggest that the base of the sedgwickii Biozone is only a few metres above the base of the formation. Cocks et al. (1984, table 3) recorded brachiopods at several levels within the upper Trefawr Formation in this section; the fauna is diverse, but numbers are generally low. Dominant taxa are Meifodia sp., Clorinda undata, Plectatrypa sp. and Eoplectodonta sp.. Rare echinoderm plates and bryozoans also occur. Small numbers of brachiopods were also reported from the Rhydings Formation, including Meifodia sp., Triplesia sp., and Katastrophomena sp..

Interpretation

The environment of deposition of both formations was interpreted by Cocks et al. (1984) to be on a marine pro-delta lobe, with the coarsening in the Rhydings Formation representing a shallower facies. The diverse Meifodia-dominated brachiopod assemblage of the upper Trefawr Formation is comparable with that seen at a similar level in the nearby Trefawr Track section, and is consistent with a relatively distal setting. The network of sites of Scrâch Track, Trefawr Track and Cwm-Coed-Aeron are all close to each other, and together give a full coverage of the stratigraphical, sedimentological and faunal sequence in the Rhuddanian to mid-Aeronian of the northern part of the Llandovery type area.

Conclusions

This is one of a set of sites in the Crychan Forest in the northern part of the type Llandovery area that together give a full coverage of the stratigraphy, sedimentological history and faunal development in the lower to middle Llandovery of this internationally important region. It comprises good trackside exposures displaying strata of the Trefawr Formation and the lower part of the Rhydings Formation, both units of Aeronian age. The key contribution of this section is that it demonstrates a transitional relationship between the Trefawr and Rhydings formations, showing that the sedimentary record is fully preserved. It also yields characteristic fossils, particularly brachiopods and graptolites, of the Aeronian strata of this part of the Welsh Basin.

Reference list

Cocks, L.R.M., Toghill, P. and Ziegler, A.M. (1970) Stage names within the Llandovery Series. Geological Magazine, 107, 79–87.

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COED GLYN-MOCH TRACK
OS Grid Reference: SN81583760–SN81953765

Volume 19: British Silurian Stratigraphy
Chapter 3: The Llandovery Series
Site: COED GLYN-MOCH TRACK (GCR ID: 1761)

This is an important reference locality in the northern part of the international type area for the Llandovery Series. It comprises a well-exposed trackside section on the western limb of the Cefn-y-gareg Syncline (Figure 3.23). The rocks exposed at this site belong to the Upper Llandovery (C) division of the Llandovery Series formulated by Jones (1925, 1949). Formal formation names were introduced by Cocks et al. (1984) to replace the letters and numbers used in the Llandovery area by Jones; for the upper Llandovery part of the succession the same formations were identified in the southern, central and northern Llandovery regions. These are the Rhydings, Wormwood and Cerig formations. As part of their remapping and revision, Cocks et al. (1984) logged a number of major sections, and the Coed Glyn-môch Track section is equivalent to their transect f3; it spans the entire thickness of the Rhydings and Wormwood formations and incorporates the lower beds of the Cerig Formation.

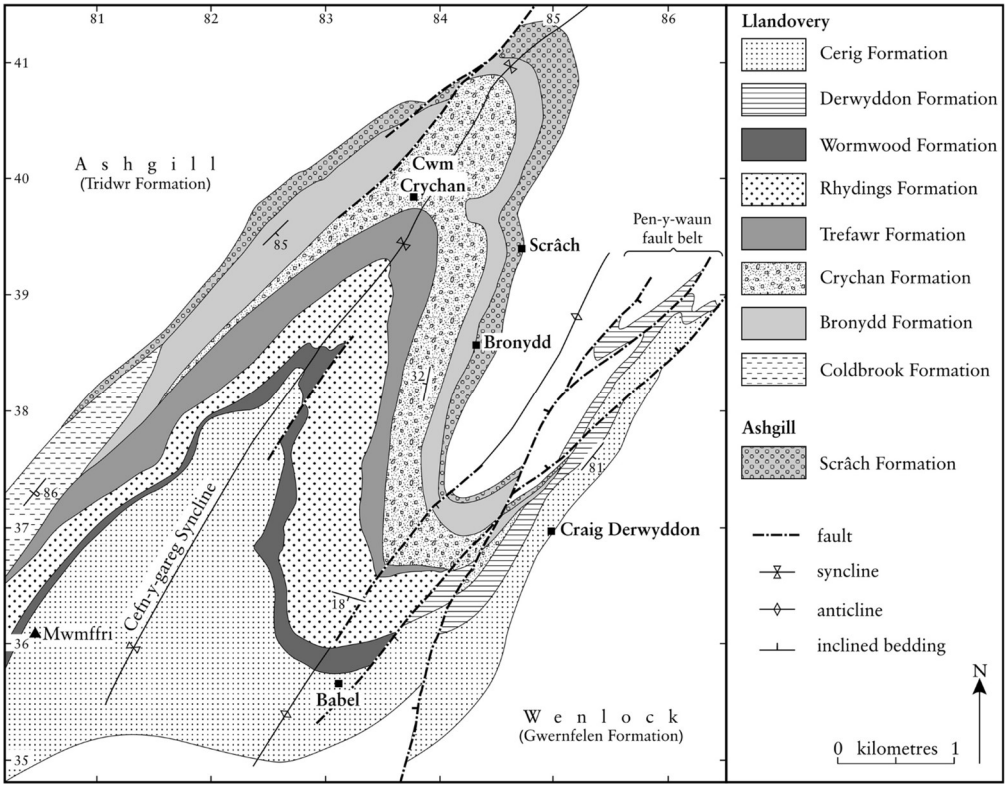

Figure 3.23: Geological map of the northern part of the type Llandovery area (after Cocks et al., 1984).

Description

The beds on this part of the western limb of the Cefn-y-gareg Syncline dip very steeply to the east and in places become vertical or overturned. The section in the track youngs to the east, and begins in the lowest beds of the Rhydings Formation. This formation comprises silty and sandy mudstones and is here more than 200 m

thick (Cocks et al. 1984, fig. 4); the overlying Wormwood Formation is about 60 m thick and comprises well-bedded but poorly laminated muddy sandstones with considerable bioturbation. Jones (1949) showed a faulted relationship between beds now assigned to the Wormwood and Cerig formations, but Cocks et al. (1984) did not map a fault at this boundary. Only the lowest beds of the Cerig Formation are exposed; the lithology returns to silty mudstones, and Cocks et al. (1984) reported the occurrence of the graptolite ?Pseudoclimacograptus (Metaclimacograptus) sp. at this locality. Brachiopods can be found throughout the section, with the faunas comparable with those seen in the southern area (see site report for the Fron Road GCR site), but details of occurrences have not been tabulated in the literature.

Interpretation

The Coed Glyn-môch Track is important in that it provides a complementary section in the northern Llandovery area to the Fron Road site in the southern area. There are minor differences in lithological development and more striking differences in thickness. The Wormwood Formation is less strongly differentiated from the Rhydings and Cerig formations in the northern area (Cocks et al. 1984), and both the Rhydings and Wormwood formations are thinner. In transect d3 of Cocks et al. (1984), along the Fron Road, the Rhydings and Wormwood formations are 370 m and 108 m thick respectively; on the Coed Glyn-môch Track, the thicknesses are 220 m and 60 m. The Coed Glyn-môch Track section also provides a fauna of brachiopods and other shelly benthic fossils, showing local development of the Pentamerus, Stricklandia and Clorinda benthic communities. The sediments suggest a relatively deep shelf setting for the Rhydings Formation, a more oxygenated and perhaps shallower environment for the Wormwood Formation, and a further transgressive deepening for the lower Cerig Formation.

The exposures in the Coed Glyn-môch Track, combined with those at Scrâch Track, Trefawr Track and Cwm-Coed-Aeron, form a network that gives a complete coverage of the stratigraphical succession through the Llandovery Series in the northern part of the international type area.

Conclusions

This important locality in the northern part of the international reference area for the Llandovery Series, combined with other GCR sites, gives a complete coverage of the stratigraphical succession in this area. It exposes the Rhydings and Wormwood formations and the lower part of the Cerig Formation, and comparisons of sedimentology, stratigraphical thickness and faunal sequence can be made with the classic parallel section in the Fron Road, in the southern part of the Llandovery type area. As a key reference site in the international type area, the Coed Glyn-môch Track section is of major conservation importance.

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