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The sedimentary succession in the Fachwen Formation, Arfon Group, North Wales

Geology and Landscape Programme
Internal Report IR/11/019

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Llanberis (SH 258000 360000)

Map

Bangor, 1:50 000 map series.

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Fachwen Formation conglomerates at Moel Tryfan.

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Foreword

This report is the published product of a study by the British Geological Survey (BGS) investigating the sedimentology of the Fachwen Group in the area around Llanberis in North Wales. The report draws on field work by the authors and earlier BGS scientists.

This work was carried out by BGS as part of the mapping programme during 2008, 2009 and 2010.

Acknowledgements

In addition to the BGS staff acknowledged in the Foreword, Stewart Molineaux provided information on the unfossiliferous nature of the Llanberis Slates, and Sandy Henderson drafted the figures.

Thanks are also due to Dr Brian Leveridge for discussion on aspects of the sedimentology.

Contents

Summary

The Arfon Group of North Wales (Reedman et al., 1984) has previously been interpreted to represent a Late Neoproterozoic to early Cambrian succession of extrusive igneous and sedimentary rocks formed in the Arfon Basin before and during uplift of the surrounding hinterland. It is overlain by the marine Llanberis Slates Formation (Brenchley et al., 2006).

Recent mapping, combined with new dating of the sedimentary rocks, has indicated that the Arfon Group is entirely Neoproterozoic in age. The sedimentary sucession overlying the volcaniclastic rock appears to be derived entirely from the tuff and the clast assemblage suggests that the basin was essentially enclosed during deposition, with little evidence for supply of material from outside the Arfon Basin.

1 Introduction

Tectonic models for the assembly of southern Britain have generally assumed that the fault-bounded Late Neoproterozoic and Cambrian terranes of Anglesey and north-west Wales are more or less autochthonous (e.g. Gibbons, 1990). This interpretation largely stems from the pre-plate tectonic theory hypothesis of Greenly (1919) who sought to interpret the provenance of clast lithologies within the Fachwen Formation of the Arvonian succession exposed in north-west Wales as being derived from local sources. More recent work (e.g. Waldron et al., 2011) has challenged these assumptions and has alluded to the importance of orogen-scale terrane translation in the assembly of southern Britain.

Two main areas of controversy surround Arvonian succession of north-west Wales: one relates to their age and the other their source region. The base of the Fachwen Formation was traditionally accepted to be the lower limit of the Cambrian (Sedgwick and Murchison, 1835). However, despite forming the original type area for the series, a lack of biostratigraphic confirmation from the succession remained problematic for achieving a reliable correlation (e.g. Rushton & Molyneux in Rushton et al. 2011). More recently, the Padarn Tuff, making up the base of the Arvonian succession, has yielded Late Neoproterozoic isotopic ages (614 ± 2 Ma, Tucker & Pharaoh, 1991; 604.7 ± 1.6 Ma, Compston et al., 2002), while the overlying sedimentary succession has also yielded a Late Neoproterozoic age from a thin tuff exposed close to the top of the Fachwen Formation (572.5 ± 1.2 Ma; Compston et al., 2002). Although this has confirmed that the Arfon Group itself is indeed Precambrian, it presents a new problem in understanding its relationship with the overlying Llanberis Slates Formation which has yielded Trilobites of Late Cambrian age in its upper part (Rushton & Molyneux in Rushton et al., 2011).

Uncertainty surrounding the age has a strong bearing on the interpretation of the provenance and admits alternative hypotheses to be developed that do not rely on the autchthonous link between Anglesey and mainland Wales during the Cambrian. Greenly (1919) contended that the Fachwen Formation was derived from the Gwna Group of Anglesey, and critically, that the presence of clasts of jasper in the Fachwen conglomerates were cited as being of particular significance. However, recent work from the blueschists associated with the Gwna Group accretionary complex in the south of Anglesey has yielded an Ar/Ar metamorphic age of around 560 Ma while a youngest detrital zircon for the lower part of the Monian Supergroup (of which the Gwna Group is contended to make up the upper unit, Phillips, 1991) has yielded and age of approximately 504 Ma (Collins & Buchan, 2004). Although there is uncertainty surrounding the exact relationships of the Anglesey successions, dates from these two unit suggest that the assemblages are younger or at very least, were not uplifted and able to shed sediment into to Arfon sub-basin during Late Neoproterozoic times while the Fachwen Formation was being deposited.

In order to shed light on terrane relationships across the region; as part of the recent BGS survey of the Nefyn district (E&W sheet 118) a reappraisal of the Arvonian succession was carried out. This study has encompassed examination of key relationships that shed light on the stratigraphic succession within the Fachwen Formation as well as the results of a detailed provenance analysis of clasts within conglomeratic facies. These data have been used as a platform from which to test the existing hypothesis for the evolution of the Arfon Basin and promote a new hypothesis for their evolution and tectonic setting in relation to adjacent geological terranes.

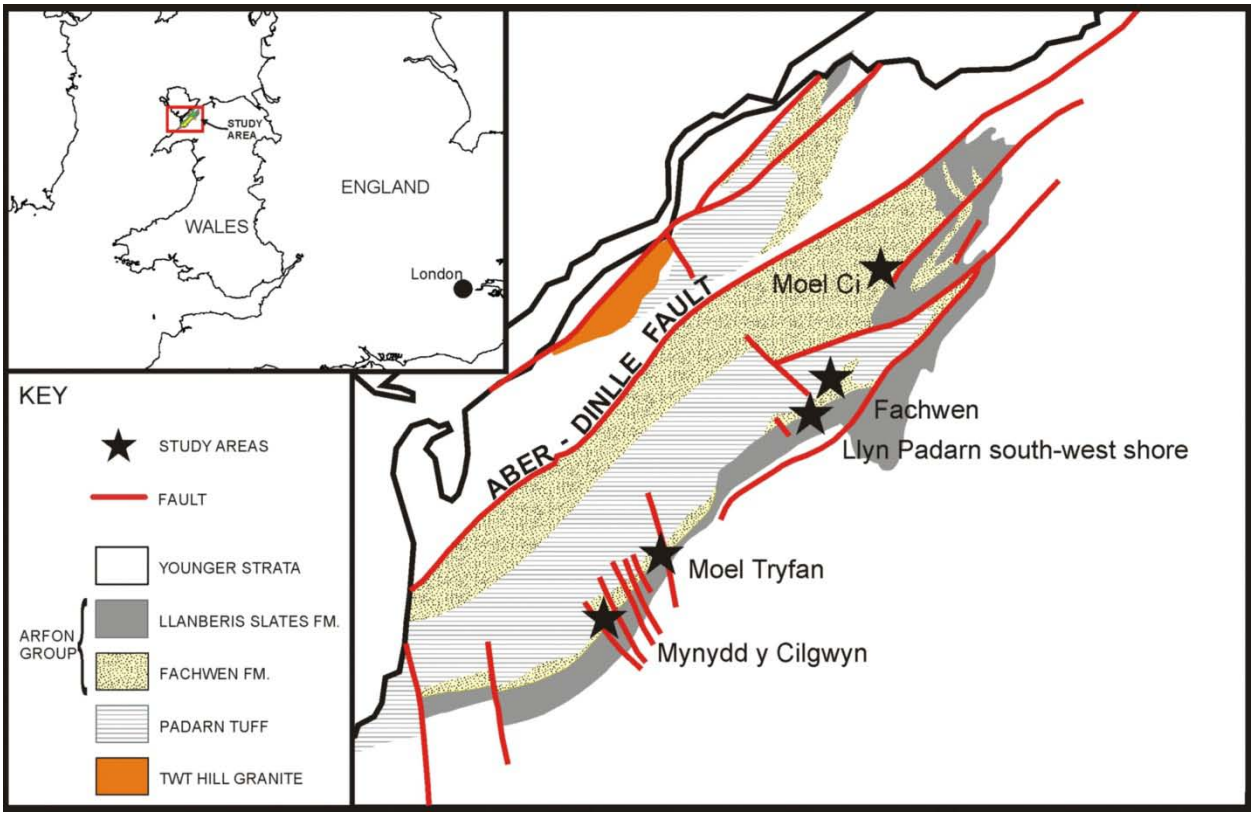

Figure 1. Location and simplified distribution of the Arfon Group and Llanberis Slates in north-west Wales. The geology of the Fachwen Formation rocks at the five named locations is referred to in detail in the text.

2 Geological Setting

The Arfon Group (Figure 1) is a Late Neoproterozoic to early Cambrian succession exposed in a north-west to south-east trending belt that lies between Snowdonia and Anglesey in north-west Wales, conicdent with and thought to be confined by the Menai Straits Fault System (Reedman et al., 1984). The present extent of exposure of the basin is 30 km in length and 10 km in width, although there has been extensive faulting and deformation of the rocks since deposition (British Geological Survey, 1985).

The oldest rocks in the Arfon Group are the Padarn Tuff Formation which has yielded Late Neoproterozoic ages U-Pb crystallisation ages from zircon of 604 Ma (Tucker and Pharoh, 1991) and 614 Ma (Compston et al., 2002). The tuff is contemporaneous with, and possibly related to, intrusion of the Twt Hill Granite (Greenly, 1944) which as yielded a U-Pb crystallisation age of 615 Ma (Schofield et al., 2010). The Padarn Tuff Formation is overlain by the Fachwen Formation which comprises coarse-grained sedimentary rocks, commonly conglomerate, with less common sandstone and tuffaceous mudstone, and subordinate tuff.

To the north-west of the Aber-Dinlle Fault, units regarded as equivalent to the Fachwen Formation are assigned to the Minfordd and overlying Bangor formations. They comprise successions dominated by sandstone, but including lenses of conglomerate and siliceous tuff throughout (Reedman et al., 1984; Brenchley et al., 2006). Both formations form crudely fining-upwards cycles, with a reappearance of conglomerate at the base of the Bangor Formation. This sedimentary succession is very poorly exposed and was not studied in detail during the current field work, although some of the work of Howells et al. (1985) has been utilised in this study.

To the south-east of the Aber-Dinlle Fault, the Padarn Tuff is overlain by the Fachwen Formation (Howells et al., 1985; Figures 1 & 2). In the vicinity of Fachwen near Llanberis, north of Llyn Padarn, the lower contact of the Fachwen rocks is reported to be unconformable (Wood, 1969), although the relationship is complicated by considerable faulting. The succession also shows a crudely fining-upwards pattern (Wood, 1969). South of Llyn Padarn, conglomerate is overlain by a succession of sandstone and mudstone beds which pass upwards into mudstone attributed to the Llanberis Slates Formation.

To the south, around Moel Tryfan and Mynydd Cilgwyn, the Arfon Group has been informally subdivided by Morris & Fearnsides (1926) into the Tryfan Grits, Cilgwyn Conglomerate and Glog Grits that form two fining-upward cycles. Our mapping has shown these to be lateral equivalent of the Fachwen Formation, but containing a greater proportion of sandstone.

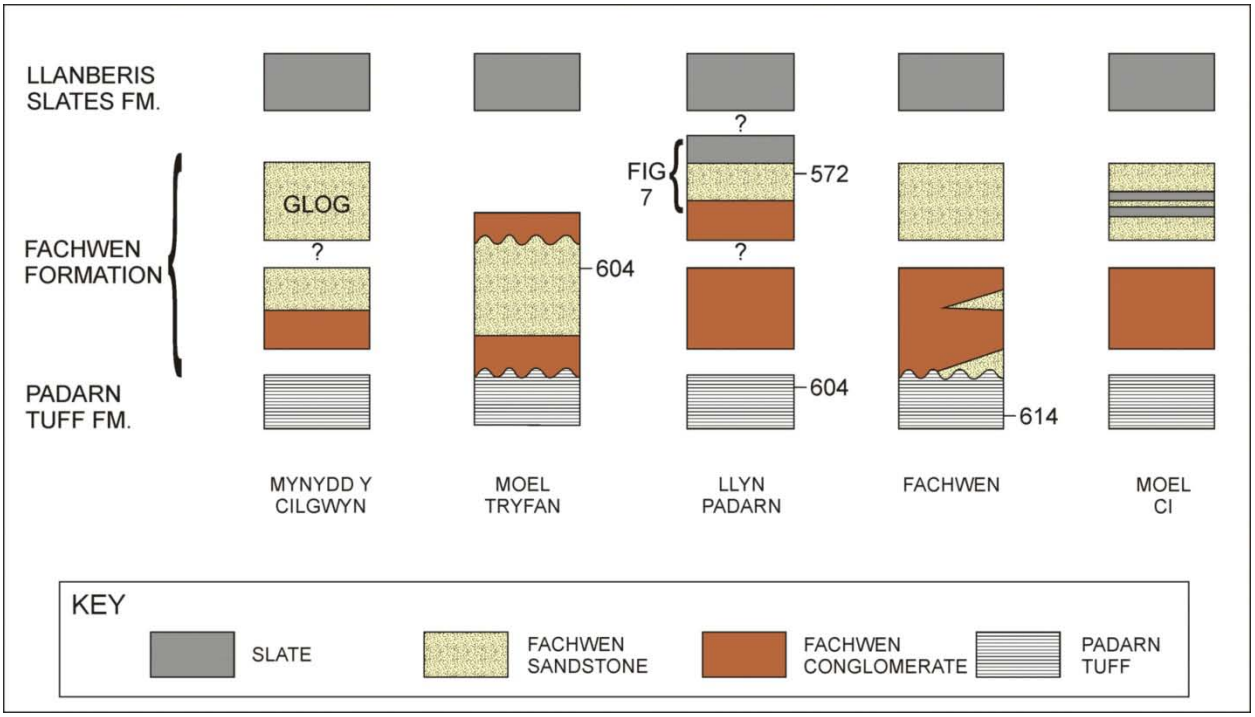

Figure 2. Simplified successions and contact relationships of the Fachwen Formation rocks at five locations south of the Aber-Dinlle Fault within the study area. Locations shown in Figure 1.

3 Methodology

The study was undertaken during field work mapping of the BGS 1: 50,000 scale Nefyn Sheet in the summers of 2008-2010. The basic methodology consisted of field survey around critical localities with an emphasis on recording and interpreting contact relationships, with logging of a well-exposed road cutting. In addition to field observations, samples were collected for isotope geochronology and micropalaeontological dating (the results of which will be reported elsewhere). The clast composition of coarse grained sedimentary rocks was assessed in the field by counting clast rock types on planar surfaces within 1 m^2 areas, the intention being to derive some semi-quantitative data to provide a comparison with the more subjective observations of Greenly (1919). Large conglomerate blocks from the count sites were collected, slabbed, polished and the surfaces photographed (Figure 3) to aid clast identification, and thin sections were made of parts of the rock containing clasts of uncertain composition.

Clast dimensions (long axis and short axis) were measured in the polished surfaces to attempt to quantify differences in deformation between conglomerates within the Fachwen Formation.

Figure 3. Polished slab surface showing a variety of tuffaceous clast types. Specimen collected from Mynydd y Cilgwyn at [NGR 49975 54582].

4 Sedimentology of the Fachwen Formation

The Fachwen Formation is well exposed on Moel Ci west of Bethesda, on both sides of Llyn Padarn and on Moel Tryfan and Mynydd y Cilgwyn north of Nantlle (Figures 1 & 2). Upper and lower contacts of the Fachwen Formation are only exposed around Llyn Padarn.

4.1 SUMMARY OF SUCCESSION

The commonly held view of the Fachwen Formation is that comprises one or two fining upwards successions in which basal coarse grained conglomerates pass upwards into sandstones. Two successions have been identified north of the Aber-Dinlle Fault (Reedman et al., 1984) and in the vicinity of Moel Tryfan and Mynydd y Cilgwyn (Morris & Fearnsides, 1926). In the area around Llyn Padarn the subdivision has not been made, however Wood (1969) shows several lenses of conglomerate within the Fachwen Formation.

During this mapping exercise it became clear that exposures of contacts between Fachwen Formation sedimentary rocks and other rock types are uncommon. Transitional facies are also uncommon and the majority of outcrops are composed of pebble conglomerate or sandstone.

4.2 MOEL CI

In the area around Moel Ci the Fachwen Formation comprises units of conglomerate, sandstone and siltstone with horizons of tuffaceous mudstone that are gently inclined toward the north-east. Although a variety of sedimentary rocks are present, there are no exposed contacts between the rock units. The abundance of faulting in the vicinity suggests that units might be fault bounded and so the actual stratigraphic order of the sedimentary succession at Moel Ci is uncertain.

On the western side of Moel Ci the formation overlies Padarn Tuff although the contact is not exposed. Units of conglomerate commonly crop out on the north-west side of Moel Ci, overlain by a sandstone dominated succession exposed on higher slopes. Below these conglomerate crags, a succession of interbedded gritty sandstone and purple, cleaved silty sandstone and siltstone is exposed at [NGR 58921 66002]. These beds display a range of sedimentary structures including loading, channelling, rip up clasts and water escape structures (distinctive sedimentology which is not observed in other exposures of the Fachwen Formation) that might indicate a shallow marine or lacustrine environment in which flood or storm processes have caused incursions of sand-prone sediment.

4.3 FACHWEN

Wood (1969) mapped the Fachwen Formation in the vicinity of Fachwen village, and decribed a sedimentary succession in which several lenticular horizons of conglomerate are interbedded with sandstone. The succession comprises a basal conglomerate overlain by a series of interbedded conglomerates, sandstones, tuffs and slates. Wood (1969) does not subdivide the Fachwen into two fining upward successions but does interpret a tuff within the sequence to indicate a temporary return to subaerial conditions.

Several exposures of the contact between the Padarn Tuff and the overlying conglomerates occur around the village of Fachwen. At [NGR 57596 62319] and [NGR57535 62222] a contact between foliated tuff and conglomerate is exposed. This contact is planar and sharp, indicating an unconformable surface. The underlying tuff becomes progressively more chloritic in the 15 m below the conglomerate (Figure 4) and contains scattered pebbles of quartzite and tuff within 5 m of the contact.

We interpret the elevated chlorite content in the upper part of the tuff as a relict weathering profile developed prior to deposition of the conglomerate. Clay minerals derived from weathering of feldspar were subsequently metamorphosed to form chlorite during regional

tectonism. This is also described by Wood (1969) who notes that "*The contact shown on the map is based on the first recognition of pebbles*." and "*The matrix of the lowest pebble-bearing horizons is indistinguishable from the underlying ignimbrite*." In this instance Wood (1969) has presumably described the weathering profile but has not identified any sharp contact between tuff and clast-dominated conglomerate, suggesting that the contact is both variable and complex and does not imply any geologically significant time break between deposition of the Padarn Tuff and the overlying Fachwen Formation.

Figure 4. Photo of probable weathered Padarn Tuff with a foliated, chloritic matrix containing pebbles 1 m below contact with the Fachwen Formation. Hammer head is 165 mm across. Graig-lwyd hill north-east of Fachwen village, [NGR 57596 62319].

Figure 5. Conglomerate of the Fachwen Formation immediately overlying the weathered tuff shown in Figure 4. Hammer head is 165mm across. Graig-lwyd hill north-east of Fachwen village, [NGR 57595 62317].

On the north-east shore of Llyn Padarn, the Llanberis Lake Railway track cutting provides a near continuous exposure from the main outcrop of the Padarn Tuff to the Llanberis Slates Formation. However, few contacts are exposed and most are marked by faults. In one outcrop the contact between two units of conglomerate is exposed. The underlying unit contains clasts < 40 mm which have a strong north-west alignment orientation. Clasts are elongated by 2-3 times their east-west dimension. Some competent clasts also contain fractures with an east-west orientation. The overlying conglomerate does not show a significant elongation of clasts which are up to 100 mm in diameter. The difference in clast elongation implies that the contact between the two conglomerates is tectonic.

On the hill Gallt-y-Foel, 700m to the east of Craig-lwyd, up to 10m of coarse grained sandstone overlies weathered tuff. There are no exposures of conglomerate and it appears that the variations in facies are relatively rapid as shown in Figure 11 of Wood (1969).

4.4 LLYN PADARN SOUTH-WEST

On the southern shore of Llyn Padarn exposures of Fachwen Formation conglomerate are common, extending up-hill to the south-west. The contact with the underlying Padarn Tuff is not exposed, however. The conglomerates do not show any distinctive sedimentary structure, and they are overlain by chloritic sandstones and tuffs which themselves pass upwards into mudstones of the Llanberis Slates Formation. There is no indication of a second fining-upward cycle within the succession.

On the A4086 1 km north of Llanberis, a relatively continuous succession is exposed in which conglomerate (Figure 6) is conformably overlain by a series of sandstones, mudstones and tuffs (Figure 7). The contact between conglomerates and tuffs appears to be relatively sharp, and at [NGR 56684 61198] conglomerate is overlain by sandstone, with little evidence for a gradual change in grain size. This sandstone is overlain by a succession of mudstones taken by Wood (1969) to represent the basal part of the Llanberis Slates Formation. Within this succession is the tuffite which has been dated by Compston et al. (2002) at 572.5 ± 1.2 Ma. New sedimentary logging reported here shows that the tuffite lies roughly 11 m below the contact with the overlying Slates (Figure 7). The tuffite is therefore much closer to the upper boundary of the Fachwen Formation than is shown on Figure 4 of Compston et al. (2002).

Figure 6. Fachwen Formation conglomerate by the south-west shore of Llyn Padarn at [NGR 56595 61257] on the A4086 roughly 150m east of the log shown in Figure 7. Hammer head is 165mm across.

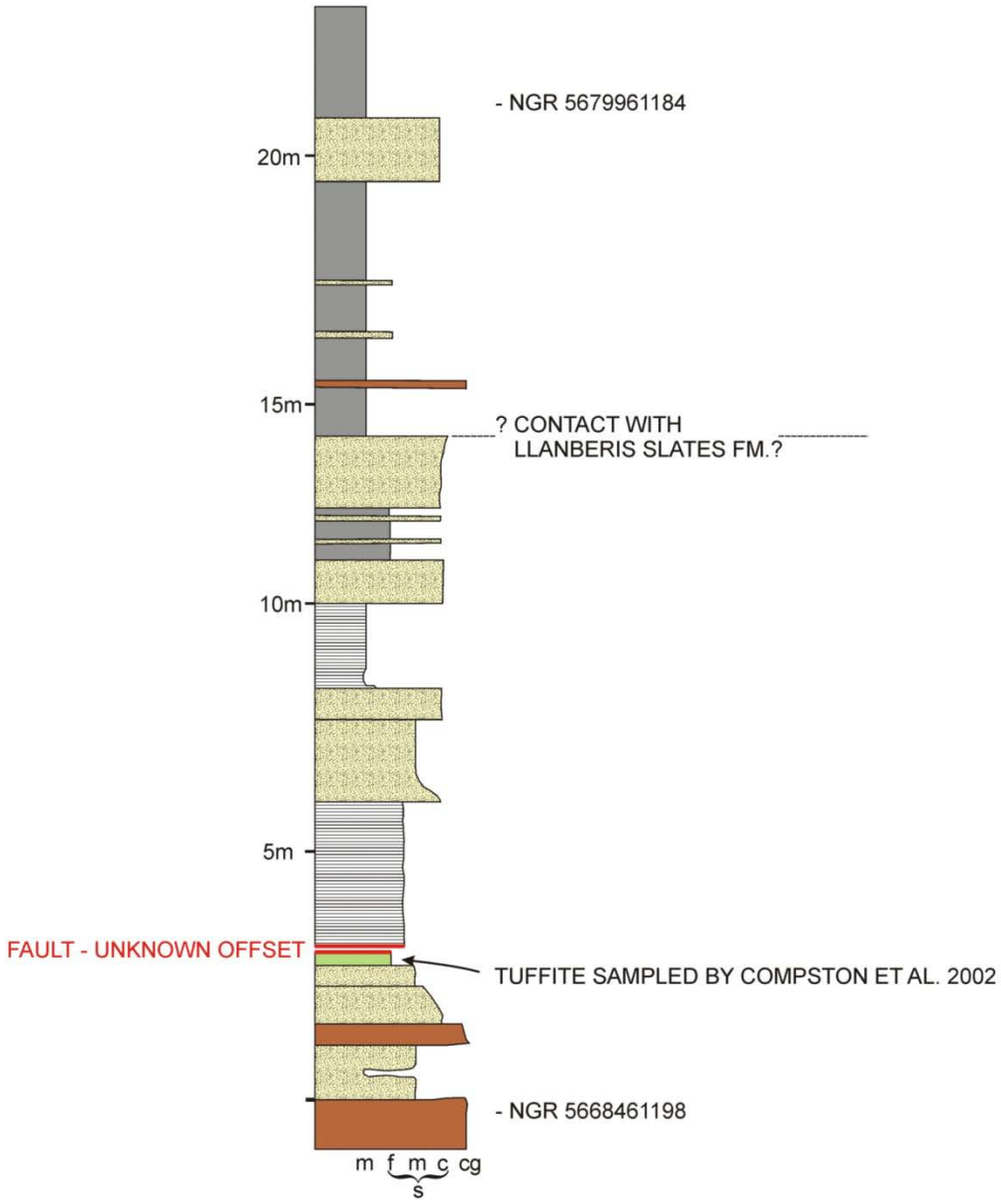

Figure 7. Log of the section on the A4086 north-west of Llanberis showing the upper part of the Fachwen Formation and its inferred contact with the lower Llanberis Slates Formation. The location of the sample dated by Compston et al. (2002) is shown. Colours in the log are for the same as those in the key to Figure 2.

4.5 MOEL TRYFAN AND MYNYDD Y CILGWYN

Morris & Fearnsides (1926) subdivided the Sedimentary rocks around Nantlle into two fining-upwards successions, the lower named the Tryfan Grits and the upper comprising the Cilgwyn Conglomerate and Glog Grits, all of which form the Fachwen Formation. This sequence of sedimentary rocks was identified in this study, however the statements made by Morris & Fearnsides (1926) regarding the thickness of succession, based on marker pebble beds identified on Mynydd y Cilgwyn and further west, could not be verified.

Two hills in the vicinity of Nantlle, Mynydd y Cilgwyn and Moel Tryfan (Figure 1), contain exposures of Fachwen Formation.

On Moel Tryfan the Padarn Tuff appears to be overlain by the Tryfan Grits and Cilgwyn Conglomerate (Morris & Fearnsides, 1926). Unfortunately there are no exposed contacts and bedding is ambiguous, so that the actual order of beds within what is likely to be the lateral equivalent of the Fachwen Formation cannot be established with certainty. Morris & Fearnsides (1926) reported logging of a tunnel under Moel Tryfan in which the rocks underlying the Llanberis Slates Formation generally dip towards the south-east. They reported a dip of 30^{o} to the south on the top of Moel Tryfan, although this bedding plane trend was not identified during recent BGS fieldwork (Figure 8a). The changes in grain size that were observed (Figure 8a) did not form distinctive, planar beds; if they were original bedding planes, there has been significant folding and deformation post-deposition.

Figure 8a. Moel Tryfan conglomerate and sandstone showing the subtle changes in clast abundance within the rock (in this case forming a surface dipping 30^{o} to the west that might be an original bedding plane). Length of hammer shaft 380mm. [NGR 51560 56198].

Figure 8b. Moel Tryfan conglomerate. Hammer head is 165mm across. [NGR 51574 56198[.

The lowermost exposure of the Tryfan Grits is conglomeratic, however, and two fining upwards cycles are present within the Fachwen Formation, with the base of the Cilgwyn Conglomerate forming the base of the upper cycle (Figure 2). This contact is described by Morris and Fearnsides (1926) as erosional, with the conglomerate cutting into the underlying siltstones.

On Mynydd y Cilgwyn a significant thickness of Cilgwyn Conglomerate is exposed, which passes upward into into sandier rocks (the Glog Grits of Morris & Fearnsides, Figure 2) towards the south. There are no clear indications of bedding, however, and no distinct contacts are exposed, the relationship between the conglomerate and surrounding rocks is therefore unclear.

Exposures of the sandstone to the south-west of Mynydd y Cilgwyn are poor and while over 600 m of grits have been recorded by Morris and Fearnsides (1926), there are no contact relationships through which the exact order of succession can be determined. The marker pebble bed described by Morris and Fearnsides (1926) was not identified during this study and so no conclusions as to the thickness of this unit could be made.

5 Clast counting, petrography and dimensions

5.1 CLAST COUNTING AND PETROGRAPHY

In the conglomeratic facies of the Fachwen Formation, both field based counting (Figure 5) and subsequent examination of polished slabs have provided estimates of the clast composition. Thin sections were made of parts of the slabs to aid clast identification.

Fourteen types of clast were identified in the field (Appendix 1) of which six are varieties of tuff or tuffite. Of the other clast types, metasandstone, quartz and microgabbro were relatively common at single locations. Vein quartz, mudstone or chert and jasper are uncommon but were identified in several locations. Clasts of microgranite and metabasalt were uncommon but observed locally.

At ten of the eleven locations, varieties of tuff made up more than 75% of the clasts counted, the exception being at the Fachwen 2 locality where only 40% of the clasts are tuff. Details of clast counts are given in Appendix 1.

Block samples were taken from three of the field localities and were slabbed and polished. Blocks were cut perpendicular to any obvious fabric, and all faces were analysed to maximise the number of clasts counted (Appendix 2).

Fourteen clast types were identified, of which eleven were varieties of tuff. Of the other types only granitoid clasts were observed in more than one face. The majority of clasts are tuffs, the other lithologies being granitoid, metasedimentary rock and jasper. Lithologies other then tuff do not make up more than 10% of the clast population in any sample.

Petrographic analysis of thin sections prepared from the polished blocks, however, did not identify any clasts that were not tuffaceous or granitic in composition. It appears that the variety in colour and texture of the pyroclastic rocks has given an appearance of a variety of lithologies in the field

This clast study confirms the analysis reported by Greenly (1919) who's work indicated that the Fachwen conglomerates are dominated by tuffs, with only quartzite and jasper found in addition to the pyroclastic material. In conglomerates overlying the Llanberis Slates Formation a much larger range of pebble lithologies was identified by Greenly (1919).

5.2 CLAST DIMENSIONS

The long and short axes of each clast were measured and the mean elongation ratio for each clast type calculated (Appendix 2). Clast dimension measurements (Appendix 2) indicate that conglomerate sample number 1019 from Fachwen and number 1020 (Figure 9a) from Mynydd y Cilgwyn contain clasts with long axes 1.80 to 2.70 times longer than the short axes. The ratio in sample 1023 (Figure 9b) from Mynydd y Cilgwyn, however, is 4.92. The difference in clast colour between the two conglomerates shown in Figure 9 might suggest a different clast composition. Petrographic analysis again suggests that the variations in colour are related to alteration in what is the same suite of clasts.

The difference in clast dimension illustrated in Figure 9 is clearly a consequence of the presence of a zone or zones of tectonic shearing or flattening within the Cilgwyn Conglomerate.

Figure 9a. Cut and polished slab of undeformed conglomerate from Mynydd y Cilgwyn, sample number 1019. The range of colours and textures is related to the variety of clasts derived from the igneous centre but also to subsequent alteration. [NGR 49975 54582]

Figure 9b. Cut and polished slab of deformed conglomerate from Mynydd y Cilgwyn, sample number 1020. The variation in colours and textures is marked but all clasts are volcanigenic or granitic in origin. [NGR 49735 54286]

6 Depositional Environment and Basin Evolution

The Fachwen Formation was deposited during or immediately following the formation of the igneous centre that gave rise to the Twt Hill Granite and Padarn Tuff Formation. The sediments were deposited in a subsiding basin, apparently in an environment with relatively rapid changes between coarse grained and finer or deeper water facies. The presence of a possible weathered horizon indicates that the conglomerates immediately overlying the weathered tuff are likely to have been deposited subaerially. This interpretation is underpinned by the observations of Wood (1969) who identified both submarine and subaerial volcaniclastic rocks near Fachwen. The transition from a fluvial or alluvial environment into marine deposition has not been confirmed, however, other than the possibly shallow marine, interbedded rocks on Moel Ci whose contacts with other facies are not observed.

It is probable that the upper parts of the succession shown on Figure 7 are marine. There are few diagnostic sedimentary structures identified in any of the Fachwen Formation rocks and other than cross bedding there is little indication of sedimentary environment. There appears to be a greater proportion of sand in the Fachwen Formation rocks to the south-west which might indicate a more distal environment with sediment supply from the north and east. This apparent lateral variation, coupled with the distinctive sedimentary rocks exposed on Moel Ci, indicates that the Arfon Basin had a more complex architecture than the simple coarsening-up sequences that have been identified on the basis of present-day outcrop.

Clast analysis indicates that the majority of sediment was derived from the igneous centre that created the Padarn Tuff and the Twt Hill granite and that the Arfon Basin was effectively enclosed during deposition of the Fachwen Formation. Greenly (1919) identified quartzite and jasper clasts and related these to the Gwna Group to the north-west. This interpretation has formed part of the basis for the autochthonous interpretation of the tectonic evolution of North Wales (Howells et al., 1985). However recent findings have cast doubt on this model. Firstly, recent detrital zircon studies from the South Stack Group, underlying the Gwna Group, have shown that the latter is younger than late Cambrian (Furongial) in age (Collins & Buchan, 2004), ruling out this succession as a potential source of clasts for the Fachwen Formation. Secondly, recent detrital zircon studies from the Harlech Dome (Waldron et al., 2011) have highlighted contrasts in the some provenance of north Wales successions and suggested the possibility that some of the fault-bounded units that make up north Wales may have been separate until early Ordovician times. Furthermore, jasper, one of the key clast lithologies quoted by Greenly (1919) as relating the two successions, is common to many areas of submarine volcanism and is therefore not certain to have been derived from terrain now forming a part of Anglesey.

The mudstones that conformably overlie the Fachwen Formation are assumed to be a part of the Llanberis Slates Formation. They lie above a tuffite which is dated as 572 Ma (Compston et al., 2002), albeit within a succession cut by a fault with unknown displacement (Figure 7). Given that the top of the Llanberis Slates Formation is dated at roughly 520 Ma and assuming continuous sedimentation, there is a considerable time period during which deposition of the mudrocks can take place. Nearly 1000 m of rock is estimated to be present in the Llanberis Slates Formation, giving a mean deposition rate of 0.02 mm/year. Even given the order of magnitude of thinning associated with compaction, the rate of sedimentation for a basin with a constant input of clastic sediment is extremely slow compared to rates of 10 – 100 mm/year .

It is possible that the upper mudstones are part of the Fachwen Formation. If this is the case, then there is likely to be an unrecognised period(s) of non-deposition within the Arfon Basin within the mudrocks.

At Moel Tryfan and Mynydd y Cilgwyn (Morris and Fearnsides, 1926), as well as in the Bangor area (Howells et al., 1985), there are two periods of deposition separated by a possible cryptic intraformational unconformity. In Bangor a period of uplift and tilting appears to separate the

two successions (Howells et al., 1985). Although this has not been identified with certainty in the Fachwen and Llyn Padarn area, Wood (1969) identified two phases of deposition of conglomerate without inferring an unconformity within the succession.

The Fachwen Formation might comprise two fining upwards successions within a transgressive environment, in which coarse grained alluvial sediments pass upwards into marine and possibly lacustrine sands and muds.

7 Conclusions

The sedimentary rocks of the Arfon Basin comprise a series of conglomerates and sandstones, derived almost exclusively from the igneous centre which gave rise to the Padarn Tuff and the Twt Hill Granite. The other clast types within the conglomerates (quartzite and jasper) have been related to sources in Anglesey, but the uncertainty over terrane reconstructions means that this source is unlikely.

The sedimentary rocks appear to have been laid down in two fining upwards successions, separated by an unconformity that, around Bangor at least, was prolonged enough to allow uplift and tilting of the lower succession.

The uppermost part of the Fachwen Formation appears to grade conformably upwards into mudstones of the basal Llanberis Slates Formation. If this in the case, the Llanberis Slates Formation was deposited over a considerable time period, and it is likely that there is an unrecognised period, or periods, of erosion and / or non-deposition within the formation.

Subsequent deformation and tectonism in the area has made it difficult to identify the sedimentary succession making up the Fachwen Formation and the limits of the Arfon Basin which might have had a more complex architecture than is indicated by the present day outcrops.

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British Geological Survey holds most of the references listed below, and copies may be obtained via the library service subject to copyright legislation (contact libuser@bgs.ac.uk for details). The library catalogue is available at: http://geolib.bgs.ac.uk.

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Appendix 1 Field clast counts

Clast types used in field clast counting.

1.	Pink tuff	pale pink, sub angular to sub rounded
2.	Pink crystal tuff	pale pink, quartz crystals and spherules
3.	White tuff	white to grey, cryptocrystalline, flinty
4.	White crystal tuff	white to grey, quartz and feldspar crystals and spherules, brown weathering
5.	Green crystal tuff	pale green, crystals of feldspar
6.	Green tuff / tuffite	pale green, foliated
7.	Pink metasandstone	pale pink to purple to red, rounded, quartzose
8.	Quartzite	white, fine grained
9.	Vein quartz	
10.	Mudstone or chert	medium grey, sub-angular, siliceous, fissile
11.	Jasper	cryptocrystalline, mottled
12.	Microgabbro	pale grey, speckled
13.	Microgranite	quartz and feldspar euhedra
14.	Metabasalt	fine-grained basic igneous

Field clast counts. Clast types are numbered according to the list on the previous page.

Locality	Grid Ref North	Grid Ref East	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total count
Fachwen 1 (1019)	56513	61068	15	0	4	5	0	19	27	5	0	3	5	0	0	0	83
Fachwen 2	56495	61054	0	0	2	5	0	1	6	2	0	4	0	0	0	0	20
Mynydd y Cilgwyn 1 (1023)	49735	54286	0	125	3	0	125	0	26	0	1	8	2	0	0	0	290
Mynydd y Cilgwyn 2 (1020)	49975	54582	0	0	0	179	5	0	3	0	0	0	3	59	1	0	253
Mynydd y Cilgwyn 3	49759	54894	0	41	0	9	108	7	0	2	0	1	0	0	0	0	168
Moel Tryfan 1	51525	56183	0	67	98	103	0	0	7	0	0	0	2	0	0	0	277
Moel Tryfan 2	51255	56213	0	0	40	58	0	0	0	56	13	4	0	0	0	2	173
Llyn Padarn 1	56567	61299	150	112	0	0	27	0	92	0	1	0	0	0	0	0	382
Llyn Padarn 2	56604	61255	106	156	0	0	46	0	59	0	2	0	0	0	0	0	369
Llyn Padarn Railway 1	57023	61629	0	0	51	67	30	10	14	0	2	18	0	0	0	0	192
Moel Ci	58872	66510	0	0	34	570	136	0	0	0	0	0	0	0	0	3	743

Appendix 2 Polished slabs: clast counts and dimensions

Clast types identified in polished slabs.

1. Green crystal tuff
2. Green tuff
3. Dark crystal tuff
4. Dark tuff
5. Grey crystal tuff
6. Grey, silicic tuff
7. Grey welded tuff
8. Brown tuff
9. Red / grey silicic tuff
10. Dark green tuff
11. White tuff
12. Granitoid
13. Metasedimentary rock
14. Jasper / other

Clast types are numbered according to the above list. The mean ratio is that between lengths of the long and short axes of the clast. Sample 1019 was collected from the south-west shore of Llyn Padarn and samples 1020 and 1023 were collected on Mynydd y Cilgwyn.

Sample 1019	**1**	**2**	**5**	**6**	**7**	**12**	**9**	**10**
Mean ratio	2.33	2.92	2.23	2.56	3.14	2.09	2.15	4.00
Clast total	5	5	5	6	1	2	5	1

Sample 1020 1	**3**	**4**	**5**	**6**	**10**	**12**	**9**	**14**
Mean ratio	2.38	2.80	1.90	2.17	2.81	1.67	1.75	1.40
Clast total	16	4	20	12	3	1	2	1

Sample 1020 2	**3**	**4**	**5**	**6**	**10**	**9**
Mean ratio	1.89	1.95	1.75	1.84	2.37	1.17
Clast total	5	18	18	18	4	1

Sample 1020 3	**3**	**4**	**5**	**6**	**10**	**12**	**9**
Mean ratio	2.38	2.54	1.79	2.40	3.73	1.00	2.83
Clast total	11	6	18	26	2	1	1

Sample 1023	**5**	**6**	**7**	**8**	**10**	**11**	**13**
Mean ratio	5.73	3.51	3.63	4.16	9.73	5.07	2.63
Clast total	30	16	11	6	17	8	3