

Survey of Moel Arthur and Penycloddiau

27 January 2015 and 15 February 2015

The Team: John Barnard, Jenny Barnard and Graham Jackson

1) Introduction

Moel Arthur (Hill Number 5155, Section 30C, OS 1:50000 Map 116, OS 1:25000 Map 265, Grid Ref. SJ145660) and Penycloddiau (Hill Number 2047, Section 30C, OS 1:50000 Map 116, OS 1:25000 Map 265, Grid Ref. SJ127678) are adjacent hills in the Clwydian range. The former is listed as a HuMP (hills with greater than or equal to 100m of drop) and the latter is listed as a Marilyn (Hills with greater or equal to 150m of drop).

The main purpose of this survey was to ascertain the position and measure the height of the summit of Penycloddiau since the summit had been altered in 2010 by Denbighshire/Flintshire Council with the construction of a soil and stone mound supposedly to provide protection for the Bronze Age burial mound.



In addition we took the opportunity to measure the positions and heights of the bwlech of Penycloddiau to check its drop, although the hill's status is not in question, and the summit of Moel Arthur.

Penycloddiau was surveyed by Myrddyn Phillips on 16 December 2014, when he measured the summit height as 440.5m to the top of the man-made mound and the drop to be 157.8m.

2) Equipment used and Conditions for Survey

A Leica NA730 Professional Automatic level (X30 telescopic system)/tripod system and a “1m” E-staff extendable to 5m were used to determine the positions of the bwlch and summits.

Absolute heights were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is a dual-frequency and multi-channel instrument, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates, and receive two signals (at different frequencies) from each of these satellites. The latter feature reduces inaccuracies that result from atmospheric degradation of the satellite signals. As a stand-alone instrument it is capable of giving position and height to an accuracy of about two metres and five metres respectively. Note that small hand-held GPS receivers used for general navigation can only receive up to 12 GPS satellites and each at a single frequency and therefore these instruments have a poorer positional accuracy of +/-5metres and a height accuracy of no better than +/-10 metres. Some recently produced hand held GPS Garmin receivers can also receive signals from GLONASS satellites which greatly improves the speed at which these units can achieve a satellite “fix”. Despite the on-board features of the Viva GS15, there are still sources that create residual errors. To obtain accurate positions and heights, corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey which were post-processed using Leica Geo Office 8.3 software.

Conditions for the survey, which took place on 27 January 2015 between 11.00hr and 17.00hr GMT, were good. The weather was clear, although the sky overcast, with a temperature of 6 degrees Celsius and a light wind. A repeat measurement of the height of Penycloddiau was made on 15 February 2015 between 11.30hr and 13.00hrs GMT under similar weather conditions but sunnier and a little less windy.

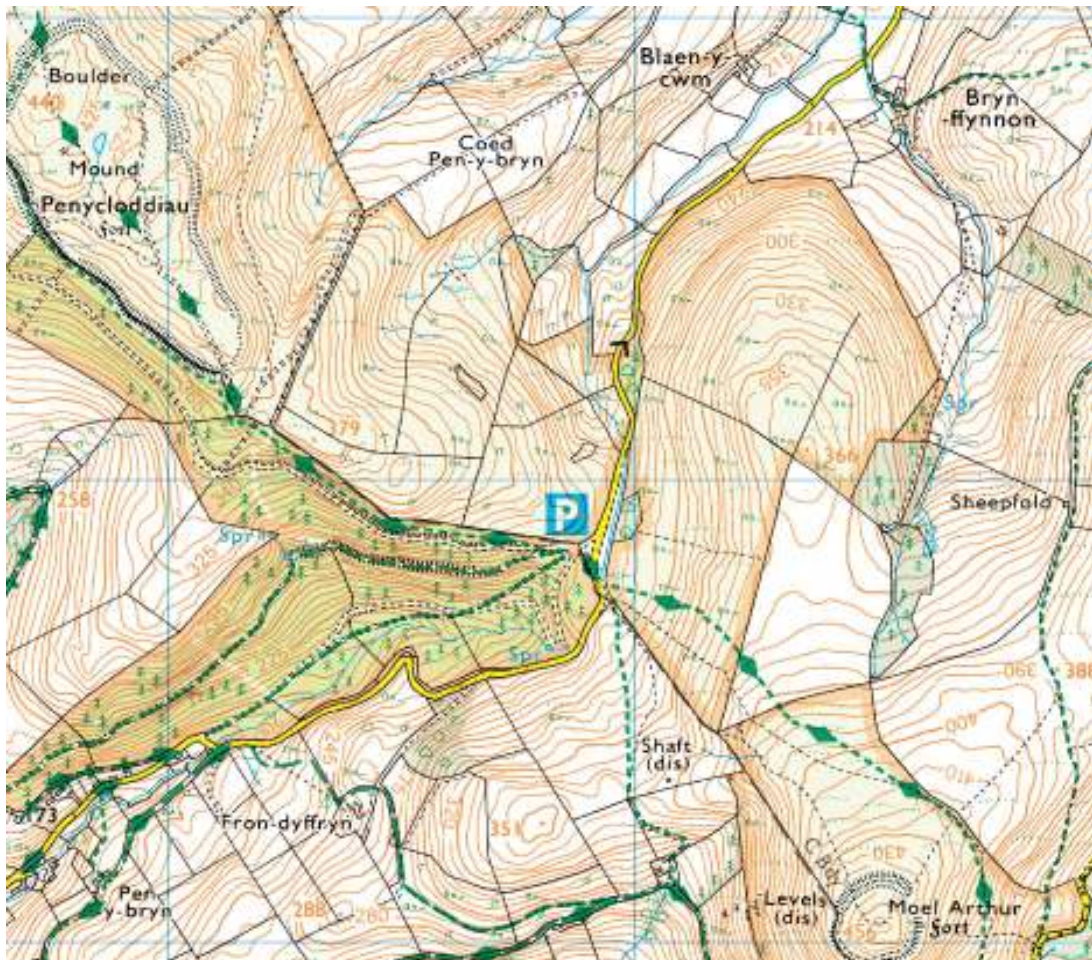
3) The Survey

3.1) Character of Hills

An extract of the 1:25000 scale Ordnance Survey map with the summits of Penycloddiau and Moel Arthur is shown below. The two hills are contained within the Clwydian range of hills which extends from South of Prestatyn on the North Eastern Welsh Coast to Cym-y-Brain at the Horseshoe Pass just North of Llangollen. The whole range of hills is very scenic and has been declared as an area of outstanding natural beauty. The long distance Offa’s Dyke path follows this range and includes a number of the most significant summits of which the most popular is Moel Famau at 554m, although Cym-y-Brain to the South is higher at 565m.

Penycloddiau and Moel Arthur are adjacent hills with the critical bwlch for Penycloddiau lying between them. Offa’s Dyke footpath runs over the summit of Penycloddiau and down to the bwlch to the South where there is a fairly large car park providing good access to both hills. Here Offa’s Dyke path continues in a South Easterly direction and skirts around the East of the summit of Moel Arthur. At the highest point of this path an easy diversion on a footpath can be made to the summit of Moel Arthur which is marked with a cairn.

Both hills are typical of the Clwydians which are predominately grassland and heather covered moors. These hills are quite steep, particularly on the Western side where there is some forestry. The Eastern side is mostly agricultural and dedicated to sheep and cattle farming. This is also a good area for nature study with a variety of wild flowers and upland birds.



3.2) Penycloddiau Summit

The survey commenced at the summit of Penycloddiau. Photographs of the summit area are shown in Appendix 1. The first task was to identify the highest “natural” ground now existing since the building of the mound in 2010. The Leica NA730 level was set up at a convenient position near the perimeter of the oval retaining wall. Having ascertained with staff readings that more distant ground was not higher, staff readings were taken around the perimeter of the wall and on ground adjacent to it until the highest point had been found. This was then marked and the GS15 was set up on the “short tripod” mounting directly over this point (as shown in the photograph in Appendix 1). Prior to this staff readings were also taken around the new cairn to find the highest point there. Once done, the difference in height between this highest point and the GS15 set up position could be calculated.

Staff reading at GS 15 setup position = 0.869m.

Staff reading at highest point adjacent to cairn on man-made mound = 0.205m.

Vertical Offset correction (Tape measurement) = 0.678m.

Vertical Offset correction for use of short tripod assembly = 0.255m. (Leica parameter)

Total Vertical Offset correction used in computations = 0.678 + 0.255 = 0.933m

GNSS data were collected for 1 hour. The position and height data for the bwlch that were recorded by the Leica Viva GS15 was post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the eight nearest functional base stations under 100km distance and the Computed model for tropospheric correction. (The nearest Base station at St Asaph was not functioning at the time of this survey). These results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	312717.110	0.002	367890.783	0.002	439.523	0.005

Height of highest ground outside the perimeter of the wall = 439.52m

Correction for height to highest point next to cairn = $0.869 - 0.205 = 0.664\text{m}$

Therefore height of highest point next to cairn = $439.523 + 0.664 = 440.19\text{m}$.

Since the height measurement of 440.19m made in this survey differs from the figure of 440.54m obtained by Myrddyn Phillips with his Trimble Geo XH6000, the GS15 measurement was repeated on 15 February 2015. In this case the GS15 was set up (as shown in the photograph in Appendix 1) directly over the highest point adjacent to the cairn on the man-made ground. GNSS data were collected again for 1 hour and processed as described above. However as St Asaph Base station was operational, a total of nine Base stations were used in the computation. The results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	312713.895	0.002	367888.677	0.002	440.155	0.006

This result of 440.16m compares well with the 440.19m obtained previously. Using the above correction, the height of the highest ground outside the wall is 439.49m. Therefore, the mean for the two datasets is 439.50m.

A ten-figure Grid Reference recorded for the summit by a hand-held receiver was:-

Garmin Oregon 450 SJ 12716 67891 Height = 452m Acc = 4m

3.3) Penycloddiau Bwlch

The vicinity of the bwlch is quite well defined as the area on the South eastern side of the minor road between Penycloddiau and Moel Arthur. This area can be seen in the photograph in Appendix 1 with the caption “GS15 (27 Jan 2015) set up near Penycloddiau bwlch”. The path here is the Offa’s Dyke way which leads down from the minor road across a boggy area to a stile and then across open hillside to Moel Arthur. Facing this way and to the right of the stile is a gate that leads into a field. The access from the road to this gate is clearly man-made and has been built up to avoid the boggy area and probably allow agricultural vehicular access to the field. The hill to hill direction for the bwlch is from Penycloddiau to Moel Arthur and therefore the bwlch, as determined by level and staff measurements probably lies on this man-made ground. To the North East of this point the map clearly shows a stream which visual inspection showed to be stagnant water by the track but a little further away it began to flow away to the North East. To the South East is a small wet gully, a continuation of the stream, which rises at first from the base of the path, but then begins to drop

after about 25m distance South East. This point could be the position of the natural bwlch. Regrettably, a passing place on the road has been constructed near here and this, combined with thick vegetation in the area, made confirmation difficult. However, staff measurements showed this to be only 0.1m lower than the position on the Offa's Dyke path.

We could not set up the GS15 at the bwlch because the tree cover would restrict sky visibility for satellite signals, so a point was chosen away from this area. Staff readings were taken at the GS15 setup point and the bwlch so that the appropriate height correction could be made.

The Leica GS15 was then set up on the "short tripod" system and GNSS data were collected for 1 hour. The position and height data for the bwlch that were recorded by the Leica Viva GS15 was post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the nine nearest base stations under 100km distance and the Computed model for tropospheric correction. These results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	313938.485	0.002	366755.871	0.001	283.620	0.007

Staff reading at GS 15 setup position = 0.946m

Staff reading at bwlch on path = 1.724m

Correction for Bwlch height measurement = -0.778m.

Vertical Offset correction (Tape measurement) = 0.692m

Vertical Offset correction for use of short tripod assembly = 0.255m. (Leica parameter)

Total Vertical Offset correction used in computations = 0.692 + 0.255 = 0.947m

Height of bwlch on Offa's Dyke path = 283.620 – 0.778 = 282.84m

Height of bwlch on "natural ground" = 282.7m

A ten-figure Grid Reference recorded for the bwlch by a hand-held receiver was:-

Garmin Oregon 450 SJ 13952 66749 Height = 291m Acc = 5m

3.4) Moel Arthur Summit

The exact position of the summit was established by taking systematic level and staff readings and was found to be ground next to the cairn. The GS15 was set up over this position and that is shown in the photograph in Appendix 2. The "short tripod" setup was used and GNSS data were collected for 1 hour. The position and height data for the summit that were recorded by the Leica Viva GS15 were post-processed with Leica GeoOffice 8.3 using imported OS RINEX data for the eight nearest base stations under 100km distance and the Computed model for tropospheric correction. These results are given in the table below:-

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	314527.516	0.003	366031.306	0.002	455.790	0.013

Vertical Offset correction (Tape measurement) = 0.537m

Vertical Offset correction for use of short tripod assembly = 0.255m. (Leica parameter)

Total Vertical Offset correction used in computations = $0.537 + 0.255 = 0.792\text{m}$

The height of Moel Arthur is 455.79m

A ten-figure Grid Reference recorded for the summit by a hand-held receiver was:-

Garmin Oregon 450 SJ 14530 66036 Height = 457m Acc = 3m

4) **Discussion of Results**

The key question for Penycloddiau is where does one define the summit position? Since the local council decided to protect the ancient Bronze Age burial ground in 2010, the original summit of the hill is no longer defined or accessible. Therefore the summit position is either the highest ground adjacent to the perimeter wall for the 2010 man-made construction or one accepts the new highest point on the man-made construction next to the cairn. Alan Dawson, the list author of the Marilyns, was consulted on this question and he informs us that he considers that the original summit has now been lost and the highest point adjacent to the wall should be accepted as the hill's highest point. This means that the height of Penycloddiau for the list of Marilyns should be the position measured as 439.50m.

Previous measurements for 1 hour datasets indicate a possible height error of $\pm 0.06\text{m}$ for a GS15 measurement. We would estimate that the summit position outside the man-made perimeter wall has been measured to $\pm 0.03\text{m}$. Therefore the overall uncertainty in the height of Penycloddiau is $\pm 0.08\text{m}$.

The main error for the bwllch measurement for Penycloddiau is the uncertainty in height relating to the identification of its position. We would estimate this to be $\pm 0.2\text{m}$ from variation of staff measurements taken in this region.

The summit of Moel Arthur could be identified precisely with level and staff measurements so the uncertainty will be that associated with an hour dataset; that is $\pm 0.06\text{m}$.

Subsequently to this survey another set of data were collected from the SQC nominated point in order to check the consistency of the GS15's operation. The average reading for height at this point for a 30minute dataset and using the Hopfield Tropospheric model to process is 136.391m with a standard deviation of 0.016m. The latest dataset gave a height of 136.403m which is within one standard deviation of the mean and therefore totally consistent with previous datasets.

5) Summary and Conclusions

The **summit** of **Penycloddiau** is at grid reference * SJ 12716 67891 and is unfeatured ground adjacent to the man-made wall protecting the Bronze Age mound. Its height is **439.50+/-0.08m**.

The **bwlech** of **Penycloddiau** is at * SJ 13952 66749 and is unfeatured ground on the Offa's Dyke path. Its height is **282.8+/-0.2m**.

The **drop** for **Penycloddiau** is **156.7+/-0.2m** and therefore this hill **retains its Marilyn status**.

The **summit** of **Moel Arthur** is at grid reference * SJ 14530 66036 and is unfeatured ground next to the cairn. Its height is **455.79+/-0.06m**.

- NB average hand-held Garmin GPS grids are quoted in the summary.

John Barnard and Graham Jackson, 15 February 2015

Appendix 1 - Penycloddiau



Leica GS15 (27 Jan 2015) set up at highest point around man-made mound



Leica GS15 Vertical offset – Tape Measurement = 0.678m



Leica GS15 (15 Feb 2015) set up at highest point on man-made mound



Leica GS15 Vertical offset – Tape Measurement = 0.577m



Leica GS15 (27 Jan 2015) set up near Penycloddiau bwlch



Leica GS15 Vertical offset – Tape Measurement = 0.692m

Appendix 2 – Moel Arthur



Leica GS15 (27 Jan 2015) set up at summit



Leica GS15 Vertical offset – Tape Measurement = 0.537m