Survey of Miller Moss

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1) Introduction

Miller Moss (Hill Number 2343, Section 34A, OS 1:50000 Map 90, OS 1:25000 Map OL4N and OL5N, Grid Ref. NY303338) is listed in the Database of British and Irish Hills (DoBIH) as a Birkett, Synge and deleted Nuttall. This hill is also listed in the Section entitled "Deleted Tops" in Anne and John Nuttalls' The Mountains of England and Wales Vol 2 England. As Ordnance Survey 1:50000 and 1:25000 scale maps have spot heights of 609m for this hill, then if that is correct, Miller Moss would not qualify as it does not reach the required 2000 feet (609.6m). However, the old "6 inch" and "1 inch" maps show a height of 2000 feet and the latest OS Map on-line shows a small 610m contour ring at the summit. Also, again from mapping, it is not clear that even if Miller Moss exceeded 2000 feet there would be enough drop to reach Anne and John's 15m requirement.

One of the authors, John Barnard, visited this hill in March 2015 in order to assess the drop from the summit to the candidate cols to the south west and east. This was done using two hand-held Garmin GPS units and taking readings of heights of both summits and cols with minimum time between the sets of readings. The results suggested that the drops to both cols were about 20m. Although this cannot be regarded as a reliable measure, it added further information to suggest a full survey of Miller Moss would be worthwhile carrying out.

Therefore, the purpose of this survey was to measure accurately the height of Miller Moss, locate the positions of the candidate cols and then measure the drop from the summit to each of these cols in order to find out if this hill would qualify as a Nuttall.

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 locate and line survey between the summit and col positions.

The absolute heights of the summit and one col were measured using a Leica Geosystems Viva GS15 Professional receiver. This instrument is dual-frequency and multi-channel, which means it is capable of locking on to a maximum of 12 GPS and 8 GLONASS satellites as availability dictates and receives 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. Despite the on-board features of the Viva GS15 receiver, there are still sources that create residual errors. To obtain accurate positions (± 0.01m) and heights (± 0.05m), corrections were made to the GNSS (Global Navigation Satellite System) data via imported RINEX data from Ordnance Survey and this dataset was post-processed using Leica Geo Office 8.3 software.

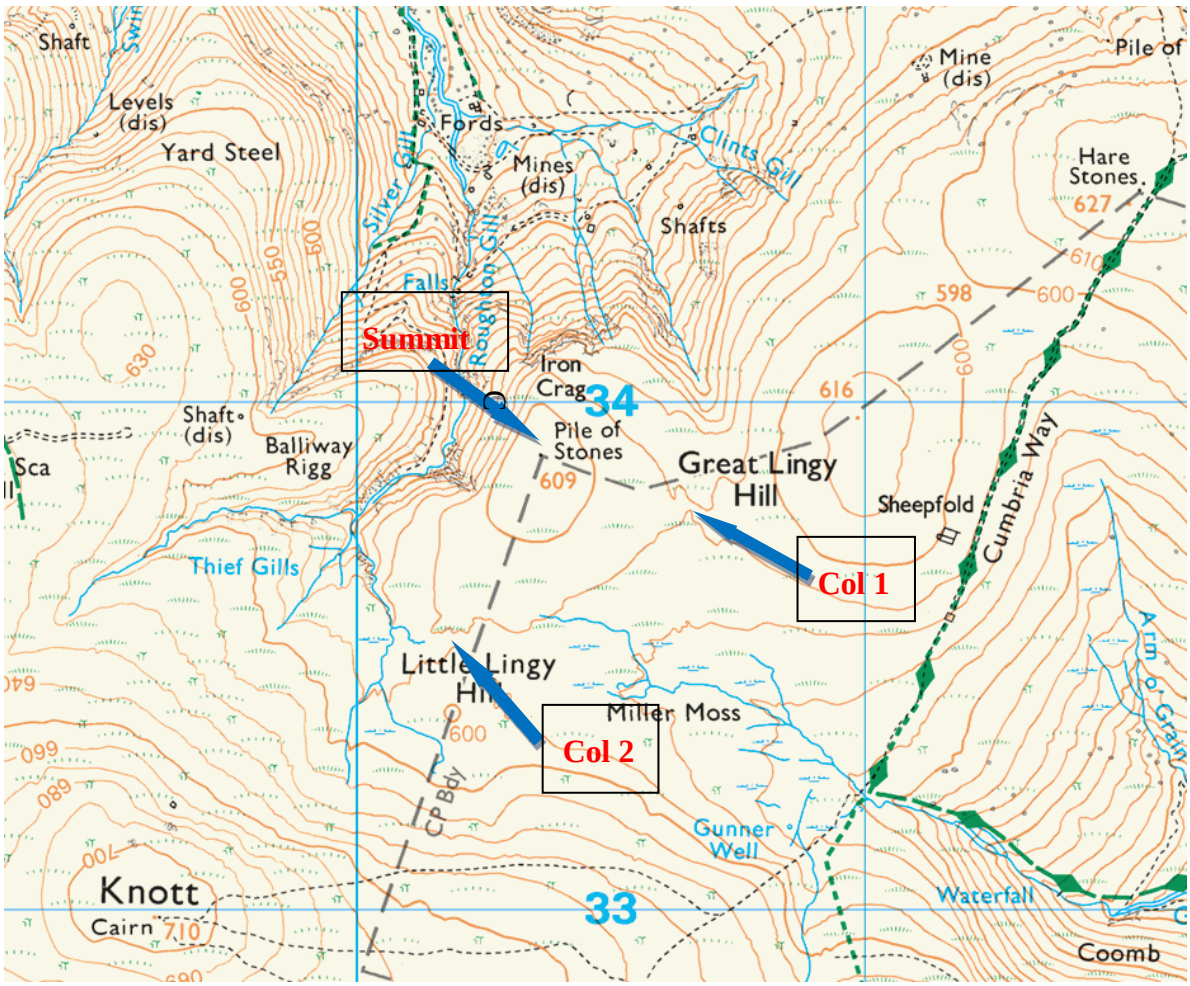
Note that most small hand-held GNSS receivers used for general navigation in the UK can receive signals from up to 12 GPS and 8 GLONASS satellites and each at a single frequency. Therefore, these instruments have a poorer positional accuracy of ± 8 metres and a height accuracy of no better than ±10-15 metres – accuracy reported as three times standard deviation. Some older and "bottom of the range" handheld receivers can only receive signals from GPS satellites. However, their

accuracy is very similar but GLONASS greatly improves the speed at which modern receivers can achieve a satellite "fix", particularly in areas where the view of the sky may be limited. Satmap Active instruments are more accurate than the current Garmin models.

Conditions for the survey, which took place between 11.00hr and 15.00hr BST, were fair. The temperature was about 20 degrees Celsius and the cloud base was above 600m, but a cooling strong breeze developed later in the day followed by rain at the end of the survey. Fair visibility allowed all optical work to be carried out easily.

3) Character of Hill

An extract of the Ordnance Survey 1:25000 scale map (Crown Copyright Ordnance Survey) showing the summit and candidate cols for Miller Moss is presented below. The name Miller Moss has been adopted for this hill even though Miller Moss actually applies to the boggy area approximately 0.5 to 1km south east of the summit. Some have suggested that a more appropriate name may be Iron Crag but that name applies to an outcrop of rocks about 200m north of the summit. Also, Little Lingy Hill has been used.



Miller Moss is situated in the Lakeland Northern Fells and lies between Knott to the south west and Great Lingy Hill to the east. It is a rather insignificant grassy lump overshadowed by its higher neighbours and for most hillwalkers is probably passed over as a way of avoiding some of the boggier ground between Knott and Great Lingy Fell.

The easiest access to Miller Moss is from the east. A minor road leads about 3km west from Mosedale where at the end there is limited parking. A good track leads up to Caldbeck Mine which was closed in 1981 and is now an SSSI as it was the only tungsten mine in the UK outside of Cornwall. About 500m beyond the mine the track divides and the one leading north west up to Great

Lingy Bothy, well maintained, is followed. From this point the summit of Miller Moss lies just under 1km distance in a west north west direction over heather and tussock grass. The ground is, boggy at first but improves towards the summit. The summit area is marked with a cairn and the actual highest point is about 8m south from it.

There are two important cols to consider, one between Miller Moss and Great Lingy Fell to the east and the other between Miller Moss and Knott to the south south west. These are labelled Col 1 and Col 2 respectively for the purpose of this report. These two cols are very similar in nature, being extensive and covered with tussocky grass and bog. Faint tracks lead down from the summit of Miller Moss to each col but not directly to them and these provided useful access, particularly for the line survey.

4) Summary of Survey

The first task was to locate the position of the summit and use the Leica GS15 to obtain a height. While the GS15 was collecting data on the summit, two of the team members went to Col 1 with level and staff to locate its position. At the same time, the third team member went to Col 2 in order to assess what needed to be done with level and staff to pinpoint its position. Once Col 1 had been located, a one-directional line survey was carried out to the summit in order to measure the drop to Col 1. Having collected the GNSS data on the summit and completed the line survey from Col 1, the team proceeded to Col 2 to locate its position with level and staff. While this work was being carried out the Leica GS15 was set up close to the col position in order to gather GNSS data to make a height measurement. A height correction was obtained with level and staff between the GS15 set up position and that of Col 2.

4.1) Survey of the Summit of Miller Moss

Previous visitors using Abney levels had identified the summit position of Miller Moss as the top of a rock about 8 metres south of the cairn. The Leica NA730 level was set up on a tripod about 5m from the cairn and south west of it. Candidate summit positions were located and staff readings taken from them. The measurements confirmed that the rock 8 metres south of the cairn was the highest point and therefore previous Abney level measurements were correct.

Staff reading at summit rock = 0.721m

Staff reading at base of cairn = 1.143m

Therefore, the summit is 0.422m higher than the base of the cairn.

To obtain an absolute measurement of height the Leica Viva GS15 receiver was mounted on a 1.000 metre pole, supported by a Leica "Quickset" tripod (see photograph in Appendix 1) over the summit position. GNSS data were collected at the point for 2 hours with an epoch time of 15 seconds.

The data were processed in Leica GeoOffice 8.3 using the ten nearest base stations and the Computed model for tropospheric corrections. The results are given in the table below: -

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	330366.259	0.002	533887.908	0.002	610.083	0.007

The summit height of Miller Moss is 610.08m. which is 1 metre higher than the spot heights on the OS Maps. The height of the ground around the cairn is 610.083 - 0.422 = 609.66m which also exceeds 2000 feet (609.60m).

4.2) Survey of Col 1 and drop from Summit

On descent from the summit of Miller Moss it appeared as though the position of the col lay on a "ridge" on the southern side. However, on closer inspection of the flat col area it was clear that the situation was more complex. Staff measurements taken on the "ridge" showed it be lower than ground to the north, in the valley to valley direction, and therefore the "ridge" could be eliminated from further survey work. A gully exiting on the north side of the col area was identified and staff measurements were taken in it in a north to south direction. These measurements showed the ground to be rising and therefore the col to be further south. Finally, the area was marked out with a cross of flags positioned about 10m apart and aligned in the hill to hill and valley to valley directions. Staff measurements at each flag identified a "flat" area about 40m by 20m where staff readings only varied by a few centimetres. The approximate middle of this area was taken as the col position.

The next task was to measure the drop to this col from the summit of Miller Moss. This was done by carrying out a line survey from col to summit. The process to do this has been reported in many of our survey reports and will not be repeated here. However, in summary, it involved taking a sequence of backsight and foresight staff measurements from the Leica NA730 automatic level in a sequence that started at the col and finished at the summit. Since the ground in the direct line to the summit from the col was very heathery making secure tripod positioning and good staff placements more difficult, we chose a route on the east side of the hill where there is a distinct path of solid ground which reduced these problems. All backsight and foresight measurements were taken using the "Triple Wire Technique". This means taking readings from the horizontal, upper and lower stadia lines and then averaging these readings. The mean reading has to be within 0.001m of the horizontal reading to proceed. If not, the reading set is repeated until the above criterion is obeyed.

The summary of the line survey readings is given in Appendix 2. The drop to Col 1 was measured to be 19.8m.

4.3) Survey of Col 2

The general topography of Col 2 was similar to Col 1 but boggier and more extensive. At first inspection there seemed to be "ridges" either side of the main col area running in the hill to hill direction which may have contained the exact position of the col. However, these two "ridges" were quickly dismissed for the exact position of the col because both were interrupted by deeper channels running away from the col area at right angles to the hill to hill direction. Staff measurements taken in these channels in the valley to valley direction showed the ground rising into the flatter col area.

A number of flags were then placed systematically about 10m apart in the hill to hill and valley to valley direction in the area identified to contain the exact position of the col and staff readings were taken from each flag position. The measurements showed the col to be contained in an oval shaped flat area about 20m by 30m where staff readings were consistent to ±0.04m.

While the search for the col position was taking place, to obtain an absolute measurement of height the Leica Viva GS15 receiver was mounted on a 2.000 metre pole supported by a Leica "Quickset" tripod (see photograph in Appendix 1) where the ground was more solid. This position was close to the anticipated col position. A staff reading was also taken at this point to obtain the height correction for the col. GNSS data were collected for 60 minutes with an epoch time of 15 seconds.

The data for the Leica Viva GS15 were processed in Leica GeoOffice 8.3 using the ten nearest base stations and the Computed model for tropospheric corrections. The results are given in the table below: -

System	Easting	error(1SD)	Northing	error(1SD)	Height(m)	error(1SD)
GS15	330296.804	0.002	533463.658	0.002	589.616	0.009

Staff reading at Col 2 = 1.00m

Staff reading at GS 15 setup position = 1.29m

Therefore, Col 2 is higher than GS15 setup position by 0.29m

Height of col = 589.62 + 0.29 = 589.9m

Drop from summit to Col 2 = 20.2m

5) Summary of Operating Conditions

Parameter	**GS15 Summit**	**GS15 Col 2**
Data Collection summit (min)	120	62
Number of Base Stations used in Processing for all points	10	10
Epoch Time (sec)	15	15
Tropospheric Model	Computed	Computed
Geoid Model	OSGM15	OSGM15
Cut off Angle (degs)	15	15

6) Coordinate Recovery Analysis

In order to verify the precision and consistency of a GNSS dataset, Ordnance Survey (OS) recommends a procedure called Coordinate Recovery Analysis. Instead of processing the data with reference to all the nearest OS Base Stations under approximately100km distance, as used in this report, the data are first processed with reference to only the nearest Base Station, in this case Carlisle (CARL). The data are then reprocessed with the survey point taken as a Reference Point and all the remaining Base stations taken as survey points. These measured values for the OS Base Stations can then be compared directly with the actual OS values for position and height. (This has been carried out via an Excel spreadsheet supplied to us by OS).

Although the spreadsheet calculates a number of different parameters, two important ones are presented in the tables below. "Height Difference **U** metres**"** is the vertical height difference between the height of the Base Station as measured in this survey compared with the actual OS value. "Separation $\mathbf{D_{ij}}$ metres" is the distance in 3-d space between the measured and actual OS values for each Base Station. The results for the summit measurement for Miller Moss calculated using the Computed tropospheric model are presented below.

Base Station	Code	Distance to Survey Point km.	Height Difference **U** metres	Separation $\mathbf{D_{ij}}$ metres
Carlisle	CARL	25	Reference	Reference
Shap	SHAP	33	-0.0486	0.0494
St Bees	STBE	40	0.0079	0.0105
Wearhead	WEAR	56	-0.0405	0.0413
Kirkcudbright	KIRK	64	-0.0042	0.0145
Eskdalemuir	ESKD	70	-0.0186	0.0201
Giggleswick	GIGG	85	-0.0432	0.0457
Catterick	CATT	95	-0.1380	0.1383
Newcastle	NCAS	100	-0.0320	0.0325
Blackpool	BLAP	101	-0.0002	0.0173

Apart from Catterick (CATT) the results show a consistent dataset, as all measured OS Base Stations are within 0.05m distance and height of the OS actual values for distances up to about 100km and below the 0.1m requirement of OS. A subsequent Coordinate Recovery analysis carried out for the GNSS data collected from Col 2 also showed the biggest separation for Catterick, so it seems that the GNSS data from that Base Station was behaving anomalously during the survey.

7) Discussion of Results

For the Leica Viva GS15, two independent repeatability studies have shown that a 120-minute data collection time with good satellite reception gives heights with a measurement uncertainty of ±0.05m (3 standard deviations).

Since the summit position was easily identified as the top of a rock we estimate the corresponding uncertainty in height to be ± 0.01m. Therefore, the overall uncertainty in the height measurement of the summit is ± 0.05m.

We estimate the height error associated with locating the cols from the variation in staff measurements over areas close to the cols and the nature of the terrain to be ±0.2m.

The height of Col 1, the critical col, was measured by subtracting the height difference as measured by line survey from the height measured from the summit GNSS data. For a line survey taken over 6 stages for a 20m drop we would expect the overall uncertainty in the height to be less than ±0.03m. Correct procedure would necessitate another line survey in the opposite direction so that the two height differences could be compared to obtain the closing error. However, we considered this to be unnecessary as the primary interest of this survey was to see if the drop exceeded 15m. The measured drop of 20m is 5m greater than this and more than two orders of magnitude greater than the measurement uncertainty of a typical line survey. Therefore, we estimate the overall uncertainty in the height of the col to be ± 0.2m.

The height of Col 2 was measured from 60 mins of GNSS data from which we would estimate the uncertainty in height to be ± 0.06m. Therefore, as for Col 1, the overall uncertainty in height is dominated by the rough nature of the terrain at ± 0.2m.

Both Cols 1 and 2 were flat and boggy over extensive areas and covered with tussock grass. For this reason, the Grid References for these cols are only quoted to 8 figures.

8) Verification by Ordnance Survey

The GNSS data for the height of Miller Moss and the Coordinate Recovery Data were sent to Mark Greaves at Ordnance Survey. The new height for Miller Moss has been agreed and 610m will appear on 1:50000 and 1:25000 scale maps.

9) Summary and Conclusions

The **summit** of **Miller Moss** is at grid reference *NY 30366 33887 and is the top of a rock about 8m south of the cairn. Its height is **610.08 ± 0.05m**.

The critical **col** of **Miller Moss** is at grid reference *NY 3066 3379 and is unfeatured ground. Its height is **590.3 ± 0.2m.**

The **drop** to the **col** for **Miller Moss** is **19.8 ± 0.2m** and therefore this hill **qualifies as a Nuttall**.

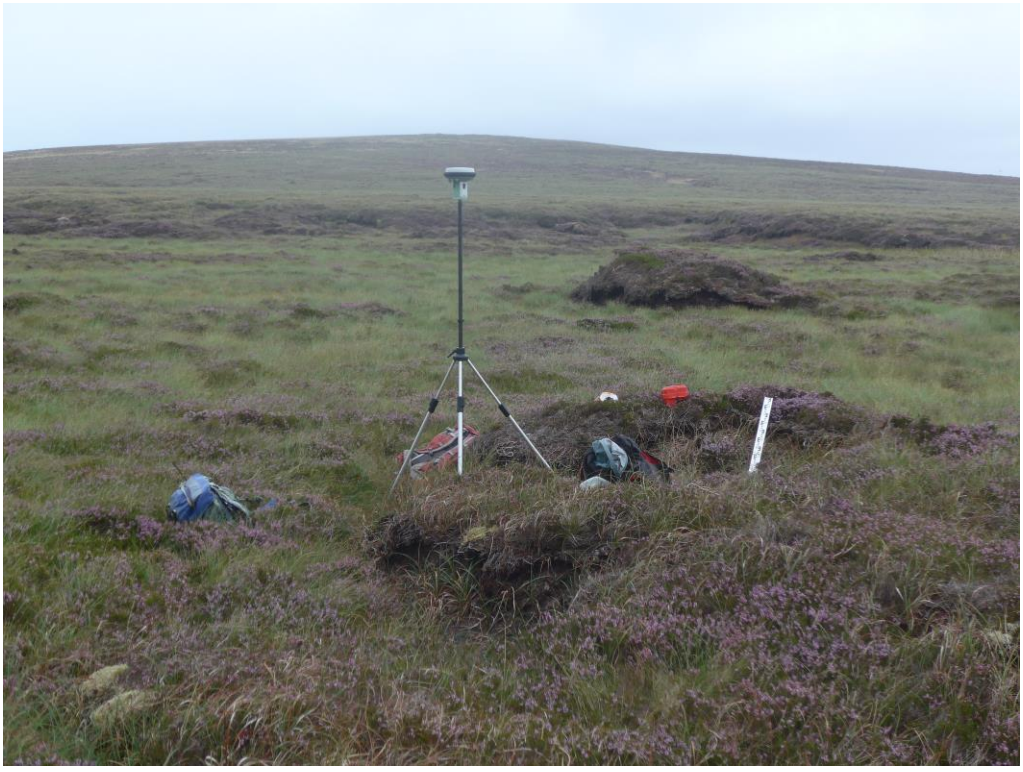
The alternative **col** at *NY3029 3346 is also unfeatured ground. Its height was measured to be lower at **589.9 ± 0.2m.**

*Grid References in OSTN15

John Barnard, Jim Bloomer, and Graham Jackson, 12 August 2018

Appendix 1

Leica Viva GS15 collecting data on the summit of Miller Moss



Leica Viva GS15 collecting data on Col 2 of Miller Moss

Appendix 2

	Title:-	Miller Moss												
	Instrument:-	Leica NA730				Date:-	01-Aug-18							
	Horizontal Line			Lower Stadia Line			Upper Stadia Line							
Point Number	Backsight R	Foresight F	Height H	Backsight R	Foresight F	Height H	Backsight R	Foresight F	Height H	Mean BS	Mean FS	Height Difference	BS Distance	FS Distance
	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres	metres
East Col to Summit (Jim B Staff, JB Level and GVJ Data recording)														
1	1.335	1.045		1.100	0.775		1.570	1.315		**1.335**	**1.045**		47.000	54.000
2	3.603	0.301		3.389	0.236		3.816	0.366		**3.603**	**0.301**		42.700	13.000
3	4.281	0.250		4.053	0.222		4.508	0.278		**4.281**	**0.250**		45.500	5.600
4	4.749	0.130		4.586	0.095		4.912	0.165		**4.749**	**0.130**		32.600	7.000
5	4.188	0.335		4.018	0.314		4.358	0.356		**4.188**	**0.335**		34.000	4.200
6	4.155	0.487		3.926	0.449		4.383	0.525		**4.155**	**0.487**		45.700	7.600
									Sum =	**22.310**	**2.548**	**19.762**	**247.500**	**91.400**