Reconstructing the lost contours of Charles Hutton

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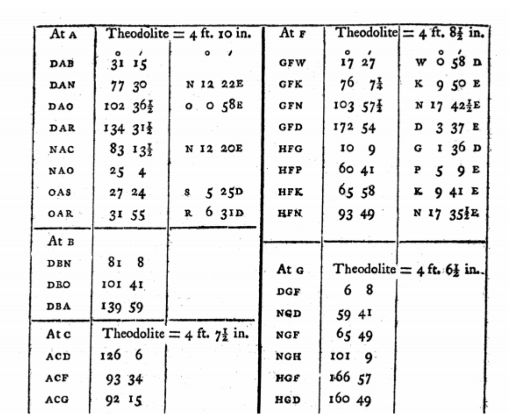
This study reports on an historical investigation of map-making practice and achievement from the late 18th century, and attempts to reconstruct the practices and outcomes of an innovative surveying and mapping exercise, using historical data and contemporary geospatial data handling. The episode involves the processing of data captured as part of an extensive project by the then (British) Astronomer Royal, Maskelyne, in the mid 1770s, to measure the gravitational attraction and density of the earth.

This experiment was conducted on the isolated mountain of Schiehallion in Central Scotland, and resulted in several differing approaches to calculating the mass of the mountain, and determining and interpreting the resultant effect on gravity measurements on its slopes. In order to do this, an accurate determination of "the figure and dimensions of the hill" (Maskelyne, 1775) was required. The survey work was undertaken under Maskelyne's supervision by his previous assistant, Barrow, and local surveyor, Menzies.

The data collected included astronomical observations to establish latitudinal positions, lengths of fixed base lines (one to the north of the mountain and one to the south), a standard traverse around the mountain to establish fixed points, and transects/vertical profiles radiating from those points. The land surveying techniques were known and widely used, although at the time having only been recently documented, in the book 'A Treatise on Mensuration'. This was published in 1770 by Charles Hutton (1737-1823) a Newcastle-born mathematician, and was the first volume on surveying written in English. In 1773 Hutton had moved south to become Professor of Mathematics at the Royal Military Academy, Woolwich, and became known to the Royal Society which asked him to process Maskelyne's data.

The original field observations (Figure 1), were published in Hutton's extensive account of his work (Hutton, 1778), which also explained how he was to calculate the mass of the mountain, dividing the landscape into a set of vertical prisms collectively defining the mountain's shape. Smallwood (2007) describes how Hutton's volume calculations, along with rock, geology and gravity information, can help estimate earth density.



At A	Theodolite = 4 ft. 10 in.		At F	Theodolite = 4 ft. 8¼ in.	
	° ′	° ′		° ′	° ′
DAB	31 15		GFW	17 27	W 0 58 D
DAN	77 30	N 12 22E	GFK	76 7¼	K 9 50 E
DAO	102 36½	O 0 58E	GFN	103 57½	N 17 42½E
DAR	134 31½		GFD	172 54	D 3 37 E
NAC	83 13½	N 12 20E	HFG	10 9	G 1 36 D
NAO	25 4		HFP	60 41	P 5 9 E
OAS	27 24	S 5 25D	HFK	65 58	K 9 41 E
OAR	31 55	R 6 31D	HFN	93 49	N 17 35½E
At B					
DBN	81 8		At G	Theodolite = 4 ft. 6½ in.	
DBO	101 41		DGF	6 8	
DBA	139 59		NGD	59 41	
At C	Theodolite = 4 ft. 7½ in.		NGF	65 49	
ACD	126 6		NGH	101 9	
ACF	93 34		HGF	166 57	
ACG	92 15		HGD	160 49	

Figure 1: example field observations

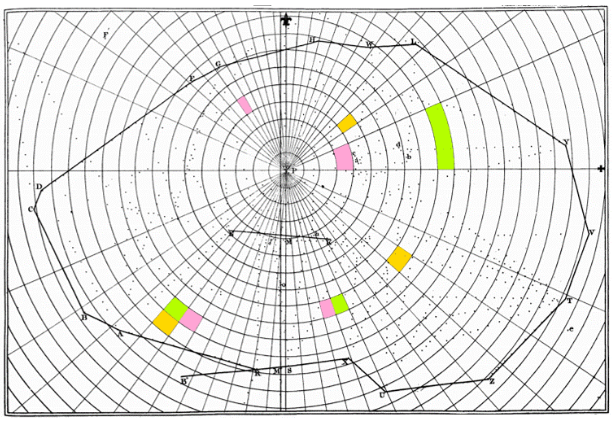


Figure 2: location of traverse, calculated height points, and prisms

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The prisms, arranged as circular sections (some individually coloured in Figure 2 to exemplify), had their heights calculated with reference to the height points within them. Clearly, however, some prisms had no heights associated with them. Hutton devised a method of interpolation of prism height for those which had no height data by creating a surface defined by contours: “I fell upon the following method … by which I was enabled to proceed in the estimation of the altitudes both with much expedition and a considerable degree of accuracy. This method was the connecting together by a faint line all the points which were of the same relative altitude: by so doing, I obtained great number of irregular polygons lying within and at some distance from, one another, and bearing a considerable degree of resemblance to each other: these polygons were the figures of so many level or horizontal sections of the hills, the relative altitudes of all the parts of them being known; and as every base or little space had several of them passing through it, I was thereby able to determine the altitude belonging to each space with much ease and accuracy.”

Although isolines were long established on some maps, and isobaths (depth curves), in particular, were visible on some hydrographic charts from the early 18th century, Hutton has some claim to be the first to use lines of equal altitude (contours) on land-based maps. Unfortunately, despite describing the method of using a ‘faint line’ to elucidate the contours, no graphical artefact exists: there is no evidence that Hutton, or anyone associated with the gravity project, ever published the contour map of Schiehallion.

Elsewhere in his account of the data processing (Hutton, 1778), significant doubts are expressed about the accuracy and validity of some of the observations, and there is the possibility that Hutton blocked publication of the contour map because of inaccurate observation or conflicting calculations.

However, the presentation of the full set of observations should allow for a reconstruction of the missing contour map. Processing and visualisation has already been undertaken manually by Johnson (Figure 3).

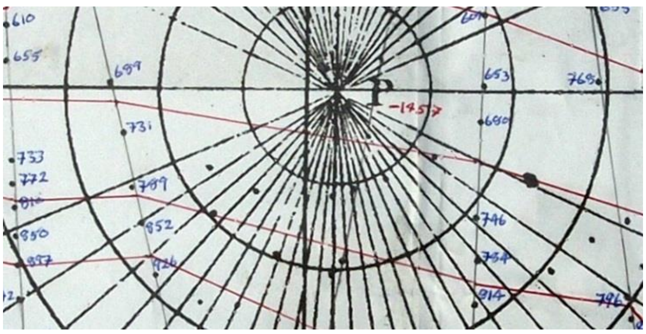

Figure 3: extract from manual contour reconstruction (Johnson, 2016)

An attempt was also made to use standard land surveying software to handle the field observations to calculate and map the data. The Star*NET package (Microsurvey, 2018) has been applied to the traverse observations, using techniques of least squares to obtain the most precise positioning of the surrounding stations. The LSS package (McCarthy Taylor, 2018) is used to enter the tacheometric detailing observations, and create an accurate digital terrain model based on the observed data from over 240 years ago. The contour lines derived from this model will be compared with current survey data provided by the British Ordnance Survey, and with satellite derived digital elevation datasets. It is hoped that data manipulation can be undertaken to successfully create a contour map which Charles Hutton would have been happy to publish.