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“The troubled history of the Scottish
triangulation 1823-1858”

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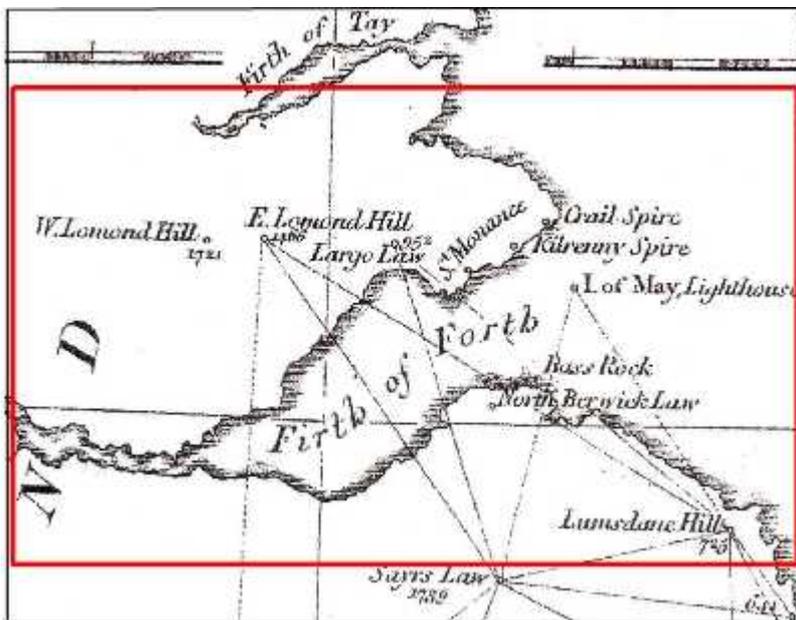
The troubled progress of the Scottish triangulation 1823-1858

David L Walker

An earlier article described how the initial triangulation of Scotland was nearly completed between 1809 and 1822, but remained incomplete until 1841, and unpublished until 1858.¹ This was put to use for various secondary triangulations in Scotland, but partly overtaken by fresh approaches during the 1840s, which were sufficient to define the county origins for the topographical survey of Scotland. After several changes of leadership, the configuration of the revised 'principal triangulation' was finally completed and published in 1858. By reference to previously little-used sources, this article explores these vicissitudes, illustrates some of the characters involved, and summarises their efforts to transpose the observed triangulation into latitudes and longitudes on the spheroid of the earth.

The initial triangulation of Scotland put to use

The triangulation of England and Wales that was published for the Board of Ordnance in 1811 was drawn upon by surveyors for many years. It extended into Scotland sufficiently beyond the Firth of Forth as to record the latitudes and longitudes of the peaks of Lomond Top East and Largo Law.² This potential baseline was put to good use in 1815 by George Thomas RN for his chart of the



Firth of Forth³ which covered the area framed in red in figure 1 below.⁴

Unprivileged in other respects, Thomas had been educated in trigonometry at Christ's Hospital. After surviving a ship-wreck in the Pacific, on the way home he was pressed into service on a frigate, where he rashly borrowed a midshipman's sextant. Brought for punishment before a captain who fortunately had also been

¹ David L Walker, 'The initial triangulation of Scotland from 1809 until 1822', *Sheetlines* 98,5-15.

² *An Account of the trigonometrical survey carried on in the years 1800 to 1809*, by Lt Col William Mudge & Capt Thomas Colby, vol III, London: W Faden, 1811, 378-379.

³ *Survey of the Frith [sic] of Forth by George Thomas in 1815*, National Library of Scotland [maps.nls.uk/coasts]. and Christopher Fleet, *Mapping a Life*, Discover nls, Issue 28, Spring 2015, 22-25 [www.nls.uk].

⁴ Extract from R Wilkinson, *Diagram of the Great Triangles in the Trigonometrical Survey of England & Wales*, 1811, © The British Library Board.

educated at Christ's Hospital, this secured his career as a master in the Royal Navy specialising as a hydrographical surveyor.⁵ His chart shows considerable topographical detail, and its marginal grid shows latitudes and longitudes that for Lomond Top East and Largo Law match those published by the Ordnance. Equipped with a 7½-inch theodolite, Thomas observed, calculated and plotted the positions of high points south of the Forth even before these had been visited by the Ordnance surveyors.

In 1819 the Ordnance placed Capt John Hobbs RE in charge of the ill-fated topographical survey of Wigtownshire (and part of Ayrshire) that has been researched by Brian Harley and Richard Oliver. As the Scottish triangulation had been extended as far as Ayrshire in 1815, Hobbs was able to secure some defined survey points from the surveyor, James Gardner, but their superior, Thomas Colby, seemed to display a lack of confidence (not for the last time) when he wrote *'as you have the observation books you will make out any others that may have been fixed'*, which left Hobbs to plead *'You are of course the best judge of the advantage I should derive from having the angles taken from all or any of these stations and I am persuaded you will let me have them.'* Sadly Hobbs and his survey both died in 1828.⁶

The next application of the initial triangulation was more enduring. Over a period of years starting in 1825, George Thomas, who had conveyed Colby (and Gardner) to the Shetlands in 1817 and to France in 1818, was ordered to the Shetlands by Capt Edward Parry, Hydrographer to the Admiralty Board, to make the survey that Thomas completed in 1833.⁷ His charts demonstrate meticulous attention to detail, inland as well as coastal, and diagrams in his supporting documents demonstrate his grasp of spherical trigonometry.⁸

From these it is evident that Thomas and his able assistant, William Lord, equipped with at least a baseline from the Ordnance, observed additional triangles from the northern tip of the Shetlands to south of the Pentland Firth (*figure 2*). By reference to the latitude of Balta, observed by the Ordnance, and its longitude, determined by Thomas's chronometer, he calculated latitudes and longitudes that Parry shared with the Danish Hydrographer and took with Thomas's chart of Unst on his voyage to the Arctic in 1828.⁹

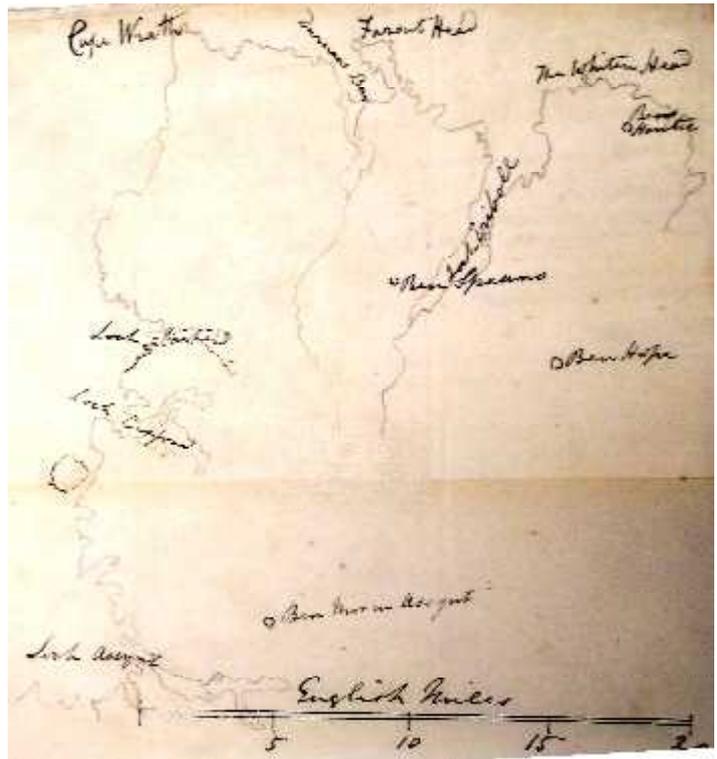
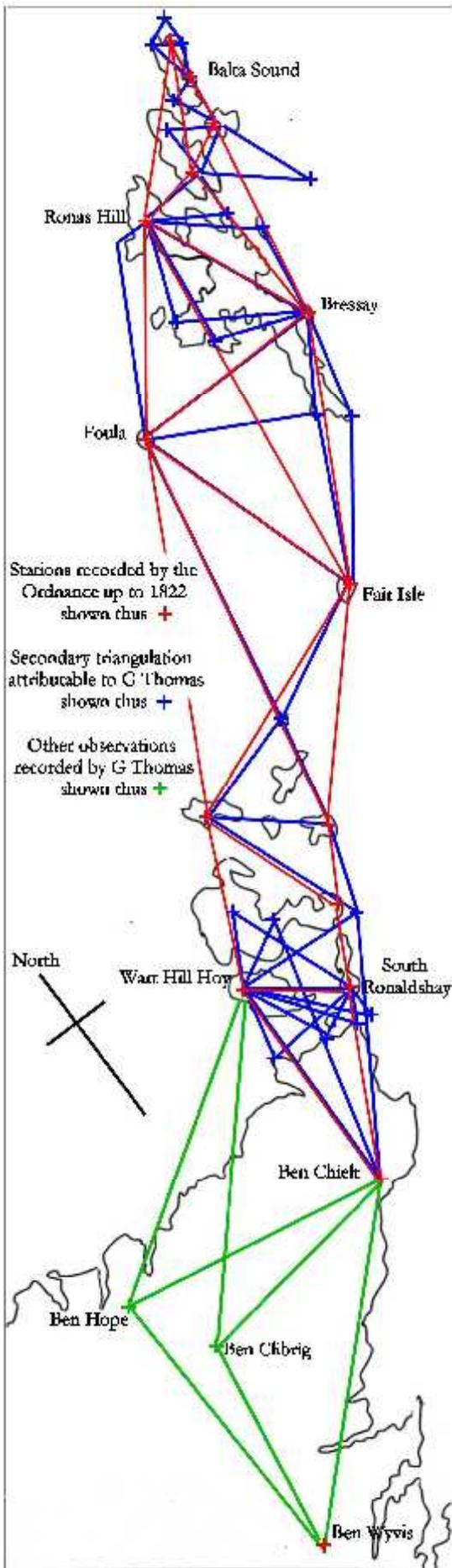
⁵ LE Taverner, *George Thomas, Master, Royal Navy*, *Mariners Mirror*, vol 36, no 2 (1950), 119.

⁶ Richard Oliver, 'Unfinished business: the lost Ordnance Survey two-inch mapping of Scotland 1819-1828 and 1852', *Sheetlines* 78, 9-31 (quotes from OS letter book 1799-1822, The National Archives, OS 3/260).

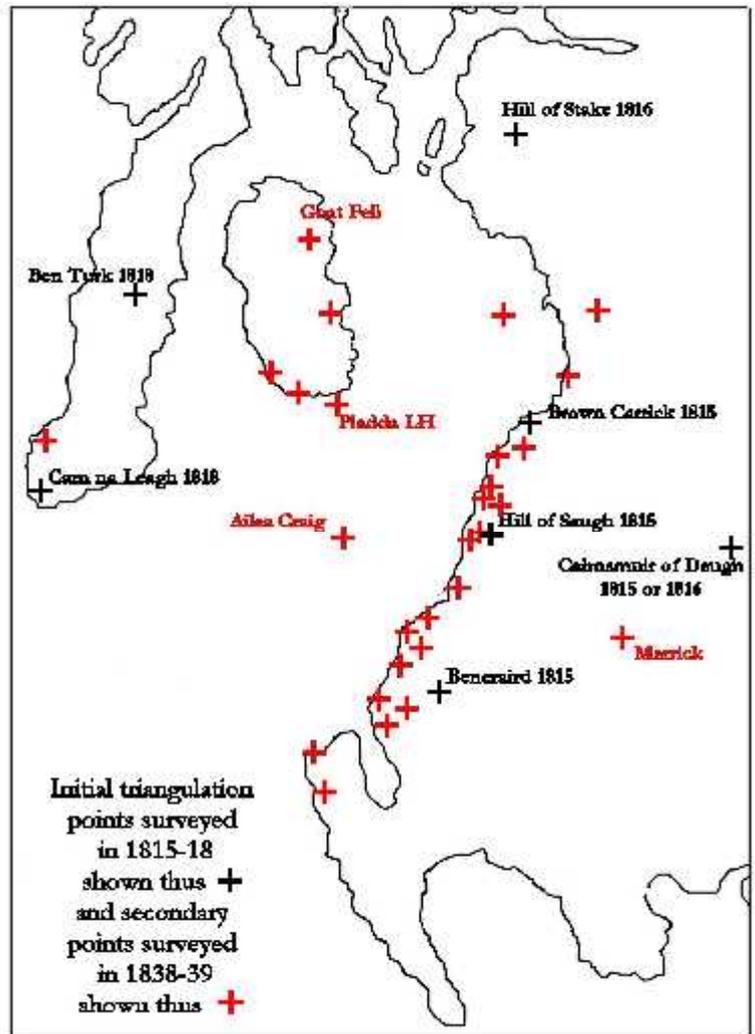
⁷ The Shetland Isles surveyed by George Thomas commanding HMS Investigator 1833, National Library of Scotland [maps.nls.uk/coasts].

⁸ G Thomas, *Projection of triangles for the survey [of the Shetlands]*, UK Hydrographic Office (UKHO), plan 530a Dr, 1827; G Thomas, *Triangles for the survey of the Orkney and Shetland Islands*, UKHO, MP 98, 107-116.

⁹ Adrian Webb, *The Expansion of British Naval Hydrographic Administration, 1808-1829*, University of Exeter, 2010, 134-135; Capt Parry to the Danish Hydrographer, 26 January 1828, UKHO, LB2, 95-97; UKHO survey ledgers, notes re E530 Dr and E530a Dr, 1827.



Left: Figure 2, Above: Figure 3, Below: Figure 4



Thomas had reported to Parry that the principal points in the Shetland Islands had been fixed by the Ordnance Surveyors.¹⁰ As this was many years before Colby's observations in northern Scotland had been published, it is unclear how much information Thomas secured from the Ordnance – or how. As his ship wintered in Deptford, not far from the Ordnance Map Office in The Tower, the most likely answer is that he simply consulted his former companion James Gardner, who was engaged there on trigonometrical calculations.¹¹

Surprisingly, Thomas's triangulation, recorded around 1830 (in UKHO MP98), included Ben Hope and other Sutherland peaks which Lt Hastings Murphy did not include in his 1834 diagram of the initial triangulation.¹² However, Ben Hope and three other peaks in western Sutherland had appeared on Murphy's tracing made in 1830 (*figure 3*), from Arrowsmith's map of Scotland published in 1807, showing the relative positions of survey points which 'may then be depended on'.¹³ It may be that these peaks were observed from a distance in Colby's expeditions of 1819 and 1822, but expunged by him as unreliable sometime between 1830 and 1834, although they had by then been used for a map of Sutherland 'on the basis of the trigonometrical survey'.¹⁴

In another application of the initial triangulation, the Board of Ordnance, at the request of the Admiralty, had commissioned Capt Henderson RE, with a small party of sappers, to carry out secondary triangulations from the Mersey to the Solway between 1834 and 1836.¹⁵ In 1838 Henderson moved on to the Firth of Clyde, and by 1840 to Port Glasgow, to observe and calculate a series of triangulation diagrams, including those between the points shown in *figure 4*,¹⁶ that provided reference points for the construction of Admiralty charts of the Clyde. Relative to points of the initial triangulation observed between 1815 and 1818, Henderson's diagrams show distances in feet between numerous secondary stations – but only a few latitudes and longitudes (in the Solway).

Completion of the initial triangulation

Thomas Colby, Superintendent of the Ordnance Survey, returned from the Irish survey to Scotland in 1838, at first supervising two younger officers, Robe and

¹⁰ *A Report of the Several Surveys now going on afloat*, UKHO MB 1, October 1826.

¹¹ David L Walker, 'James Gardner - surveyor, computer, publisher and engraver 1808-1840', *Sheetlines* 101, 32.

¹² *Sheetlines* 98,14-15 and The National Archives, MFQ 1/269/13.

¹³ Lt Hastings Murphy at Ordnance Map Office, Tower to Capt Beaufort RN dated 5 April 1830, UKHO LP1857 M, f558 and enclosure (copied by permission of UK Hydrographic Office).

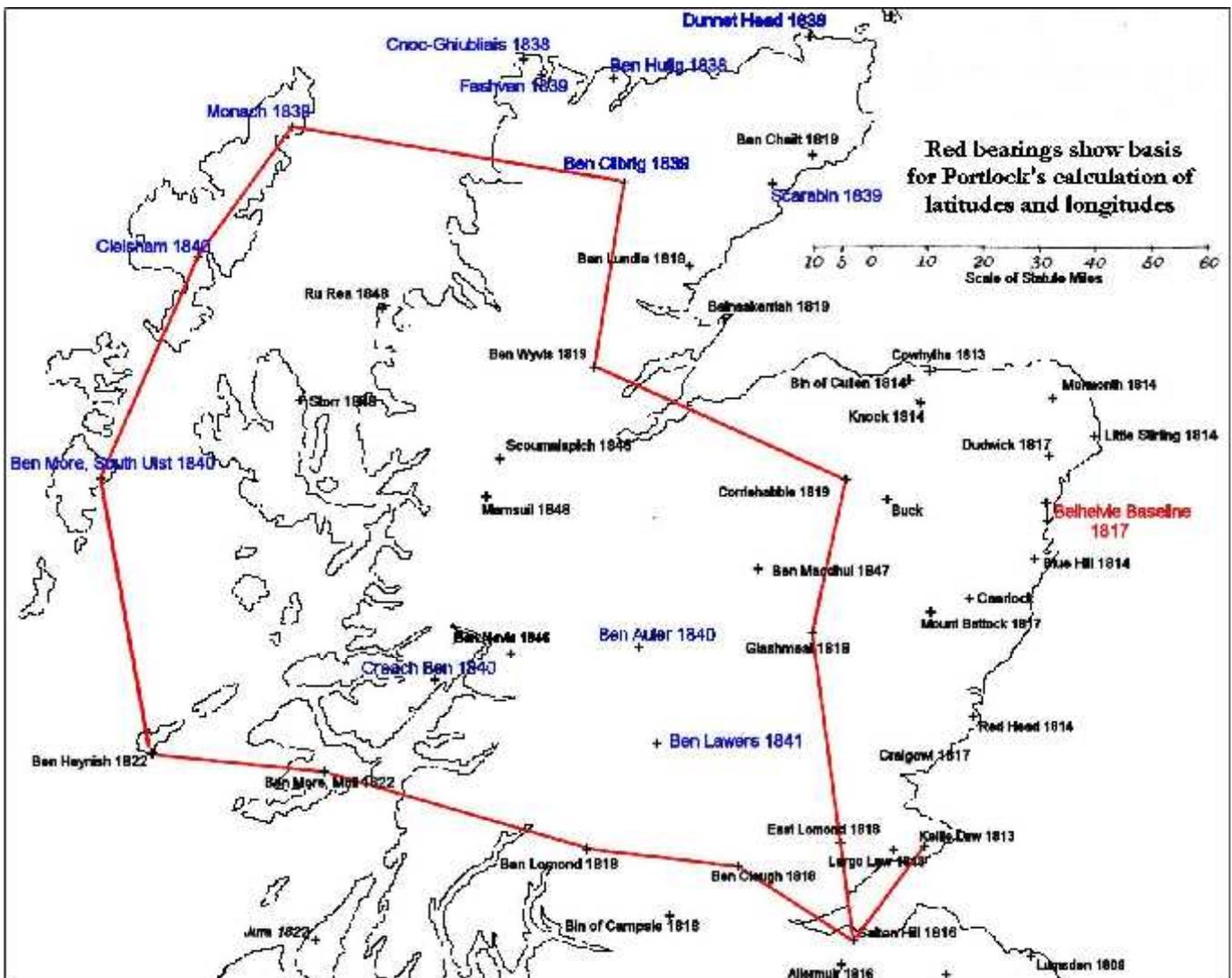
¹⁴ Gregory Burnett and William Scott, Surveyors to His Grace the Duke of Sutherland, *Map of the County of Sutherland made on the basis of the Trigonometrical Survey of Scotland in the years 1831-32*, National Library of Scotland [maps.nls.uk/counties/index.html#sutherland].

¹⁵ David L Walker and Adrian Webb, 'Some collaboration between the Ordnance Survey and the Hydrographic Office in the Nineteenth Century', *Sheetlines* 102, 10-14.

¹⁶ Alexr Henderson, Capt RE, *Triangulation Diagrams of Ayrshire and Arran*, UKHO L1578 Press 57 (16f), 6 March 1839 and UKHO L1579 Press 57 (16f), 23 March 1839.

Robinson, at Ben Hutig.¹⁷ Colby then returned to England and they went on to Cnoc-Ghublias and Dunnet Head, near to the north-western and north-eastern extremities of Scotland. Robinson returned in 1839 to Fashven near Cape Wrath, Ben Clibrig and Scaraben in Sutherland and Monach in Lewis, and in 1840 to Cleisham in Harris and Ben More in South Uist – all as shown in figure 5 below. Together with observations at Ben Auler and Creach Ben in the Central Highlands, this programme largely fulfilled Colby's intentions as set out in 1834.

Stimulated by Col Colby's mention of 'the energy and zeal of the officers who remained encamped during the inclemency of the weather at the end of [1840]', Lts Robinson, Hamley, Hornby and Craigie earned the compliments of the Master General of Ordnance and the Ordnance Board for their conduct 'in carrying on their operations on Ben More in South Uist and Creach Ben in Morvern'.¹⁸



¹⁷ *Account of the Observations and Calculations of the Principal Triangulation etc*, Drawn up by Capt Alexander Ross Clarke under the direction of Lt Col H James etc, Ordnance Survey: London, 1858. Its list of stations at pp 71-166 is also the source for other references to trigonometrical observations, unattributed below.

¹⁸ Office of Ordnance, R Bagham to Inspector-General of Fortifications, The National Archives (TNA), WO 55/961, 5 Feb 1841.



Unusually, an illustration (*figure 6, above*) survives of the survey camp at Creach Ben that shows men from the Corps of Miners and Sappers building windbreaks, surveyors at work on the summit of Creach Ben, and the path from the camp to the summit.¹⁹ On the Canmore website this is complemented by a recent photograph of the same setting (*figure 7, below*).²⁰



¹⁹ Engraving dated 1851 by John Weale of High Holborn, 'Surveying' in *Aide Memoire to the Military Sciences*, vol iii, Second Edition, 1862, copied by permission of British Library;

²⁰ Copied by permission of Historic Environment Scotland, Canmore site ref NM85NE 2, Creagh Bhein.

Robinson's zeal was also recognised in more practical ways: in 1840 his advice had secured the purchase of a hut in place of three double marquees, a new observatory tent, and adaptation of the axles of the theodolite wagon so as to bring the weight nearer to the ground on mountain roads. In 1841 the Board of Ordnance advised the Inspector General of Fortifications *'that it had accepted Colby's request on the advice of Lt Robinson in charge of the triangulation of Scotland on the advantages which arise from the substitution of portable huts in lieu of double canvas marquees for encamping the officers and men during trigonometrical operations'* – and so the purchase was authorised of seven more huts ranging in size from 12ft by 12ft to 9ft by 9ft at a cost of £170, *'to be divided equally between the Scotch and English surveys.'*²¹

In 1841 one of the survey officers, probably Lt Hornby, published first-hand reports from Merrick and Ben Lawers that include revealing comments on the local people. Writing from Merrick in July, the officer scoffed that *'The thinly-spread natives in the country around can't make us out at all. Some of them think we are preparing signal stations in the event of a French invasion; and others, that the sappers and miners are boring immense holes for the purpose of blowing old Merrick into the air.'* But from Ben Lawers in December his report was ruefully respectful: *'The tenants of Breadalbane will feel a great loss from the departure of the party, as they were the means of circulating a great sum of money in employment for labourers to carry fuel and provisions to the top. The wages they earned [were] from 18s to 21s per week, and most of them say that 1841 has been the best harvest they ever made.'*²²

Calculations of latitude and longitude

While adept in the field, Colby's officers were less confident in transposing their observations from the apexes of an irregular polyhedron into latitudes and longitudes on the spheroid of the earth. So Colby sought help from the Astronomer-Royal, Professor George Airy, who on 13 July 1840 provided model trigonometrical calculations for 'point to point' determinations on the spheroid. This model was applied by the Ordnance to the angles observed and the distances calculated (apparently from the Belhelvie baseline) for a closed chain of stations extending between Kellie Law on the Firth of Forth and Cleisham in the Outer Hebrides, as shown in figure 5. By reference to the supposed latitude, longitude and meridional bearing at Kellie Law, the Ordnance calculated latitudes and longitudes that Capt Portlock shared with Airy on 11 March 1841. However, Colby on 10 March 1843 had to write to Airy to confess that the results kept by the Ordnance 'got lost in the confusion caused by the fire'. Lt Yolland was blamed for this misfortune, although not previously given any credit for the calculations. Fortunately, Airy was able to provide a duplicate set within a few

²¹ TNA, WO 55/961, f170 12 Feb 1840, f776 1 July 1840, f210 19 Feb 1840 and f326 10 March 1841.

²² Manchester Times & Gazette, 24 July 1841 and The Times, 1 January 1842 (from Nineteenth Century Newspapers on-line).

days. His files (which survive today) evidently were as well-organised as his mind.²³

It is not apparent that the latitudes and longitudes calculated in 1841 were ever put to use. Ben Cleugh and Cleisham, well separated and both adopted later as ‘initial points’ or county origins, provide useful examples. In both cases latitudes calculated in 1841 were about 3 seconds less and longitudes over 10 seconds less than those adopted for county origins²⁴ (and referred to below). More importantly, these calculations set an enduring precedent for the adoption by the Ordnance of Airy’s figure of the earth, ie the estimated polar and equatorial dimensions of the spheroid that he had first published in 1830.²⁵

Fresh approaches 1: trigonometrical observation delegated to NCOs

Writing to his wife on 8 May 1840, Colby was pleased to report how he had ‘*a very long conversation with Sir Hussey about the proposed survey of Scotland, and that the Inspector General [of Fortifications had] recommended the instruction of the young officers of the Corps, and non-commissioned officers on the survey. This [was] complimentary but what [would] Pasley say to it?*’²⁶ Any reservations held by Charles Pasley, Head of the School of Military Engineering at Woolwich, proved unimportant as he was moving on to become Inspector-General of Railways. More importantly, the Master General, on the advice of the Brigade Major of the Royal Corps of Sappers and Miners, agreed to augment each of its survey companies by a sergeant, a corporal and a second corporal (offset by the loss of three privates).²⁷

The first NCO trained to observe with one of the 36-inch theodolites was James Steel, of whom it was written: ‘*From the first he had a taste for the investigation of abstruse questions of science and philosophy, and his strong mind and perseverance, his power of application and fullness of resource, have made him acquainted with a fund of knowledge and information not commonly possessed by men in his sphere of life. As a mathematician he holds a fair reputation for proficiency and accuracy, but it is chiefly with the work of triangulation and astronomy he has most distinguished himself. His early service was passed on severe hill duty. Ben Auler and Creach Ben were his first mountain stations. There he experienced a round of the varied hardships and dangers peculiar to a trig camp. Possessing a buoyant temper and a hardy constitution he for many years bore with happy composure all the stern trials and changes to which the service exposed him, and carried on his duties with un-relaxed ardour*

²³ Papers of George Airy, Camb. Univ. Library Manuscripts, RGO 6/417, item 2, ff 14-29.

²⁴ Roger Hellyer and Chris Higley (eds), *Projections and Origins, collected writings of Brian Adams*, London: The Charles Close Society, 2006, 62-65.

²⁵ GB Airy, *Figure of the Earth*, Encyclopaedia Metropolitana, vol V, (reprinted)1848, 165-239.

²⁶ Sir Charles Close, *The early years of the Ordnance Survey*, 1926, republished with an introduction by J B Harley, Newton Abbot: David & Charles, 1969, 68.

²⁷ Master General to Lt Gen Mulcaster, TNA, WO 55/961, f396, 19 June 1840.

and success. At Creach Ben he learned the use of the instrument, and succeeded Lieutenant Hamley R.E. in its charge in 1841.'²⁸

Amongst the other NCOs who made impressive contributions was Corporal Winzer, who for example, in 1846 alone, spent six weeks observing at Mordington, four weeks at Lumsden, six weeks on Sayrs Law, fifteen weeks on Ben Nevis and eleven weeks on Kellie Law – and this was before allowing for travelling time with the 36-inch theodolite.

Fresh approaches 2: trigonometrical stations added and revised

The deployment of NCOs facilitated another strategic change, in England and Wales, as well as in Scotland, that is touched upon rather lightly in the 'official history' which says: *'The primary triangulation did not satisfy geodetic requirements everywhere and most of the observations made before 1824 had to be repeated ... The work of improving and strengthening the primary triangulation continued under Yolland during the 1840s and was eventually completed in 1852.'*²⁹

It may not have been foreseen that observations from almost all of the primary stations would need to be repeated, mostly by non-commissioned officers instead of commissioned officers, to more rigorous standards than previously, and over longer periods at each station. But, if this was foreseen, it could hardly have been announced that NCOs were being called upon to 'improve and strengthen' their officers' observations.

In the event, in Scotland, about twelve additional stations were occupied, including the peaks of Ben Nevis and Ben Macdhui, although not all of these were utilised for the principal triangulation. About fifteen stations were re-visited, and only the geographical 'outliers' were utilised without being re-visited.

Fresh approaches 3: the Belhelvie baseline superseded

Another strategic change was the substitution, for calculating the sides of Scottish triangles, of the base line measured at Belhelvie in Aberdeenshire in 1817 by that completed at Lough Foyle in Northern Ireland in 1828. The only reference in the 'official history' to this very significant change seems to place it in 1854 where it says: *'[T]he Lough Foyle and Salisbury Plain bases were measured with the compensation bars, whereas steel chains were used between inadequately marked terminals for the others. The triangulation was therefore made to depend on the Lough Foyle and Salisbury Plain bases only.'*³⁰

However, calculations of the latitudes and longitudes of the principal points in Scotland (on a similar basis to using Professor Airy's 'point to point' model) are extant for 1851. These refer to a missing 'Book 2', and the page order of these references (illustrated in fig 8, below) suggests that Scottish triangles were by then calculated from the south-west rather than the north-east, that is from Lough Foyle rather than Belhelvie. Moreover, an unusual mention in some Scottish

²⁸ TWJ Connolly, *The history of the Corps of Royal Sappers and Miners*, 1857, vol 2, 277-278.

²⁹ WA Seymour (ed), *A history of the Ordnance Survey*, Folkestone: Dawson, 1980, 139.

³⁰ WA Seymour (ed), *A history of the Ordnance Survey*, Folkestone: Dawson, 1980, 142.

newspapers suggests that this change took place before October 1846: '*Perhaps it is not generally known*' it was reported '*that the base-line upon which the triangulation of the three queendoms and all their islands is reared was measured in Ireland ... any distance from any point in Scotland to any other, with the bearing, can be determined to a nicety, without a line ever having been actually measured in Scotland. They are all divided from the original base-line in Ireland ...*,'³¹ Surprisingly, this dates the decision to abandon Colby's own Belhelvie baseline before his retirement in April 1847.

From triangulation to topographical survey

After the false start in Wigtonshire (as mentioned above), the topographical survey of Scotland was resumed in 1843, and proceeded county by county, as described by Brian Adams. His paper explains how each county was plotted by reference to its own 'county origin', which in a few cases covered an adjoining county. It lists the latitude and longitude of these county origins, but he does not discuss the determination of these latitudes and longitudes from the trigonometrical survey of Scotland.³²

Some of the 'initial points', as the county origins were at first known, coincide with the principal trigonometrical stations for which latitudes and longitudes were re-determined about 1851³³ (as described above). For each of another five county origins (at least), extant calculations demonstrate how latitude and longitude were determined on the 'point to point' basis using the previously triangulated distance and bearing from each of several principal stations of 'known' latitude and longitude. This is illustrated in figure 8, below, for the county origins of Ayrshire, Renfrewshire, Roxburgh, Selkirk and Stirling, for each of which the several slightly different determinations were simply averaged.

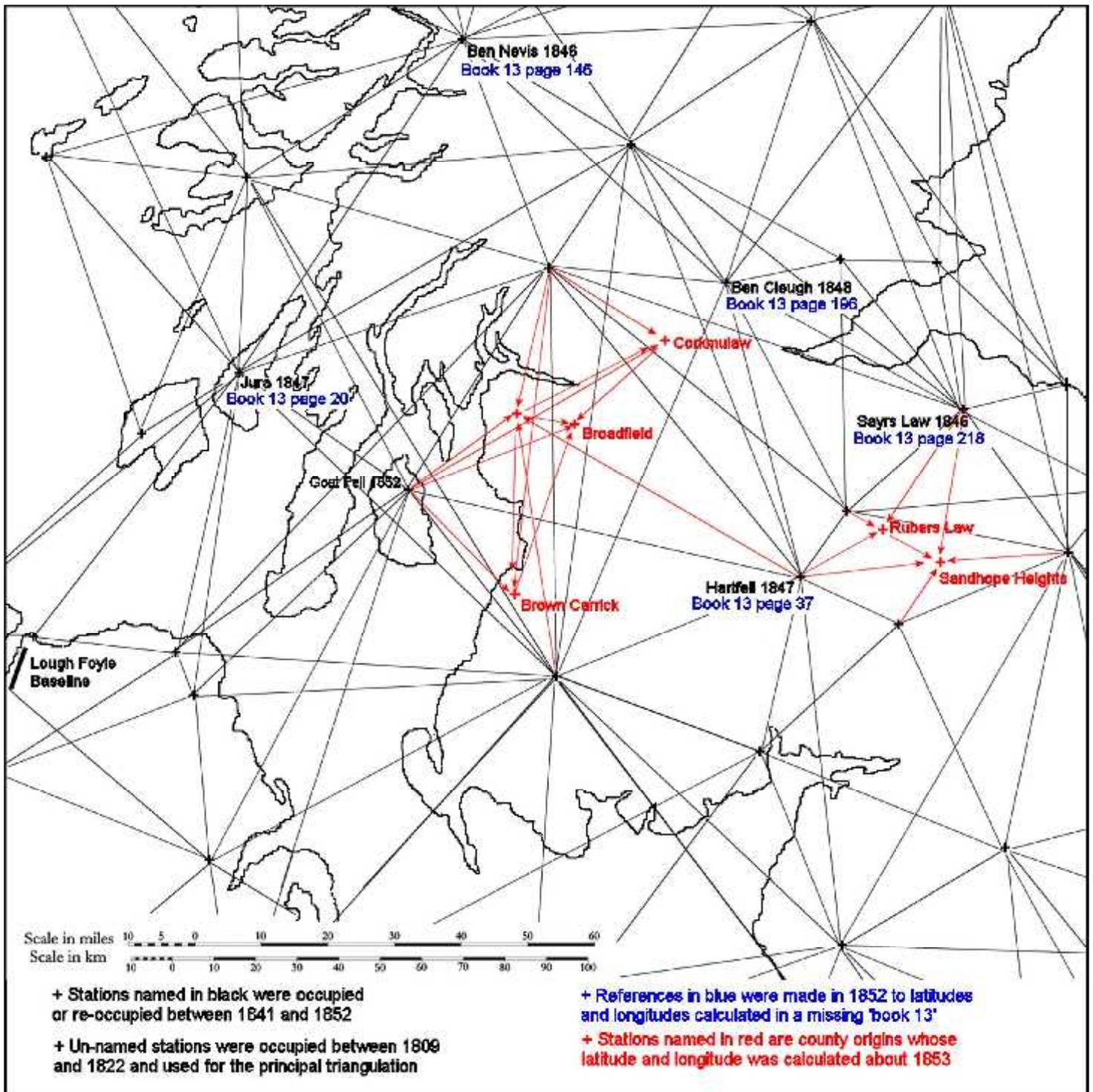
Changes in leadership 1847-54

Although recommended by Colby, Yolland was too junior to succeed him as Superintendent in 1847, and found himself reporting to the newcomer Col Lewis Alexander Hall, who had little relevant experience. Pre-occupied with a host of commitments, including the on-going publication of six inch maps, trigonometrical information for the Admiralty's Hydrographer and maps for the General Board of Health, Yolland must have found it irksome to have to advise the man appointed to, as he thought, his job.

³¹ Aberdeen Journal, anon., 14 October 1846 (from a report in the Glasgow Citizen), Nineteenth Century Newspapers on-line.

³² Roger Hellyer and Chris Higley (eds), *Projections and Origins, collected writings of Brian Adams*, London, The Charles Close Society, 2006, 87.

³³ *Latitudes and Longitudes of Initial Points in Scotland etc*, TNA, OS 2/648, 239-246. Calculation books OS 2/647 and OS 2/648, apparently maintained by Lt D F McCarthy, include an exhaustive comparison of alternative formulae for transposing observed triangles into latitude and longitude. They also include tables that he constructed in 1847, using Airy's figure of the earth, which continued to be used for converting seconds on the spheroid, at various inclinations to the meridian, into feet on the 6 inch (and other) sheets.



After the triangulation of Great Britain had supposedly been completed in 1841, the unheralded but intensive programme of new and repeated observations that took place in the 1840s left outsiders in the dark. Professor Airy wrote to Yolland on 11 May 1848 that *'I find that I am not the only person who is disposed to grumble at the non-publication of so much of the Great Triangulation of Great Britain as applies to the Great Arc of Meridian'*³⁴ and *'I want you to inform me whether it is in contemplation shortly to publish the Triangulation'*.

³⁴ This point was not necessarily rhetorical: the Penny Cyclopaedia of the Society for the Diffusion of Useful Knowledge (vol 25 p 217) remarked in 1843: *'Were it not indeed for the*

Yolland replied on 13 May 1848 agreeing that *'from the advanced state of the observations no time should be lost in setting about [its publication]'* and suggesting that *'if a representation from you or emanating from the Councils of the Royal or Astronomical Society were made to the Lords of the Treasury or to the Master General of the Ordnance ... such representation would probably be attended to without delay and produce an effect very different to what might be expected from any subordinate officer in my position, stepping out of the line of his official duties.'*³⁵

The deteriorating relationship between Col Hall and Capt Yolland, who had been accustomed to corresponding direct with officers having common interests but higher rank, is illustrated by Yolland's letter of 16 August 1852 in response to the recently promoted Rear Admiral Sir Francis Beaufort, apologising that Col Hall had *'recently made some alterations in the mode of carrying on the duty here which will preclude me from complying with your requisitions on the instant.'*³⁶ After he had posted Yolland to Ireland in November 1852, Hall's lack of mathematical advice led him to write to the Astronomer-Royal that he would be much obliged if he would advise Capt Cameron, to which Airy responded with *'Notes on the method proper to be used for reduction of the Grand Triangulation of the British survey.'*³⁷

However Hall's request was overtaken by the appointment of Col Henry James to succeed Col Hall, and the very fortunate, or well-planned, return from Canada of the mathematically-talented Capt Alexander Ross Clarke, who in 1854 embarked upon an ambitious re-evaluation of the trigonometrical observations of Great Britain and Ireland, selected from the potentially bewildering collection accrued by that time.

The principal triangulation completed

Unencumbered by other duties, Clarke in remarkably short time completed the work that enabled Col James to advise a Commons Select Committee, in April 1856, that the principal triangulation had been completed within the previous fortnight, and that a paper would be read at the Royal Society in the following week. This after the years of delay attracted a sardonic comment from one MP: *'Do you say it has been completed within the last fortnight?'*³⁸

admirable maps which are from time to time issued from the Ordnance map-office, it might be inferred that the survey had been discontinued during the last thirty years.'

³⁵ Papers of George Airy, Camb. Univ. Library Manuscripts, RGO 6/417, item 16, ff 136-139.

³⁶ Capt Yolland to Rear-Admiral Beaufort, U K Hydrometric Office, LP 1857Y, 84.

³⁷ Papers of George Airy, Camb. Univ. Library Manuscripts, RGO 6/419, item 7, ff 149-174, 29 Oct 1853.

³⁸ British Parliamentary Papers, *Report from the Select Committee appointed to consider the Ordnance Survey of Scotland; with the Proceedings, Minutes of Evidence, Appendix, and Index*, 1856, XIV, 733-738.

The Royal Society paper,³⁹ attributed to James but obviously written by Clarke, is as much concerned with geodesy, particularly the figure of the earth, as with the triangulation, and it was not until two years later that the Ordnance Survey published its full evaluation of the principal triangulation.⁴⁰ Clarke's work was a mathematical and administrative triumph. To solve a multitude of simultaneous equations, he adapted the 'least squares of errors' procedures developed by Gauss and Bessel in the 1830s to estimate the most probable solution of the trigonometrical network to satisfy three conditions: angles of each triangle (less spherical excess) to equal 180°; sum of the angles observed at each station to equal 360°; and estimates of the length of each side of each triangle to be equal.

Although the Royal Society paper and the account of the principal triangulation established Clarke's reputation as a geodesist, and provided the basis for future work in other countries, they had surprisingly little enduring influence within the Ordnance Survey. Latitude and longitude continued to be calculated by reference to Airy's spheroid rather than Clarke's spheroid. Murphy's tables, calculated on Airy's spheroid, continued to be used for routine transposition between map co-ordinates and latitudes and longitudes. In 1860 Clarke wrote to Professor Airy, expressing his appreciation of the paper Airy had published in 1830, and suggesting that the time had come for a new edition – to incorporate his latest work, as Clarke presumably imagined. Airy had no difficulty in killing off this idea with kindness, responding that *'There is not the least prospect that I shall ever be able to undertake such a work. But I much wish that you would undertake it.'* and referring to foreign work on the theory of homogeneous ellipsoids which meant that *'A treatise in English embracing all these [theories] is much to be desired.'* Clarke then became concerned whether he would be involved in expense for printing plates &c, and both parties would have been relieved when the publishers proved unwilling to consider a new edition.⁴¹

Postscript

Seventy-five years later, Airy's spheroid rather than Clarke's spheroid was adopted for the re-triangulation that started in 1935, and it continues in use today as the basis of the National Grid. Airy in 1830 had lucidly analysed all the international measurements of arcs of the earth (although Colby had not contributed any account of the British triangulation beyond 1811), but his actual calculations covered only four pages. Clarke's calculations cover 400 pages and he had the benefit of another forty years of British observations, as summarised above. However, Airy's work had been put to use when it was needed, and it is understandable that after 1858 the Ordnance Survey regarded the potential

³⁹ *On the Figure, Dimensions, and Mean Specific Gravity of the Earth etc, communicated by Lt Col James RE FRS &c Superintendent of the Ordnance Survey*, Phil. Trans. R. Soc. Lond., 1856, vol 146, 607-626 [on its website].

⁴⁰ *Account of the Observations and Calculations of the Principal Triangulation etc*, Drawn up by Capt Alexander Ross Clarke under the direction of Lt Col H James etc, Ordnance Survey: London, 1858.

⁴¹ Papers of George Airy, Camb. Univ. Library Manuscripts, RGO 6/420, item 31, ff 445-447.

confusion that could have stemmed from making a change (and the extra work involved) as an unnecessary cost simply to make an imperceptible improvement in the accuracy of its maps.⁴²

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CCS on BBC

Several familiar CCS faces were featured in a recent BBC4 TV programme in the *Timeshift* strand. Entitled *A Very British map: The Ordnance Survey Story*, it dealt with the history of the maps and the organisation in an interesting and engaging way, with much fascinating archive footage and marred only by the voiceover persistently pronouncing the non-existent 'i' in Ordnance.

The programme was first shown on 9 September, (series 15, programme 2) and will no doubt be repeated on BBC4 from time to time; well worth watching out for if you missed it.

CCS on WIRED

Yet more CCS faces appeared in a major article in the prestigious online journal WIRED.com in July. This told the story of the secret Soviet mapping of Britain and elsewhere during the Cold War, a topic *Sheetlines* has covered on several occasions since 'Uncle Joe knew where you lived' in 2005 (*Sheetlines* 72,26 and 73/6).

The story can be read at <http://www.wired.com/2015/07/secret-cold-war-maps/>

CCS communications

The Society has been using email to notify members of topical items of interest or upcoming events. Our list of members' email addresses is incomplete and, in some cases, out-of-date. If you have not been receiving CCS emails and would like to do so, please write to info@charlesclosesociety.org. This is also the address to use if you wish to be removed from the Society mailing list.

⁴² Sir Charles Close, *The early years of the Ordnance Survey, 1926*, republished with an introduction by JB Harley, Newton Abbot: David & Charles, 1969, 148-149.