Edward Sabine and the "Magnetic Crusade"

Peter Collier

Abstract The last decades of the nineteenth century witnessed a number of attempts at international cooperation in cartography, including the establishment of the Greenwich Meridian as the standard for both time and longitude, and Penck's proposal for the International Map of the World. What is less well known was an earlier cooperative venture, the so called 'Magnetic Crusade'. At a time when maritime navigation was still dependent on the magnetic compass, it was important to know the variations in magnetic declination. Edward Sabine was charged with running the Magnetic Department and established an international group of collaborators, including important scientists such as Gauss, to collect data from around the world. Sabine was also able to use the network of British colonies and their observatories and voyages of exploration to polar regions, including the Franklin relief missions, to collect data. This chapter will explore the work of Sabine's department, its network of collaborators, the attempts made to impose standards on the measurements made, and the maps it produced.

1 Introduction

There were a number of attempts at international cooperation in cartography in the last decades of the nineteenth century. The proposal to standardise time and longitude on Greenwich, replacing a multitude of local times and local meridians, is perhaps the best known. Penck's proposal for an International Map of the World, with standardised scale and symbolisation was never fully realised. However, these were not the earliest examples of international cooperation. In the middle of the nineteenth century a now, largely forgotten, international campaign was successfully pursued to measure and map variations in terrestrial magnetism. Edward Sabine, the mastermind of this campaign, was in his day a famous man of science, but like his campaign he is now largely forgotten. While the scientific and political aspects of

P. Collier (✉)
University of Portsmouth, Portsmouth, England
e-mail: peter.collier@port.ac.uk

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this work have been discussed in a number of papers (see for example O'Hara 1983; and Cawood 1979), little has been written about the more cartographic aspects of the work, or about it as an international enterprise.

The magnetic compass was a fundamental tool in European maritime navigation from the around the end of the twelfth century until the development of gyro compasses, although the Chinese had been using them from sometime between the ninth and eleventh centuries (Temple 2007: 162–166). Problems with compasses due to the attraction of magnetic objects on ships became apparent with some of the early trans Atlantic voyages of the early sixteenth century, but the problem of variations in magnetic declination only started to become apparent with voyages into polar or near polar regions. Stephen Burrowes is usually credited with first noting the problem on a voyage off North Cape. Gellibrand, a professor at Gresham College, determined the amount of the variation and in 1635 published a paper on the subject (van Bemmeln 1898). Edmond Halley made a number of voyages in the late seventeenth and early eighteenth centuries which were sponsored by the English government to chart magnetic variations, publishing his results in the Philosophical Transactions of the Royal Society, together with his theory for the variations in intensity and direction (Fig. 1).

In the early nineteenth century, the work of Alexander von Humboldt, Jean-Baptiste Biot and François Arago, amongst others, reawakened British interest in the field of terrestrial magnetism at a time considerable scientific rivalry between Britain and France. As Cawood (1979) demonstrates, the revival of interest in terrestrial magnetism was also bound up with the development of the British Association for the Advancement of Science and the politics of early nineteenth century science. As Cawood (1979) notes, the leading men of science involved, John Herschel, William Whewell, George Peacock, and Humphrey Lloyd, were all associated with the reform movement within British science. The campaign to study terrestrial magnetism became, in the words of one of those involved 'by far the greatest scientific undertaking the world has ever seen' (Whewell 1857).

The scheme was not originally a British conception. The originator was Alexander von Humboldt, who had already established a number of magnetic observatories in Russia. In 1836 Humboldt had written to the President of the Royal Society to advocate the establishment of a series of observatories in British territories in which simultaneous observations could be made. Airy and Christie were asked by the Council of the Royal Society to report on Humboldt's letter. In their report they drew attention to the advantages of participating in such a scheme and identified the best locations for the proposed observatories (Christie and Airy 1837). They also noted that Humboldt urged direct cooperation between the Royal Society of London, the Royal Society of Göttingen, the Royal Institute of France and the Imperial Academy of Russia. The letter from Humboldt gave great encouragement to the British advocates of the programme in presenting a case to the government.

As the crusade was not a solely British affair, the role of Edward Sabine in managing an array of international collaborators, and Humphrey Lloyd in developing the necessary scientific apparatus, were to be key to its successful prosecution. In practice, Sabine was never able to convince Arago to cooperate, and cooperation with Göttingen was partial, at best.

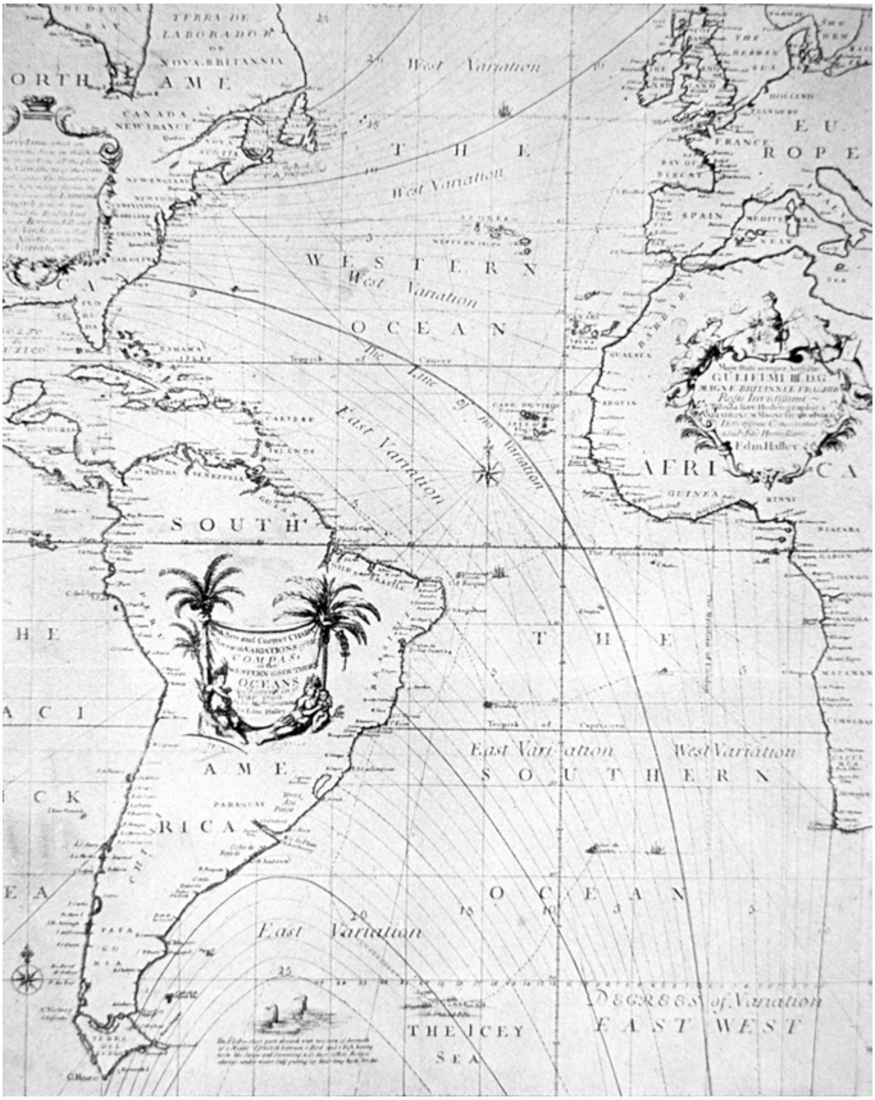

Fig. 1 Halley map of magnetic declination (courtesy of NOAA)

2 Edward Sabine

Edward Sabine is little remembered today, but in the mid nineteenth century, he was amongst the most famous men of science in Britain. Sabine was born into an Anglo-Irish military family in Dublin in 1788. At fourteen he entered the Royal Military Academy at Woolwich and was commissioned into the Royal Artillery in December 1803, at the age of just fifteen. After service in Gibraltar and various home stations, he was sent to Canada in 1813, serving during the defence of Quebec and in the Niagara Campaign against the Americans. Although Sabine was to retire with the rank of General, he never again saw active service, nor saw much regular military service during the rest of his career. Following the end of the North American and Napoleonic Wars, Sabine became interested in scientific matters, and these became the focus of the rest of his life.

Through his family connections he found it easy to enter into the scientific life of early nineteenth century Britain. His eldest brother, Joseph, was a founder member of the Linnean Society, and his brother-in-law, Henry Browne, provided Sabine with his first magnetic instruments and tuition. In 1818 he was assigned as astronomer to John Ross's polar expedition (Fleming 1998: 38). Among his tasks were the measurement of the direction and intensity of the earth's magnetic field, determination of longitude and latitude, observations of atmospheric refraction and the aurorae. His work on the Ross expedition led to his first paper on magnetic variations (Sabine 1819), although the voyage also led to a quarrel between Sabine and Ross over Sabine's assignments and the credit for the work he had carried out. The quarrel with Ross had no adverse affect on Sabine's career and in 1819, he sailed again, this time with William Edward Parry (Fleming 1998: 63), on the first British expedition that overwintered in the Arctic. James Clark Ross also worked with Sabine on the Parry expedition, and was to work with Sabine again on the magnetic survey of Ireland in the 1830s.

In the 1820s Sabine was chiefly involved in geodetic research, measuring variations in gravity in the Atlantic, Caribbean and Spitzbergen. In 1825 he worked with Herschel and two French scientists on the determination of the longitude differences between the London and Paris meridians. This was followed in 1827 and 1829 with a comparative study of gravity pendulums and magnetometers at the Paris and Altona observatories. This work carried out with François Arago and Heinrich Schumacher brought him into contact with other prominent scientists.

In 1834 Sabine worked with James Clark Ross and Humphrey Lloyd on the magnetic survey of Ireland. Lloyd, who was astronomer at the Dublin Observatory, was to be one of Sabine's most important collaborators on the Magnetic Crusade, and largely responsible for the design of the equipment used (O'Hara 1983). He subsequently carried out magnetic surveys in Scotland (1835) and in England (1836). During this time he was actively building support for the "magnetic crusade", which he was to run through the Magnetic Department, until it closed in 1877.

3 Building Support for the Magnetic Crusade

An important connection for Sabine's future career and the magnetic crusade that was made through his polar work was with John Barrow, Secretary to the Admiralty. Barrow, through his work in the Admiralty, actively promoted exploration, and polar exploration in particular. The Barrow connection was to benefit him enormously as through it he gained access to naval facilities, normally unavailable to Army officers. Barrow also supported the election of Sabine to the Royal Society. Another of Sabine's naval supporters was Francis Beaufort, Hydrographer to the Admiralty, an important voice in both scientific and naval circles.

Sabine was also busy building a network within scientific circles, initially at the Royal Society. As Good (2011) notes, Sabine was very good at working within societies and institutions, using his connections to further his scientific work. He became a secretary of the Royal Society in the 1820s, and in 1828 a member of the board of scientific advisors (a body that had replace the Board of Longitude). As Good (2011) also notes, Sabine was not a reformer, while most of the scientist with whom he was to collaborate on the magnetic crusade were very much opposed to the nepotism which was a feature of the early nineteenth century Royal Society. However, Sabine's personal qualities and organisational ability meant that he did not alienate these important allies. Sabine was slow to recognise the potential importance of the British Association for the Advancement of Science (founded 1831), joining only in 1835. However, once he had joined he used the annual meetings to present the results of his work and to promote his activities. In 1839 he became its General Secretary, and President in 1859. In 1845 he was appointed Foreign Secretary of the Royal Society, in 1850 he was elected Treasurer and Vice-President, and President from 1861 to 1871. It is worth noting that in his work as Foreign Secretary of the Royal Society, and in his other dealings with foreign scientists, he was greatly assisted by his wife, Elizabeth, a linguist who translated works by von Humboldt, Arago and von Wrangel.

In addition to support from the Admiralty, Royal Society and British Association, Sabine was also able to draw on the support from the Army. He had been granted relief from normal duties to pursue his scientific career by the Duke of Wellington, and apart from a period in Ireland in the 1830s he was free to continue with that career. His plans for a network of magnetic observatories would need the services of Army officers to carry out the observations. While the support of the Admiralty for the crusade made practical sense, there was no obvious benefit to the Army. However, in the post-Napoleonic period there were few opportunities for employment and advancement for Army officers, and many officers would have welcomed the break from normal duties and the possibility it offered of advancement. The Army was therefore happy to second officers to the crusade, usually from the Royal Artillery, although it often raised problems regarding the costs incurred. Sabine started building his support for the crusade in 1835, and with support from Parliament, the campaign obtained the support of the Melbourne government in 1839 for James Clark Ross's Antarctic expedition.

4 The Aims of the Magnetic Crusade

As Good (2011) notes, the magnetic crusade had a number of aims. The first aim was to acquire masses of data. This would involve the use of ships and a network of magnetic observatories collecting data over many years. A second aim was to understand the cause of geomagnetism and the laws governing it. A third aim was to put together the necessary instruments, facilities and personnel to carry out the crusade, on a scale never before attempted for any scientific endeavour. Sabine's earlier work with Ross and Lloyd in Ireland had done much to lay the ground work for the project, and both Ross and Lloyd were to play a significant role in its work. Sabine had also encouraged amateur men of science to collect magnetic data during their travels. For example in 1838 Mr Ainsworth carried out a series of observations of magnetic intensity while on a journey to Constantinople. Once he had arrived in Constantinople, Ainsworth was able to send to Sabine the needles used in making the observations, using a warship and via Francis Beaufort. The needles themselves had been previously used on Chesney's Euphrates expedition. Before Ainsworth journey the needles had also been compared with others due to be used on an expedition to Kurdistan. It is clear that the crusade was in some senses just bringing together and systematising something which was already happening.

In Europe, François Arago, Carl Friedrich Gauss and Christopher Hansteen had done much to advance the theory of geomagnetism, and the work of the crusade was very much informed by their theories. However, it was far from being one-way traffic. While Sabine had the first English account of Hansteen's theory, Gauss's own work drew on the data presented by Sabine in the 1836 Report of the British Association. Ainsworth had also used Arago's cabinet at the Paris Observatory when making his observations there. In addition to the magnetic observatories already established at European astronomical observatories, Alexander von Humboldt had also established a number of magnetic observatories in Russia, which were subsequently taken over by Gauss. Part of the aim of the magnetic crusade was to use, and even extend, the continental network of observatories, through negotiation with scientist like Gauss and Arago.

5 Operationalising the Crusade: The Imperial Network

As noted above, the crusade as originally envisaged, involved the use of British warships to collect magnetic data on voyages across the oceans and in polar regions. In addition, magnetic observatories were to be established, usually in association with existing astronomical observatories. Special care had to be taken in constructing the magnetic observatories, which had to be of wood, with only copper nails being used in the construction.

Humphrey Lloyd had already established a magnetic observatory in Dublin, but under the planned crusade, there was to be a magnetic observatory in Greenwich, together with four manned by members of the Royal Artillery in Toronto, Cape of Good Hope, Van Dieman's Land and on St Helena, and four supported by the East India Company in Madras, Simla, Bombay and Singapore.

Prior to being sent to set up the observatories, the personnel selected were usually sent to Dublin to receive instruction from Humphrey Lloyd on carrying out the observations. They were then supplied with a set of equipment. Lieutenant Lefroy, who was to be an important contributor to the crusade, and an important scientist in his own right, before going in October 1842 to carry out observations in Upper Canada, was supplied with the following equipment:

1. An inclinometer of nine French inches diameter, by Gambey (this instrument was being lent by Robert Fitzroy, and had previously been lent for the magnetic survey of the British Isles, demonstrating the key role still being played in scientific research by wealthy amateurs).
2. A Fox's inclinometer of seven inches diameter.
3. A portable unifilar magnetometer for the measurement of absolute horizontal force.
4. An azimuth compass.
5. A portable declinometer.
6. A portable bifilar magnetometer.
7. A portable induction inclinometer (Sabine 1846: 240).

Sabine provided very detailed instructions regarding how the observations were to be conducted. This was reinforced from time to time by circulars sent to the various observatories (see, for example Sabine 1841).

Lefroy had previously been sent in 1839 to establish the observatory on St Helena. Conditions must have been fairly primitive and the allowances paid inadequate, despite the government funding, as in 1842 Lefroy was forced to write to Sabine requesting the money to buy forage for his horse, a request that Sabine had to forward to the Deputy Adjutant General's Office for approval by the Lords of the Treasury (Magnetic Department Letter Book 1842).

Lefroy had been sent to Canada to become Superintendent of the Toronto Observatory. As part of his work there he carried out an eighteen month expedition, travelling some 5,000 miles and with his assistant, Bombardier Henry, carried out observations at more than 300 stations. However, Lefroy was unusual in carrying out observations over such a wide area, most observations were made at or near the established observatories.

Among the naval expeditions that carried out magnetic observations was that of James Clark Ross. Ross left England in late 1839 and headed south with two ships, HMS Erebus and HMS Terror, stopping at St Helena to establish the observatory used by Lefroy. They then stopped at the Cape to establish the observatory there. In May they reached Kerguelen Island, where they established a temporary observatory and recorded hourly readings for two months. They then sailed for Hobart, arriving in mid August and constructing the third observatory of the voyage.

On 12 November Ross's ships headed south, crossing the Antarctic Circle on 1 January 1841, After breaking through an outer barrier of pack ice, the two ships proceeded south discovering two volcanoes (Erebus and Terror) and the ice shelf which bears Ross's name, all the time conducting magnetic measurements. After exploring along the ice shelf for 250 miles, Ross finally turned back to over-winter in Hobart (Sabine 1843a). The first season of exploration and measurements were followed by a second season between July 1841 and April 1842, when they arrived at the Falkland Islands (Sabine 1844). In 1845, the Pagoda, under Lieutenant TEL Moore of the Royal Navy was sent from Cape Town to complete the survey of high southern latitudes (Sabine 1846).

6 Operationalising the Crusade: The International Network

While Sabine had more or less direct control over the observatories within the Empire, he had far less control over those of the international participants, and some, such as Arago in Paris refused all cooperation. More interesting was the relationship with the Magnetische Verein centred on Göttingen and on the work of Gauss and Weber. While the whole network used Göttingen Mean Time as the basis for observations, the Verein did not participate fully as it employed its own system of observations (Cawood 1979: 513).

In 1839 Sabine and Lloyd travelled to Göttingen, Berlin and St Petersburg to complete the arrangements for the planned observations. Following the trip, Lloyd was able to report to Herschel that the Russian observatories were prepared to cooperate and that Adolf Theodor Kupffer of St Petersburg had agreed to reorganise the observatories at St Petersburg and Barnaoul to correspond with British observatories, he held out little hope of cooperation with Göttingen, Berlin or Leipzig (Lloyd 1839). He was also able to report that Adolphe Quetelet in Brussels, Carl August von Steinheil in Munich, Palm Heinrich Ludwig von Boguslavsky in Breslau, Karl Kreil in Prague, and his successor in Milan, had agreed to participate.

In 1842 Lloyd reported that ten Russian observatories had participated, St Petersburg, Yekaterinburg and Kazan in European Russia, Helsingfors in Finland, Nikolayev in the Crimea, Tiflis in Georgia, Barnaul and Nerchinsk in Siberia, Sitka in North America and Beijing in China. In addition, observatories in Algiers, Brussels, Prague, Milan, Breslau, Munich, Cadiz, Philadelphia, Cambridge (Masachussets), Cairo, Trevandrum and Lucknow had carried out observations. The observatories in Algiers, Brussels, Breslau, Cadiz, Cambridge, Cairo, Trevandrum and Lucknow had all used instruments of similar design to those in Dublin. It is interesting to note that the observatories in Trevandrum and Lucknow were founded by the local rulers, the Rajah of Travancore and the King of Oude, respectively, and were in addition to those established by the East India Company.

While Lloyd could only encourage foreign observatories to use the same or similar designs for the equipment to those that he was using in Dublin, Sabine could insist that any expeditions supported by the British Government had to use equipment approved by Lloyd and himself. Although Gauss and Weber resisted any changes to their working methods and equipment, most of the measurements were made with compatible equipment, ensuring a high degree of standardisation. It is also worth noting that, despite the disagreements over the conduct of observations, Gauss and Sabine remained on good terms.

An important factor that helped Sabine to maintain his network, and his key place within it, was that his correspondents anywhere in the world could send him data without having to pay for its transmission. As he wrote to John Locke in Cincinnati, if the packet addressed to Sabine was enclosed within an outer envelope addressed to Secretary of the Admiralty, London, and put into the post office in Boston or New York, it would be sent to him free of postage (Sabine 1843b). As John Barrow was still then Secretary of the Admiralty, this was clearly a continuing benefit resulting from Barrow's patronage.

7 Cartographic Output of the Magnetic Crusade

As noted above, the main aims of the crusade involved the collection of vast amounts of data and the development of improved theories. There were, however, more practical products of the work in the form of maps showing variations in magnetic force and magnetic declination around the world. The first of these (Fig. 2) accompanied "Contributions to Terrestrial Magnetism" (Sabine 1840). Which was the first of ten papers published in the *Philosophical Transactions of the Royal Society* between 1840 and 1866, not all of which contained maps. The map was derived from observations collected by a Lieut. Sulivan RN during voyages to and from the Falkland Islands in 1838 and 1839, and a series of observations made between 1834 and 1839 by James Dunlap of the Paramatta Observatory.

The next map to appear accompanied "Contributions to Terrestrial Magnetism No. III" (Sabine 1842). The map depicts the course and magnetic force reading captured by Sabine's friend James Clarke Ross during the 1840 voyage in HMS Erebus. Apart from the locations of a few points for reference, such as Trinidad and Ascension Island, no geographical features are shown Fig. 3.

"Contributions No. IV" (Sabine 1843a) mainly contained data but no map. "Contributions No. V" (Sabine 1843c) continues on from No. III, and covers Ross's voyage with the HMS Erebus and HMS Terror, between November 1840 and April 1841. This contribution is accompanied by three maps, one showing variations in magnetic intensity, and one show variations in magnetic inclination, and one showing magnetic declination. All three maps show some coastline. "Contributions No.VI" (Sabine 1844) depicts the courses and observations of both HMS Erebus and HMS Terror between May 1841 and August 1842. Unlike the earlier maps, this shows much more detail of coastline.

While the earlier "Contributions" were all a product of naval voyages more or less under Sabine's control, "Contributions VII" is the first fruit of Sabine's international network. Subtitled "Containing a Magnetic Survey of a considerable portion of the North American Continent", it drew mainly on the observations of Lefroy and Henry, but also drew on observations made by "several gentlemen of the United States" (Sabine 1846). Sabine's American collaborators included Major James D. Graham, United States Corps of Topographical Engineers, who was a

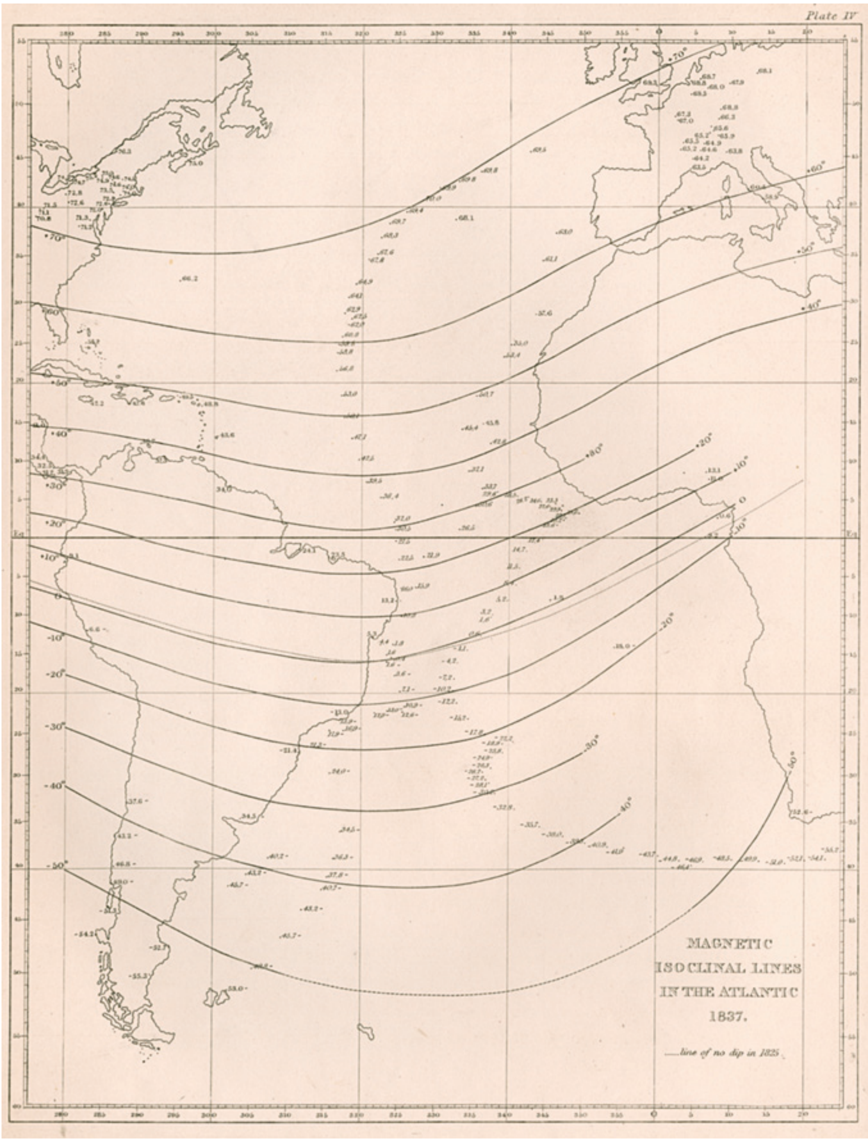

Fig. 2 Map to accompany "contributions to terrestrial magnetism" (Sabine 1840 © Royal Society)

Commissioner, Principal Astronomer and Head of the Scientific Corps engaged in the boundary demarcation between the United States and British North America. Graham's observations were mainly obtained in the course of the boundary survey between 1841 and 1845. Dr Locke of Cincinnati provided data on 100 stations between the eastern seaboard and the Mississippi and between 38° and 48° North.

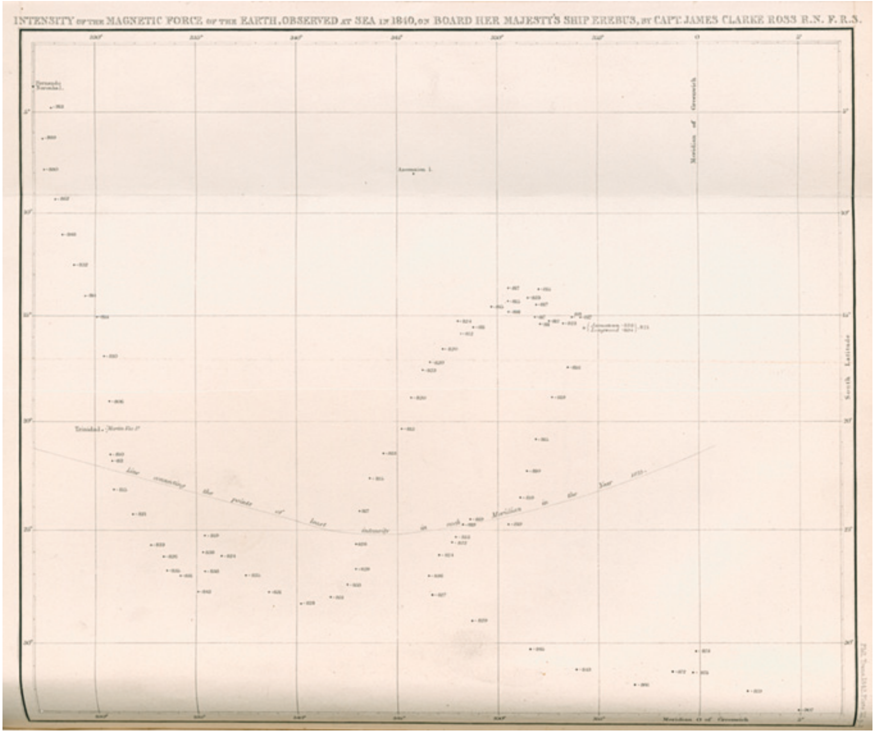

Fig. 3 Map to accompany "contributions to terrestrial magnetism no. III" (Sabine 1842) showing Ross's course in his voyage during 1840 on HMS Erebus (© Royal Society)

Dr Alexander Dallas Bache, Director of the Coast Survey of the United States and James Renwick provided data collected as part of their work for the United States Government, and Sabine also drew on published observations carried out by Loomis and Nicollet. From the data Sabine was able to produce two maps, of isoclinal lines and isodynamic lines (Fig. 4).

Contributions to Terrestrial Magnetism IX (Sabine 1849) contained maps of the Atlantic Ocean between 60° North and 60° South (Fig. 5). The map of declination was produced after "repeated representations from the Hydrographer of the Admiralty", who urgently required such a map for the purposes of navigation. The map was produced using 1,480 individual determinations made between 1828 and 1840, all reduced to 1840 by taking into account annual rates of change. To do this Sabine had taken the map produced in 1787 by Hansteen to calculate average rates of change for each location used. The data came from 15 voyages and 15 series of land based series of observations, including those made by Robert Fitzroy in 1832–1834 on the coast of South America and on the Falkland Islands while on the Beagle. Observations were also taken from observatories at Algiers, Brussels, the Cape of Good Hope, Christiania, Dublin, Greenwich, Makerstoun, Paris, St Helena and Toronto.

Fig. 4 Map to accompany "contributions to terrestrial magnetism no. VII" (Sabine 1846) showing magnetic inclination over North America (© Royal Society)

Although there were further "Contributions" published over the next couple of decades, some of which had maps, while others consisted mainly of tables, Sabine was drawn more and more into investigations of data from a few permanent observatories, primarily Kew. It was from the runs of data recorded at these stations that Sabine was able to develop his ideas concerning the influence of the moon on variations in geomagnetism.

All the major reports on the Magnetic Crusade and its cartographic products were produced by Sabine. Indeed, Sabine oversaw all the computations carried out on the raw data supplied by the various observatories and expeditions. This was a source of friction with some of the observers who wished to carry out their own computations. In this context, it is interesting to note that Lefroy did not publish an account of his expedition until the year of Sabine's death (Lefroy 1883).

As can be seen from the examples included, the maps were very simple in their design. In common with most maps of the time they were monochrome, and hand colouring was a luxury rarely lavished on maps published in journals. The maps are all at small scale, although no indication is give of scale on the maps themselves. Considering the maps were intended to form a series illustrating the data captured during the magnetic crusade, there was no attempt to provide standardisation of lettering. Given the areal coverage of the sheets, it is not surprising that a variety of projections were employed, although none are identified on the maps. From the maps examined, the Mercator projection seems to have been used for the Atlantic maps, but a conic projection was used for the Southern Ocean and North

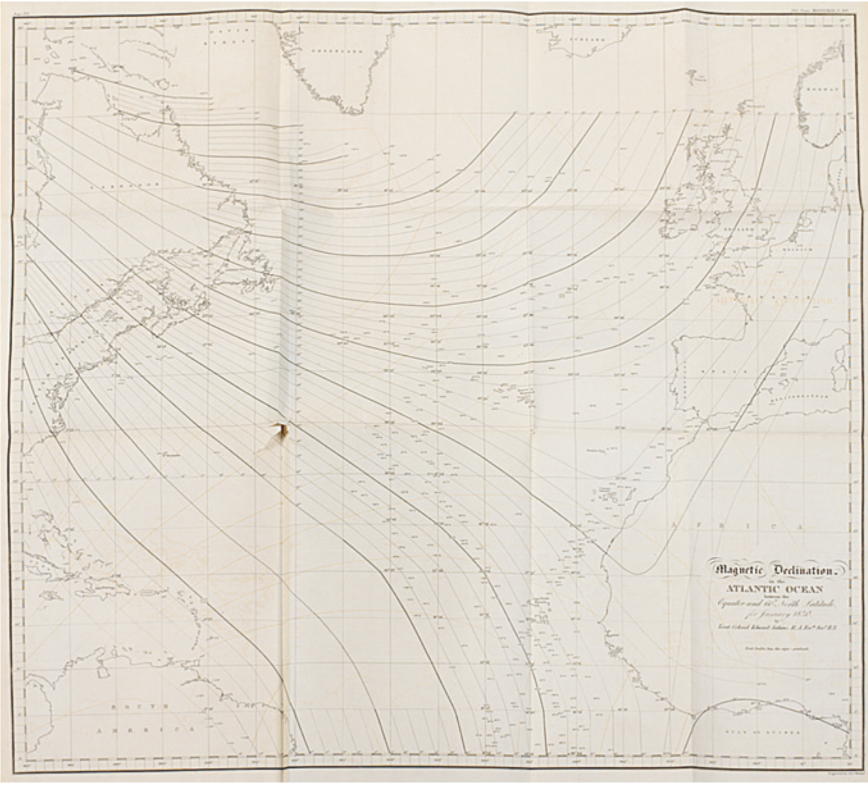

Fig. 5 Map of the Atlantic between 0° and 60° north to accompany "contributions to terrestrial magnetism no. IX" (Sabine 1849) showing magnetic declination (© Royal Society)

America. The use of the Mercator projection made sense for the Atlantic maps, since they were intended to provide data for navigation charts, but the choice of conics for the other maps requires further exploration.

8 Conclusions

The magnetic crusade was a pioneering example of international cooperation in data collection for scientific purposes. The data collected served both the scientific understanding of both temporal and spatial variations in terrestrial magnetism, and improvements in navigation at a time when the magnetic compass was still an important instrument. Sabine's role was important in creating the organisational infrastructure necessary to maintain the campaign involving so many people and over such a time span. Lloyd's role was important in defining standardised equipment and a standardised mode of observation. The reluctance of Gauss and Weber to participate in no way detracted from the final work. Importantly, through publication in the Philosophical Transactions of the raw data, the formulae used in the calculations and the calculated results, Sabine provided all the information needed to check his results, and if necessary change the results by applying different formulae. The publication of all the data also meant that anyone wishing to create larger scale charts could do so from the published data, which normally had geographical coordinates to 1 min of arc. The scale of the project and the vast amount of data it generated lend support to Whewell's (1857) contention that it was the greatest scientific project of its, or any previous age.

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Author Biography

Peter Collier was formally employed as a cartographer and photogrammetrist at the Directorate of Overseas Surveys before following an academic career. He always had an interest in the history of survey and mapping, and this has been mainly focused on the development and application of new technologies. Since 2001 he has been involved in the History of Cartography project, initially as an author of an exploratory essay, and subsequently as the author of several entries for Volume 6 (20th century). More recently he has also worked as an Associate Editor on Volume 6. He is also on the advisory Board for Volume 5. He has been a vice chair of the Commission on the History of Cartography of the ICA since 2007, organising a symposium for the commission in Portsmouth in 2008. In 2011 Peter took over as editor of the journal *Survey Review*.