PROVING INSTRUMENTS CREDIBLE IN THE EARLY NINETEENTH CENTURY: THE BRITISH MAGNETIC SURVEY AND SITE-SPECIFIC EXPERIMENTATION

by

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For several decades now, many histories of science have sought to emphasize the important role of instruments and other material objects in the operation of science. Many, too, have been attentive to ideas of space and place and the different geographies which are visible in the historical practice of science. This paper draws on both traditions in its interpretation of a heretofore neglected aspect of Britain’s nineteenth-century geomagnetic story: that of the British Magnetic Survey, 1833–38. Far from being a footnote to the more expansive geomagnetic projects then taking place in mainland Europe or to the later British worldwide magnetic scheme, this paper argues that the British Magnetic Survey represents an important instance in which magnetic instruments, their users and their makers, were tested, developed and ultimately proved credible.

Keywords: instruments; geomagnetism; site-specific experimentation; Edward Sabine; Humphrey Lloyd

This is the story of the British Magnetic Survey (BMS) of 1833–38. However, we start after this survey had ended and another had begun.

In 1842 Lieutenant John Henry Lefroy was en route to Canada and the beginning of his magnetic survey of the Northwest Territories there. Accompanying him were two dip circles: one designed by the Cornish instrument maker Robert Were Fox; the other by the Frenchman Henri-Prudence Gambey. These instruments measured the angle at which a magnetic needle was inclined to a magnetic pole in different parts of the Earth, and they relied for their accuracy on both the perfection of their construction and the magnetic needles used within them. Needles were, however, mutable objects: their magnetic strength was not constant. There were good needles, which held their strength or at least degenerated at a consistent rate; and there were bad needles, which seemed to lose strength randomly.

Mr Goodman’s article was joint winner of the 2016 Notes and Records Essay Award, open to researchers in the history of science who have completed a postgraduate degree within the past five years.
The status of a particular needle needed to be known to an observer so that the many observations recorded with it could later be reduced and made comparable. Not knowing the state of the needle made terrestrial magnetic observation a guessing game. Edward Sabine knew this only too well. After all, he was the de facto organizer of Britain’s so-called magnetic crusade, which established geomagnetic observatories throughout the British Empire and launched geomagnetic expeditions such as Lefroy’s to Canada and the more famous voyage of James Clark Ross to the Antarctic from September 1839.2 When equipping Lefroy’s expedition, it was vital that Sabine provide good, reliable needles. In the frigid high latitudes of the Canadian Arctic it would have been difficult for Lefroy to find a replacement for a bad one. Writing in Philosophical Transactions in 1846, Sabine spelled out the fact that the needles that had travelled with Lefroy to be used in the Gambey dip circle ‘were the same which had been used in the British Survey, when they were proved to be free from index error at all inclinations, by the observations of Captain Johnson, R.N. and myself in the Regent’s Park’.3

What follows is an exploration of the British Survey and its significance, as Sabine touches on, in testing and proving instruments of geomagnetic study. In tracing the course of this survey it will be demonstrated that knowledge of the science of terrestrial magnetism was embodied in the instruments of its study and entwined with specific sites. The experience of handling, testing and modifying magnetic instruments during this domestic survey was a formative one for magnetic instrument users and makers. Work during the BMS led to developments in both magnetic instrument design and the method of their use. As we follow instruments and their users on this survey, we observe how certain places came to be established as ‘truth-spots’ for this science, in the time before the establishment of specific geomagnetic observatories in the British Isles and elsewhere.4

**Course of the Survey**

Put simply, the BMS was just that: a survey of the Earth’s magnetic field throughout the British Isles. To be more precise, it was a survey of two particular properties of the Earth’s magnetism. The first was its inclination, then commonly referred to as dip and defined as ‘the horizontal angle between a magnetic needle and geographic north’ which ‘varies depending on one’s proximity to a magnetic pole’. The second property was intensity, which varies both spatially and temporally and ‘may be measured in terms of its vertical and its horizontal components [and] by means of a suspended magnetic needle’.5 In the BMS, only the horizontal component of the intensity was recorded; instruments for the accurate measurement of its vertical component were only perfected in later years.6 The BMS produced three substantial publications and several maps of England, Scotland and Ireland showing the isodynamic (equal intensity) and isoclinal (equal dip) lines in these locales. These maps were the first of their kind for Britain and some of the earliest produced anywhere in the world.7 The British Association for the Advancement of Science (BAAS) was the vehicle by which the survey was launched, and it was to this organization that reports were made and through which they were later published. The principal participants in the survey’s execution were Edward Sabine, an army officer and physicist; Humphrey Lloyd, also a renowned physicist and based at Trinity College, Dublin; and James Clark Ross, a polar explorer, naval officer and scientific observer. They were later joined by John
Phillips, better known for his work in the field of geology; and Robert Were Fox, the reputable Cornish instrument maker, geologist and physicist.

Originally, a domestic magnetic survey had been called for by the BAAS in 1831. Prompted by the magnetic survey work of James Dunlop in Scotland in 1830 and a renewal, or ‘revival’, of interest in the physical sciences in Britain from the late 1810s, the BAAS felt it ‘highly desirable that a series of observations upon the Intensity of Terrestrial Magnetism in various parts of England be made by some competent individual’. The call went further, requesting that, as a matter of considerable importance, ‘a certain number of observations should be made throughout Britain with the Dipping Needle’. The competent individual first identified to carry out the survey was William Scoresby, an Arctic explorer, natural philosopher and Church of England clergyman. However, Scoresby was unable to perform the assignment and instead passed the work to his friend Thomas Stewart Traill in Liverpool. The ‘standard Hansteen needle belonging to the Royal Society of Edinburgh’ was duly passed to Traill for the work. Traill commenced his observations in early 1832 but only managed to publish eight observations of intensity, taken in Liverpool and Manchester, before career interests took him elsewhere and his brief affair with the BMS was ended. It was shortly after this, in 1833, that Lloyd and Sabine began corresponding with one another and together developed a plan for a more extensive British survey, using a far greater number of instruments and needles. For the purposes of this account, the BMS is understood to have truly begun only once Sabine and Lloyd had taken the reins.

It was shortly after their epistolary relationship had started that Lloyd and Sabine began terrestrial magnetic observation in Ireland. This initial period of work lasted from 1833 to 1835: Lloyd from his base at Trinity College, Dublin, and beyond, and Sabine in Limerick, where he had been stationed on military service. Initially, however, Lloyd had to confine himself to making only those observations that helped to verify his new method of observing both the intensity and dip of the Earth’s magnetic field with the same needle, known as the stational method. Lloyd had been prevented from beginning a series of regular geomagnetic observations because the Hansteen magnetometer he required and which he had requested from George Dollond had reached him late. Lloyd was referring to George Dollond, from the Dollond dynasty of optical, mathematical and scientific instrument makers, who had been in operation since the mid eighteenth century. It was not until July 1834 that observations for the British survey began in earnest.

Over the period 1834–35 Lloyd, Sabine and, on occasion, James Clark Ross collaborated on the Irish portion of the BMS. Lloyd made the majority of observations ‘in the field’, i.e. beyond the magnetic stations at Dublin and Limerick. These two places were adopted as sites at which observations were made that could stand as a means for comparison once a series of field observations had been completed elsewhere. Magnetic needles more often than not lost strength over time and thus it was vital to have a standard to refer to when comparing and reducing results.

Lloyd observed from Ballybunan (nowadays Ballybunion) in the southwest to Carlingford in the east and Strabane in the north, and at 21 other stations. Sabine and Ross collaborated over the regular exchange of results, needles and instruments for the purpose of verification at other base stations. For instance, on 7 November 1835 Lloyd sent his Hansteen’s needles to Sabine and asked him to vibrate them—a method of measuring the intensity of the Earth’s magnetism—in Limerick. They had already been vibrated in London and Dublin but Lloyd
wanted Sabine to observe with them in Limerick to serve as a ‘double comparison’. To make the observations strictly comparable, Lloyd also provided Sabine with further details of his method of observing those needles. The 1834–35 Irish series was revisited and extended in later years, through new comparisons of the intensity at London and Dublin, by Lloyd, in 1836; between Dublin and Bangor by Sabine later in the same year; by Sabine again between London and Dublin in 1838; and in a complete series of observations by Ross in 1838, ‘at twelve distinct stations throughout the island’.

In July 1836 Sabine travelled from Dublin ‘by steamer direct to the Clyde’ and from there to 27 other points in the north, east, south and west of Scotland. Sabine first observed in Helensburgh and moved through several of the islands of western Scotland on a yacht provided by James Smith of Jordanhill, President of the Andersonian Institution at Glasgow. Sabine travelled north through a combination of steamers and mail coaches, then descended south along the east coast of Scotland as far as Dryburgh, before heading west through Glasgow to Stranraer and thence back to Dublin. Ross would later observe in Scotland and provide more results for comparison and for computation of the yearly variation of terrestrial magnetic intensity and dip there.

The final portion of the BMS—England and Wales—was complete by 1838. This was carried out by the ‘quadruple alliance’ of Sabine, Lloyd, Ross and John Phillips and supplemented by observations made by Robert Were Fox at eight stations from London to the Scilly Isles. Fox had previously recorded a small number of observations in Ireland after the 1835 BAAS meeting in Dublin, but this was before his involvement with Sabine and others on the BMS. The results were initially published in 1836 in Report for the Royal Polytechnic Society of Cornwall for 1835 but were also included in the final publication of the BMS, printed in 1839. Phillips had written to Lloyd as early as July 1835 to inform him that he had begun to make a series of magnetic observations in the north of England and to ask Lloyd whether he would like to use this series, together with Lloyd’s own observations, to draw up a paper for the BAAS. Apparently Lloyd had ‘not the least idea’ that Sabine and Ross proposed to ‘magnetize’ in England at this time and so asked Sabine in a letter whether he (Sabine) and Ross would include Phillips’s work in their survey or whether they intended to work alone. If the latter, then Lloyd himself was only too happy to combine his own work with that of Phillips. As it happened, Phillips was invited to join Lloyd and Sabine’s project. Phillips was ‘flattered’ to receive such an invitation and began work on dip observations in Yorkshire in the spring of 1836. These observations formed the basis of a paper revealed to the BAAS in 1836, which put forward Phillips’s belief that isoclinal lines ‘in flat areas were bent to the south and on hills to the north’. This opinion was criticized by William Scoresby and William Ritchie but defended by Lloyd.

Substantial observations were made throughout England and Wales in 1836–38. Lloyd observed here between April and October 1836, Sabine between May 1837 and October 1838, Phillips between June 1837 and March 1838, Ross at various stages between August 1837 and December 1838, and Fox between August 1837 and August 1838. These observations took in large swathes of England and parts of Wales, from Newcastle to York to Aberystwyth, London and Falmouth, and at dozens of stations in between. Although Sabine and Lloyd were the principal observers on the BMS and were responsible for the reduction of results and the computation of the isoclinal and isodynamic lines, they benefited greatly from the services of Fox and especially Phillips, in large part as a result of the latter’s extensive observations in the north of England. Morrell muses that Phillips may have joined the BMS ‘perhaps as a change from topographical geology’. Indeed, at one
stage Phillips regrets to inform Sabine that he meant ‘to try the dip, again in winter, but my other association have called me off to Belemnites & Orthoceratites!’\textsuperscript{43} At this time, Phillips was also engaged in the Ordnance Geological Survey of Britain, begun under the direction of Henry De la Beche in 1835. Phillips was an ‘experienced field surveyor’, but an inexperienced yet motivated terrestrial magnetic observer.\textsuperscript{44}

Most accounts of Britain’s nineteenth-century geomagnetic activity do not interact with the BMS beyond this point. Admittedly, it was not the grandest undertaking of this period, especially in comparison with continental exploits and the later British worldwide magnetic scheme. The BMS did not involve the creation of a system of observatories or a great and daring expedition. However, this is no reason to doubt its significance. The BMS sheds new light on the practice of managing instruments on the move and, in consequence, on how scientific knowledge was made, and made credible, on the move. Attention is warranted here because, as Finnegan explains, ‘when scientific knowledge travels it transmutes’, and investments of labour and resources must be made to translate such knowledge and make it applicable from one place to another.\textsuperscript{45} How and where this translation occurred is important for understanding the operation of science at this time. Furthermore, the exigencies of the BMS demonstrate how it was often in moments of crisis, when instruments existed in states of disrepair, that new knowledge was arrived at.\textsuperscript{46}

\section*{LLOYD’S PRACTICAL EDUCATION AND INSTRUMENTS IN THE BMS}

Have you ever remarked that needles which are very well balanced as long as they remain at home, become unsteady & unsettled when they travel?\textsuperscript{47}

A magnetic instrument in the nineteenth century was a peculiar item. Its magnetized needle—on which the instrument relied—was changeable; sometimes this was gradual, at other times instantaneous. This change, or more specifically this loss of magnetic force, could occur even if the needle was kept stationary and away from other disturbing elements, such as iron. More commonly, however—and as Humphrey Lloyd indicates above—such change was occasioned by travel. In the bounded and controllable environment of Trinity College, Lloyd’s magnetic needles behaved themselves. They could be housed safely away from the disturbing influences of other ferruginous metals and prevented from receiving any jars or concussions that might unduly affect a needle’s magnetism. This problem was as geographic as it was scientific. All needles were subject to degradation of their magnetism, but in the more controllable environment of the observatory such loss could be limited, or at least more frequently and easily observed and accounted for. The rate at which a needle changed here was more predictable and manageable. When they travelled, however, when the space through which needles passed became less secure and more contingent on a number of other factors—the weather, the method of conveyance—needles were liable to become ‘unsteady & unsettled’. However, such travel was essential to observations of terrestrial magnetism—a science that, after all, sought to chart a global phenomenon. Needles had to be interchanged, observed and verified by observers in different locations if results obtained with them were to be made credible. This almost paradoxical situation—that travel was both essential for, and detrimental to, the science of terrestrial magnetism—is made explicit through the trials and tribulations of the participants and instruments of the BMS.
On 24 January 1834 Lloyd wrote to Sabine to confirm receipt of the latter’s ‘dipping apparatus’—an 11-inch Dollond circle that Sabine deemed ‘inconvenient for carriage’—and its needles. This instrument and its needles had already been in circulation for several years: Sabine had tested the instrument and needles for Captain John Franklin before Franklin had carried it on his second Arctic expedition between 1825 and 1827. It was ‘afterwards given by Government to Mr David Douglas to take with him to the Columbia River’ but Douglas had learned to observe with Sabine’s even larger dip circle, a copy of which Sabine then produced for him and swapped for the 11-inch Dollond.

Sabine had sent the instrument and its needles to Lloyd for inspection. Lloyd was ‘quite at a loss what to say about them’. The error due to friction in the instrument was far higher than that of Lloyd’s own ‘small & light needles’ and Lloyd says he ‘never was so convinced of [their] superiority’. Although the eminent astronomer and director of the Brussels Royal Observatory, Adolphe Quetelet, had told Lloyd ‘not to get a circle of less than 8 inches’, Lloyd explains that he is guided by his own ‘experience’ in this matter and believes that Sabine would be of his opinion had he ‘taken a single observation with my little 4 1/2 circle’. The dip circle that Lloyd refers to here is probably that of Thomas Charles Robinson’s construction, an instrument maker who worked out of Devonshire Street, London. It is referred to as such in Sabine’s memoir of the BMS in 1838. Similar, though not exact, examples of such an instrument now reside on the shelves of the Science Museum’s stores at Blythe House in London. They are rather unassuming objects: light, of simple construction, much less robust than the dip circle produced by Robert Were Fox in 1832 and much less cumbersome than an 11-inch Dollond circle, constructed in the 1820s, which also sits on the shelves at Blythe House. Lloyd’s Robinson circle was evidently made to be easily transported but not to withstand the rigours of observations on ships—as the Fox-type circle was—and so was ideally suited, as Lloyd makes clear, to the BMS and, specifically at his time of writing to Sabine, to Lloyd’s survey work in Ireland. Or so Lloyd thought.

Lloyd encountered several instances of error in his dip circles during this early portion of the BMS. Sabine and Ross were to meet similar difficulties with their own instruments. In fact, such were their problems, Sabine was compelled to remark, in the final publication of the BMS, that the Irish results ‘are those which were the earliest obtained … which had consequently the disadvantages of less experience in the observers, and less perfection in the instruments’. One such instance of instrumental error occurred within Lloyd’s 1835 Irish series, although Lloyd did not realize this until 1837. Lloyd was at that time revisiting his earlier work, so that he might provide Sabine with ‘some postscript on the subject of the Irish lines’ for the cumulative report on the BMS that Sabine was putting together for the BAAS. ‘Let me tell you of a magnetic mishap which has occurred to me’, Lloyd writes to Sabine, ‘which had well-nigh thrown discredit upon all my dip circle observations.’ The problems had arisen when Lloyd had purposefully destroyed the balance in two of his dipping needles, ‘so that they rested nearly in the horizontal position’ and could therefore be used for intensity measurements. The results procured with the instrument after this time seemed to Lloyd so anomalous that he was ‘compelled to reject them altogether’.

In 1837 Lloyd wrote out these observations again on paper and took a ‘good stare at them’. The result of this inspection was ‘the conviction that the varying positions of the needle could not be the result of the Earth’s magnetism & gravity alone & that some disturbing force had intervened’. Lloyd ‘could think of nothing likely to produce these
effects unless magnetism in the dipping apparatus itself—and on putting [this] hypothesis to the test of experiment it was fully verified!' Lloyd found the magnetism 'was greatest in the graduated limb, the very part in which, from its proximity to the needle, it must operate most powerfully'. This was a mortifying realization, as 'it was possible that all [his] observations might have been so much lost labour & that [his] share in the Irish lines only serve to misplace them!' Lloyd had then to consider the 'painful question' of 'how far the numerous results obtained with this instrument were vitiated by this newly-discovered source of error' and, if so, what the probable limits of error were.

To avoid such a calamitous mistake, Lloyd was forced to take apart his dipping apparatus and perform a series of experiments on it to determine the strength of the magnetism in various parts of the instrument. ‘This was a troublesome experiment’, but necessary to the correction of his results. In this moment, we see Lloyd disassembling and reassembling his knowledge of the dip circle anew and through it working out and providing solutions for one of their several possible fallibilities. In the end Lloyd was able to salvage his results and in doing so urged others, particularly Ross, to test for a similar source of error in their own dip circles. Lloyd highlighted the circle that Ross used at Westbourne Green in 1835 as Lloyd believed that some of the ‘discordant results’ Ross had obtained with it might be explained this way and similarly made credible.

More and more in the eighteenth and early nineteenth centuries, the epistemic authority of natural philosophers and the results they published were contingent upon the instruments they used: on their ‘manufacture, usage and institutional association’, as Withers put it. As Naylor has also made clear, the determination of an instrument’s accuracy in the early nineteenth century was to a large extent reliant on the person or persons operating them. Instruments and their users had to undergo a process of trial and negotiation before their credibility as a reliable instrument, and a reliable observer, could be known. This process was at work, in the subject of terrestrial magnetism, during the BMS.

At the beginning of the BMS, Lloyd was a relative novice in the field of geomagnetism, having primarily been concerned with physical optics before this time. Though obviously cognisant of geomagnetism by 1834, he still considered himself ‘the pupil’ to Sabine, his ‘master on these subjects’. A strong dose of modesty undergirds this statement, but it was not without some truth. By 1840, however, Lloyd was known—at least by James David Forbes, Professor of Natural Philosophy at the University of Edinburgh and an expert on heat at this time—as the ‘British Oracle’ on the subject of geomagnetism and expert on the instruments of its study. This was a considerable leap. In part it can be attributed to Lloyd’s theoretical exchanges with Carl Friedrich Gauss during the 1830s. Knowledge of the system of observatories that Gauss and Weber set up in 1834 to accommodate the simultaneous observation of terrestrial magnetism in Europe was formative for Lloyd, their results being of the ‘highest interest’.

However, it was Lloyd’s experience of personal involvement in a magnetic survey that translated this knowledge into practical understanding. Lloyd, writing at the end of his Irish observations, remarked to Sabine that were he to undertake the work again he would adopt the precaution of taking ‘contemporaneous observations ... at some fixed station with a standard needle’ as ‘the only way of eliminating the irregular fluctuations’, which Lloyd felt were ‘very considerable’ and made correct observation difficult. Although he was well aware of Gauss and Weber’s system at this time, he needed to experience working with magnetic instruments and undertake magnetic survey work to understand what was required in successful geomagnetic science. His experience of travelling with,
handling, using, altering and testing magnetic instruments during the course of the BMS was a critical part of Lloyd’s terrestrial magnetic education, one that—alongside his theoretical exchanges with Gauss at this time—enabled him to become such a feted geomagnetic investigator. Lloyd’s experience here, and the educative effect it had for him, is one more indication of the need, called for by Schaffer, to study instruments in their varying states of disrepair.  

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**THE TROUBLE WITH NEEDLES**

Sabine, unlike Lloyd, was a renowned magnetic observer by the time of the BMS, having been attached as a scientific officer to several expeditions from 1818. He had travelled to, and used magnetic instruments in, some of the most extreme climates in the world. However, his ability as a magnetic surveyor and his understanding of the instruments at his disposal were still tested during the exigencies of the BMS.

In the later magnetic crusade, needles and instruments would have to travel thousands of miles to stock observatories and accompany surveyors. But travel on any scale could unduly affect an instrument or a needle’s ability to work correctly. Sabine experienced this almost as soon as his Scottish survey began in 1836. For this series, Sabine planned to use only one needle. It was kept in a case ‘securely and immoveably’ although ‘the soft iron keep which connected its poles’ did permit a certain amount of spring owing to its own elasticity. On disembarking from the steamer that had carried him on the short journey between Helensburgh and the island of Great Cumbrae in the west of Scotland, ‘there being a good deal of sea, the case containing the needle fell from the table to the deck’. The fall occasioned a slight jar to take place: slight, ‘but still sufficient to be audible’. Sabine was immediately suspicious that even such a minor accident might have affected the needle. He was proved right in this after his next set of observations, which showed a ‘greater difference from the Helensburgh results than was likely to be due to the geographical distance between them’. The needle’s natural magnetic degeneration had been accelerated or, as Sabine put it, the needle had been brought ‘at once to its permanent state’. Comparison of results at Dublin at the end of the series was the final confirmation that Sabine needed: it showed Sabine that his needle had indeed suffered a severe and immediate change in its magnetic strength. Dublin was the place that Sabine had established as his base station for the Scottish series before his arrival at Helensburgh and the place to which he had to return to test the veracity of his observations.

Several things can be gleaned from this incident. First, it demonstrates the importance of establishing particular places to stand as base stations. The credibility of results relied on this in the science of terrestrial magnetism because of the degradation of strength experienced by the tools of its trade: needles. These sites came to act as examples of Gieryn’s ‘truth spots’, sites that were understood to ‘lend a special credibility to scientific claims’. During the BMS, base stations were not (yet) observatories but more public, less controlled or controllable spaces: gardens or parks. They were though a fixed point in time and space by which a needle’s state could be assessed and results compared with a standard. Base stations were the means by which observations in different locales could be translated into one common set of results. Field-based observations did not travel from the spot on which they were made to the map, the table, or the page on which they were represented without first being compared and reduced in accordance with observations from a
predetermined base station. These base stations were the necessary space through which instruments, users and their observations travelled and were scrutinized before their trustworthiness and veneer of universality could be applied.

Furthermore, Sabine’s troubles remind us that needles did not always travel well. They were susceptible to even the slightest of jars. Because of the nature of a magnetic needle, their users only came to understand them ‘by degrees’ and over time, as Phillips once remarked to Lloyd.\textsuperscript{78} Phillips meant by this that it took time for an observer to understand what sort of needle he was in possession of: what the strength of its magnetism was, how gradually its strength declined and how well it performed on the move. Such an appreciation could only be arrived at over time and with frequent comparisons of observations made at a particular place.

Understanding that needles and instruments could be altered by travel also draws attention to the particular skills and experience that a geomagnetic observer needed to have so as to observe correctly. An observer needed to know when an instrument was or was not working correctly and what needed to be done to resolve mechanical problems. Lloyd, and to an extent Sabine, gleaned such knowledge during the BMS and during their time spent handling magnetic instruments. This was not information that could be easily absorbed and put into practice through reading instructions alone; nor could it easily be taught in a few days. John Henry Lefroy said as much in his autobiography. Several individuals, including Lefroy, received training from Lloyd in Dublin from 1839, before their assignments as director at one of the colonial or East India Company observatories set up at spots all over the globe.\textsuperscript{79} Lefroy’s destination was St Helena. However, he felt ill-equipped for the task ahead of him, his stay in Dublin being, he believed, ‘not long enough for thorough mastery of our work.’\textsuperscript{80}

Successful observation of terrestrial magnetism, as Professor Charles Daubeny explained in his opening address to the British Association’s 1836 meeting, was a terribly difficult thing to achieve. It required the collection of data ‘from such a variety of isolated points, distant one from the other, both in time and place’ that were ‘dependent for their accuracy upon the occurrence of favourable circumstances’ and demanded from the observer ‘an uncommon union of skill and experience’.\textsuperscript{81} Observers needed practical experience to be educated in such a difficult science. For its participants, the BMS provided such an education.

**Instrument makers and the BMS**

Education in geomagnetism was not available only to the observers of the BMS. Instrument makers also developed their craft at this time. Lloyd’s experience of finding the dip circle he used in Ireland magnetic throughout, rather than only in the needle (see above), had led him to question the workmanship of English instrument makers. He believed that French makers were more careful than English dip circle manufacturers to avoid crafting dip circles liable to exhibit such a ‘vice’.\textsuperscript{82} By 1838, and the end of the BMS, this opinion had changed, and Lloyd was much more assured of English instrument makers’ capabilities.

During the course of the BMS, the instrument maker T. C. Robinson—who designed many of the English dip circles—was afforded the opportunity of developing his art and tweaking his dip circle construction. He did this in conjunction with James Clark Ross and Mr Frodsham in London in 1837.\textsuperscript{83} Although it was the cause of Lloyd’s ire, the most frequent problem with
Robinson’s dip circles was not the presence of magnetism throughout its construction: it was the imperfect curvature of the axle, which meant that the needle could not return to rest correctly.

At Ross’s behest, Robinson had four needles made on the model of continental needles, believed to be of superior construction at that time, by which ‘the axle, instead of being permanently fixed to the needle, was secured in its place merely by strong friction, and could be taken out, turned a portion of a circle on its own centre of rotation, and replaced’. Robinson and Frodsham—whose chronometers were ‘so well known for their excellence’—each made an axle for these needles. After successive trials of the axles in different positions it was determined that ‘Mr Frodsham’s axle proved the best’. However, now Robinson, ‘with this experience’, was able to replace the axles ‘of the other three needles with three which should be the workmanship of his own hands’. The needles were again tested in different positions of the axle; the results, although not completely perfect, showed that significant progress had been made. These trials ‘fully impressed Mr Robinson with the necessity of employing more effectual means for ensuring a true figure to the axles of dipping needles; and in several which he has since made, and which have been carefully examined, he has proved successful’. Results of experiments with these axles in June and July 1838 showed that ‘a great improvement’ had been made in Robinson’s circles.

Dip circles of Robinson’s construction would later take part in the magnetic crusade—on Ross’s Antarctic expedition and at colonial observatories—having been proved credible and trustworthy through trials staged because of the work of the BMS. The ‘discordant results’ that Ross had made in Westbourne Green in 1835, which Lloyd had referred to in his letter to Sabine of 12 October 1837, had been made with a Robinson dip circle. Much more accurate observations at the same site in 1837 and 1838 by Robinson, Ross and Phillips with a Robinson circle were presented by Sabine in his 1838 BAAS Report on the BMS and showed ‘how great an improvement’ had been effected in our English dipping needles since that period. The performance of the Fox-type dip circle—constructed in Falmouth by Thomas Jordan—during the BMS was also praised and said to indicate ‘the great care bestowed on their workmanship’. The performance of the Fox type in Ireland in 1835 is one of the reasons that John Franklin gave his support for it to be taken on an expedition to the Arctic commanded by George Back. Franklin, writing to Fox, expressed how ‘pleased’ he was ‘with the result of your [Fox’s] observations in Ireland’ and with the modifications that Fox had made with the needle. Because of this, Franklin was ‘convinced that the Instrument must be adopted when its comprehensive merits & uses are known’ and trusted that Francis Beaufort, first secretary of the Admiralty, would ‘yield to [his] solicitation and allow it to be taken’.

The BMS was a testing ground on which magnetic instruments, particularly of English origin, made their reputation, a time when instruments such as Robinson’s dip circles were literally and metaphorically deconstructed, to have their reliability re-established anew. Sabine remarks on this again in a letter to John Herschel in July 1839. ‘The dipping needle is much improved of late years’, Sabine assured Herschel, as shown by its performance at Westbourne Green in 1837 and 1838 by those who ‘have cooperated in the deduction of the Isoclinal & Isodynamic lines in Britain’.

SITE-SPECIFIC EXPERIMENTATION

Westbourne Green crops up again and again during the BMS, as does Regent’s Park. Both of these London parks became intimately connected with the science of terrestrial magnetism.
It was known, as Daubeny noted, that the execution of this science was predicated on the collection of data from a variety of different points, ‘distant one from the other, both in time and place’. But it also needed specific sites in which, and through which, the results of its labour could be made credible. It was to these places—Westbourne Green and Regent’s Park—that instruments of questionable reliability were sent, where they were measured and to where they returned at a later date, to confirm their reliability. The physical sciences in the nineteenth century relied more and more upon the credibility of instruments for their authority. In the case of geomagnetism, its mobile instruments first had to spend time in a fixed location. It was then and it was there that instruments could be observed and their comparative reliability assessed.

The trial of Robinson’s dip circles at Westbourne Green is one such example of what could be called the site-specific experimentation of terrestrial magnetic science. Westbourne Green was where anomalous results had first been discovered in James Clark Ross’s series of dip observations in 1835 and was where his dip circle had to return to in 1837 and 1838 for the improvement of Robinson’s construction to be verified. Similarly, when Lloyd informed Ross in March of 1837 that he had developed a new method by which ‘bad’ observations of dip might be made into good ‘true’ ones, Ross proposed that ‘the process should be tried upon his observations with different needles at Westbourne Green which give results so wide apart at present’. In that instance it was not only the needles on trial, but a new method of Lloyd’s creation. The trials could not have happened elsewhere. The venue in which the trials of Ross’s dip circle and the new method of Lloyd’s took place mattered. Westbourne Green was more than a pleasant backdrop for these trials; it was an active part of them. It was the place that allowed Lloyd’s method and Ross’s dip circle to escape place. Following Gieryn’s argument, Westbourne Green acted as a ‘truth-spot’, or ‘the place of provenance’ that enabled the ‘transit of some claims from merely local knowledge to truth believed by many all around’. To prove that Ross’s dip circle or Lloyd’s method could be used ‘elsewhere’ it had first to be proved in a specific ‘somewhere’—in this case at Westbourne Green.

Regent’s Park, northeast of Westbourne Green, was another significant site for British geomagnetism. Sabine had observed there as early as 1821 to ascertain the absolute dip in London and it continued to serve as the location for this determination throughout the 1820s and 1830s. It was also where Sabine had tested Franklin’s instrument and needles before the latter’s Arctic expedition in 1825. Like Westbourne Green, it functioned as an authorized site for the testing of magnetic instruments. As we saw in the introduction to this paper, it was in Regent’s Park, during the BMS, that Sabine proved those needles that accompanied the Gambey dip circle in Canada with John Henry Lefroy to be ‘free from index error at all inclinations’.

In the BMS, Regent’s Park was also returned to again and again, to provide observations from other stations in the British Isles with a standardized comparison. To unite all the observers, who used different instruments and observed at different times of the day and of the year, in one complete survey, such a standard measurement at Regent’s Park was necessary. There was even a specific space within this park in which observations needed to be made: the nursery garden. It was important to adhere to such specifics. Ross had to delay answering Sabine’s request for him to participate in the BMS in July 1834, because he first needed to find out whether he could ‘have access to those parts of the Regent’s Park where you [Sabine] have before made your magnetic observations’. Ross knew the importance of ‘those parts’; he was not completely sure of his role until he could get to the same spot to observe.
In Dublin, terrestrial magnetic observation was undertaken in the Provost’s Garden at Trinity College—specifically at the garden’s centre point.\textsuperscript{100} It was hoped that this spot would be far enough removed from disturbing forces that accurate observations could be made. It was where the absolute determination of the dip and intensity for Dublin—and Ireland as a whole—was made. This garden was therefore used as the standard comparison for other observations made during the Irish survey, just as Regent’s Park had been for the English portion of the BMS. This was not a random choice: Sabine had come and looked at the spot when he and Lloyd were still only talking of making geomagnetic observations together.\textsuperscript{101} Sabine evidently liked the spot, for he gave it his blessing. Lloyd, too, was convinced of the authority of this spot. He assured Sabine that ‘we may place much confidence in the final result’ of his determination of the horizontal intensity in 1835 because it had been made in this space, which was jointly decided to be free of other disturbing influences.\textsuperscript{102}

Through Lloyd and Sabine’s discussions and the belief that the spot in the garden was far enough away from any magnetic material but still close enough to provide ready access, this site became an authorized place in which legitimate geomagnetic observations could occur. It was to this site, ‘our old station in the Provost’s garden’ as Lloyd describes it to Sabine, that Alexander Dallas Bache—the esteemed American physicist and one of the earliest and most influential proponents of geomagnetism in that country—came and observed, to make a comparison of the horizontal force in Philadelphia and in Dublin in late 1836.\textsuperscript{103} When Lloyd was away from Dublin, Sabine made sure that someone else gave him access to the Provost’s Garden to allow him to make observations at the correct spot.\textsuperscript{104} To have made them elsewhere in Dublin would have been pointless. They would not have been comparable; they would not have been as assured of their authority. Terrestrial magnetism was a global phenomenon but its accurate study in the early nineteenth century relied on the observer’s inhabiting such specific spaces. The argument here is the argument that threads its way through many geographies of science: ‘that science depends on the manufacture and management of different spaces . . . to accomplish its objectives and establish its credentials.’\textsuperscript{105}

**CHANGING PLACES**

In July 1837 Lloyd drew up plans for his new magnetic and meteorological observatory in Dublin. He ordered instruments and sketched out how the space would be organized: what would go where, so that one instrument would not disturb another. Significantly, Lloyd told Sabine that the observatory would be built in the Provost’s Garden, ‘somewhere about the spot where you took your last observations’, meaning the spot at which they had been making observations since 1835.\textsuperscript{106} This site had been designated as the only site in which such observations could be made accurately, so it made sense to build the observatory there. It had been constructed as such a legitimate site through the work conducted during the BMS: the hundreds of observations that were made there for the survey as well as through the discussions of Sabine and Lloyd. The observatory was to bind up and wall in the site and wear its skin of legitimacy.\textsuperscript{107}

Regent’s Park did not follow the same path; no geophysical observatory was built to inhabit this space. It existed as a venue for the production of credible geomagnetic science only for a relatively short period. Sabine had observed the dip there as early as 1821 and, between himself and Ross, at many times subsequently. The annual decrease in
the dip over these years in England was computed through the comparison of observations at this place. Sabine calculated the rate of decrease in England between 1821 and 1837 to have been 2.4′, a result that Sabine felt ‘extremely unlikely to be more than a tenth in error’. 108 Sabine was confident in his claim to such a small degree of error. It might have had something to do with Sabine’s own bullish nature: he had always been a suspiciously precise observer and probably wanted to remain such. 109 It certainly does have a lot to do with the refinement of dip instruments by 1837, as has already been noted, and more experience in handling them. However, I argue that such confidence was also entwined with the site at which Sabine observed. Here, like the Provost’s Garden in Dublin, was a spot that had been visited again and again during the 1830s and over the course of the BMS. It was a trusted site; if there were disturbing elements in the park they were known about and could be accounted for. It was a legitimate site for the observation of terrestrial magnetism and it gave Sabine confidence in the results achieved there.

At least it did for a time. Comparable observations made at Kew showed that the dip observed in Regent’s Park was probably slightly higher than it ought to have been. By 1838, Sabine had lost confidence in his Regent’s Park observations because of the Kew results. Although the locality made the 1821 and 1837 dip results more ‘strictly comparable’, Sabine now felt that it was not a site ‘in which we can feel confident that no change may have occurred in regard to magnetic influence’. Sabine concluded that now, in 1838, ‘the Regent’s Park is ... not so eligible a situation ... for magnetic experiments as it was in 1821’. 110 The built environment of London had encroached on the site and Regent’s Park had shown itself to be insufficiently capable of keeping the outside world and its magnetic influences out. 111

Regent’s Park, Westbourne Green and Trinity College were terrestrial magnetic ‘truth-spots’, at least for the majority of the 1820s and 1830s. They were sites which brought certain actors together—in this case observers and instruments—and facilitated certain practices necessary to the construction of trust in this science. 112 It was such ‘situated practical activity’ that allowed authorized knowledge claims to be made in a form that made them credible elsewhere. 113 However, they were also mutable spaces. They were not ‘rigorously guarded’; they existed somewhere between the public and private domains, field and observatory science. 114 In Regent’s Park, the public domain expanded too far and changed it irreversibly as a suitable site for terrestrial magnetic observation. In the Provost’s Garden this was prevented by the erection of physical walls against the outside world. Lloyd’s observatory provided a new, safe, controlled environment for the observation of terrestrial magnetism. Other geomagnetic or, more broadly, geophysical observatories were built at about the same time or slightly later than Lloyd’s in Britain and elsewhere in the world. 115 These observatories, and the practices they engendered, have been the focus of significant recent studies. 116 The BMS reminds us that before such institutions housed regular terrestrial magnetic research, observers had to construct their own, more fluid, more public, places to lend their observations the credibility they required.

**Conclusion**

It is now clear why in 1846 Sabine felt it necessary to remark that the needles for the Gambey dip circle that Lefroy used in Canada had been proved free of error through observations made as part of the BMS in Regent’s Park. Needles, it was known, had to be ‘well trained’ before they could be trusted. 117 It was appropriate that Sabine referred to
the specific place—Regent’s Park—in which this proving took place. Regent’s Park, like Westbourne Green and the Provost’s Garden in Trinity College, Dublin, were the spaces in which the science of terrestrial magnetism was anchored, where credibility could be ascertained and authority lent to the needles or instruments that passed through there. In conjunction with observers, instruments and instrument makers during the BMS, these sites helped to confer legitimacy on the science of terrestrial magnetism in the first half of the nineteenth century. Many of the instruments that travelled and were a key part of the later magnetic crusade—Robinson’s dip circles, Gambey’s dip circles and Fox’s dip circle—were assessed during the course of the BMS and at these specific sites. However, that is not to say that this was the only arena in which this happened: Fox’s circle travelled to Canada during the 1830s as well.

In their 1981 book on the BAAS, Morrell and Thackray rightly point out that before 1839 geomagnetic activity in Britain was primarily concerned with the perfecting of magnetic instruments.118 By foregrounding the instruments as the locus of this investigation, we are now able to appreciate the how and the where of this perfecting. Such domestic surveys were not limited to the study of geomagnetism. Similar pursuits were undertaken in other Earth sciences in the early nineteenth century and within a variety of different places. Instruments here had to travel, had to be used on the move and had to be proved reliable. The BMS is one case study that goes some way to showing that the relationships between instrument and maker, instrument and space, instrument and user all were important to this construction of reliability.

ACKNOWLEDGEMENTS

This paper is part of my ongoing PhD thesis at the University of Glasgow. I therefore thank my supervisors, Simon Naylor and Hayden Lorimer, for all their help and guidance during this process. For this paper specifically I must say an extra thank you to Simon for reading and commenting on earlier versions. To all the staff at the Royal Society Library and Archives, to Alexandra Johnson at the Science Museum for kindly giving me access to the cornucopia which is Blythe House, to Hannah for keeping me on track and to the judges of the Notes and Records Essay Award, I say a big thank you.

NOTES

3 Ibid.


Ibid., p. 524.


For a more detailed explanation of the statical method, see ibid., pp. 18–19 and 21–24.

Humphrey Lloyd to Edward Sabine, 20 November 1833, National Archives (hereafter NA) BJ 3/7/2.


‘Observations of the direction and intensity of the terrestrial magnetic force in Ireland, made by the Rev. Humphrey Lloyd, M.A., FRS, Captain Edward Sabine, FRS, and Captain James Clark Ross, R.N., FRS’, Report of the British Association for the Advancement of Science for 1835, Royal Society (hereafter RS) Tracts: 252/10, 117–162, at p. 117. The delay in beginning a regular series of observations was also due in part to the fragile health of Lloyd at this time and to his other scientific and university commitments. See NA BJ 3/7/5.


Vibrating the needle was the method by which a needle or cylinder was suspended horizontally and made to vibrate; the time in which it completed 300 vibrations—within a predetermined arc—was measured with a chronometer. A good needle would swing for 10 minutes or more before coming to rest, according to Gillian Turner, North pole, south pole: the epic quest to solve the great mystery of Earth’s magnetism (Awa Press, Wellington, 2010), p. 107. The method is most commonly associated with Christopher Hansteen, who standardized the number of vibrations required to 300. It was replaced by Lloyd’s statical method over the course of the 1830s.

Lloyd to Sabine, 7 November 1835, NA BJ 3/7/21.

Sabine, op. cit. (note 22), p. 166.

Edward Sabine to Humphrey Lloyd, 13 July 1836, RS MS/119/17 (vol. 1).

There are several instances of error in accounts of the BMS, notably in Cawood, *op. cit.* (note 2), p. 505, which states that the last part of the BMS was completed and presented to the BAAS in 1836, rather than 1838. Similarly, Sabine’s ODNB entry puts him in Scotland in 1835 instead of 1836 and in England in 1836, where he did not observe to any extent until 1837–38.

Lloyd to Sabine, 3 August 1837, NA BJ 3/7/40.

Sabine, *op. cit.* (note 22), p. 49.


Sabine, *op. cit.* (note 22), pp. 69 and 140.


Morrell, *op. cit.* (note 21).

John Phillips to Edward Sabine, 4 November 1837, RS MS/259/994.


Lloyd to Sabine, 6 May 1835, NA BJ 3/7/19.

Lloyd to Sabine, 24 January 1834, NA BJ 3/7/5.

Sabine to Lloyd, 28 July 1834, RS MS/119/3 (vol. 1).


Sabine, *op. cit.* (note 22), p. 68.

The Science Museum holds 6-inch Robinson dip circles, such as Phillips used in his dip observations in England in 1837 and Ross in Scotland in 1838. Object Number 1876–789.

Sabine, *op. cit.* (note 22), p. 188.

Lloyd to Sabine, 3 August 1837, NA BJ 3/7/40.

Sabine, *op. cit.* (note 22).


Lloyd to Sabine, 12 October 1837, NA BJ 3/7/42.


67 Lloyd, *op. cit.* (note 48).


69 O’Hara, *op. cit.* (note 6).

70 Lloyd to Sabine, 17 November 1835, NA BJ 3/7/22.


72 Schaffer, *op. cit.* (note 46).


74 Sabine, *op. cit.* (note 22), p. 106.

75 Sabine, *op. cit.* (note 27), p. 106.


78 Phillips to Lloyd, 23 July 1837, RS MS/119/32 (vol. 1).


83 It is unclear which of the Frodshams this was, because there were several working in the instrument trade at this time. It is likely to have been either William James Frodsham—who equipped Sabine with chronometers in 1822 and again in 1823 for Sabine’s scientific work on the west coast of Africa and later in Spitzbergen, measuring the shape of the Earth—or his son, Charles Frodsham, who had his own chronometer-making premises in London in the 1830s. See Vaudrey Mercer, *The Frodshams: the story of a family of chronometer makers* (Antiquarian Horological Society, Wadhurst, 1981), pp. 8, 28 and 76–77.

84 All quotations *op. cit.* (note 22), p. 52.


88 Sabine, *op. cit.* (note 22), p. 56.


91 Similarly, Fox’s dip circle travelled to many different places, most notably Canada, before being used during the magnetic crusade.
Sabine to John Herschel, 12 July 1839, RS Herschel Papers HS/15/46.

Dauben, op. cit. (note 81), p. xxiii.


Lloyd to Sabine, 28 March 1837, NA BJ 3/7/35.

For an introduction to the way in which space and place have shaped science, see David Livingstone, Putting science in its place: geographies of scientific knowledge (University of Chicago Press, 2003).


Levere, op. cit. (note 80).

Sabine, op. cit. (note 22), p. 141.

Lloyd to Sabine, 6 May 1835, NA BJ 3/7/19.

Ibid.

Ibid.

Lloyd to Sabine, 10 December 1836, NA BJ 3/7/34.

Sabine to Lloyd, 8 October 1836, RS MS/119/18 (vol. 1).

Finnegan, op. cit. (note 45), p. 383.

Lloyd to Sabine, 26 July 1837, NA BJ 3/7/39.


Sabine to Lloyd, 23 November 1837, RS MS/119/42 (vol. 1).

Charles Babbage was a fierce critic of Sabine’s near-perfect pendulum experiments in the 1820s. See Babbage, Reflections on the decline of science and on some of its causes (R. Clay, London, 1830); see also Katharine Anderson, Predicting the weather: Victorians and the science of meteorology (University of Chicago Press, 2005), pp. 143–145, for further, later, examples of Sabine’s suspiciously precise results.

Sabine, op. cit. (note 22), p. 64.


Robinson, op. cit. (note 107).


Morrell and Thackray, op. cit. (note 12).