# The Role of Networks in Changing Survey Teaching and Practice in Nineteenth Century Britain and the British Empire

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## SUMMARY

The methods available to a land surveyor in the nineteenth century changed very little over the course of the century. Baseline measurement saw the introduction of compensating bars, and their replacement by invar tape, but there were few changes in theodolites, other than the introduction of more compact designs which made them more portable, and improvements in reading systems. However, there were major changes in which methods were considered acceptable, which had an impact on the teaching of the subject.

This paper examines the debates over the most appropriate methods and equipment to use and the impact of that debate on the teaching of surveying in Britain. It will focus on both military and civilian training and the role that the growing Empire had on shaping the subject. It will look on the part played by a number of important surveyors, such as Colby, Sabine and former surveyors from the Survey of India, such as Waugh and Holdich, who did much to reform both teaching and practice.

It will also look at the role played by the Royal Geographical Society which was, for much of the late nineteenth century, the only civil organisation providing training to a generation of officials in the new African colonies. In particular, it will look at the conflict over methods between Markham and Holdich and the roles played by their very different backgrounds in influencing their attitudes towards survey methods. It will examine how these leading players were able to activate their networks of contacts to further their aims of determining the ways in which survey should be practiced and taught.

# The Role of Networks in Changing Survey Teaching and Practice in Nineteenth Century Britain and the British Empire

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## 1. INTRODUCTION

During the course of the 19th century there were few significant technical developments in surveying. With the notable exception of base-line measurements, the techniques and equipment in use at the end of the century were, essentially, those available to surveyors 100 years earlier. Any changes in survey practice in the course of the century were, therefore, more likely to be due to changes in ideas concerning accepted practice, or the imposition of working methods by key individuals who had the power or authority to impose their views. In the case of Britain, another factor, the rise of the British Empire, especially in India and Africa, was to create new demands for mapping that could not be met by the methods of the Ordnance Survey, and led to heated debate of which methods should be used. During this debate, a number of key individuals were able to use their networks to influence the outcome of the debate in favour of their preferred methods. Rather than refer separately to the Surveys of Bengal, Madras and Bombay, the various military and revenue surveys, and the Great Trigonometrical Survey, the term Survey of India will sometimes be used here anachronistically as short-hand for all the surveys which were later combined into the true Survey of India.

## 2. SURVEYING IN 1800

At the start of the 19th century the Ordnance survey was in its infancy and not yet in a position to dictate practice. Surveyors had been recruited to the Survey from a variety of backgrounds, and this was reflected in their preferred working methods. The trigonometrical survey had largely adopted the methods used in the 1780s by Roy for the trigonometrical connection between the Paris and Greenwich observatories. A baseline had been measured on Hounslow Heath (the site of London‘s Heathrow Airport), using glass rods laid end to end on trestles. The angles of the triangles were then observed using Ramsden’s 36 inch theodolite. The Ramsdem theodolite was to remain in service with the Ordnance Survey until 1853.

Topographic survey was carried out using a range of techniques tied to a secondary triangulation scheme. Theodolite and chain traverses were run along road, with offsets being used to capture detail close to the road. Points further from the road were captured by intersection from theodolite positions. The points fixed by the traverse and intersection were then used as a framework within which the rest of the detail could be located by field sketching using a ‘surveyor’s sketching portfolio’ (Seymour, 1980). As the detail survey was mainly being plotted at two inches to one mile (1:31,680) for reduction to one inch to one mile (1:63,360), it was felt that the errors from the controlled sketching were not significant. The results from some larger scale surveys were also incorporated into the first Ordnance Survey map. These seem to have been carried out using more rigorous methods throughout. The instruments used in the sketching included a small four-inch sextant and the azimuth prismatic compass. As Seymour (1980) notes, these methods had hardly changed since the days of Roy's work on the Map of Scotland in the late 1740s and early 1750s.

The one noticeable absence from the list of methods and equipment mention in the Ordnance Survey's accounts of the time, was the plane table. Frome (1840) considered the plane table to be too inconvenient to be considered portable, although Dawson (1803) described its use for detail survey in his 'Course of Instruction in Military Surveying', and most other texts of the time also describe plane table surveys. This apparent aversion to the use of the plane table in the early years of the Ordnance Survey remains largely unexplained. It may have been that many of the private surveyors used in the early days were unfamiliar with the technique at a time when there was little medium or small scale mapping going on in Britain.

Although Dawson had published his instructions in 1803, it seems that it was not used on formal courses, but rather the military surveyors who were responsible for the fieldwork had all undergone training in the field, as there were no established courses in surveying at the time. A school of surveying for training military surveyors was not established until 1833 (Linley, 1973). In marked contrast, a school was established in Bengal in 1783 at the instigation of the Chief Engineer, Henry Watson, with Reuben Barrow as instructor (Phillimore, 1945). It is arguable that the advantage in survey instruction enjoyed by India was to continue throughout the 19$^{th}$ century, and to be joined to a technical advantage in the second half of the century. Charles Close seems to have been of this opinion, when he writes of his reform of survey instruction in the early years of the 20$^{th}$ century in Chatham, to bring it into line with practice in India (Close, 1932).

## 3. STANDARDISING SURVEY PRACTICE IN BRITAIN

Mudge, the first Director of the Ordnance Survey, seems to have been content for his Army or civilian surveyors simply to use the techniques with which they were familiar for topographic survey, with little or no attempt to standardise methods. As Seymour (1980) notes, the 'fair-drawn maps…..were essentially personal productions of the individual surveyors; there are considerable variations in style, in colouring and in the use of symbols'. Frome (1839) also describes the detail as being surveyed 'partly be measurement and partly by sketching'. In trying to build up the Ordnance Survey, and to supervise its operations over a wide area, it is probable that Mudge never had the leisure to step back attempt a through review of its operations and methods. His successor, Colby, when faced with the task of surveying Ireland, realised that a much more systematic and uniform approach would be necessary. Colby's reforms of survey methods in the 1820s were to inform Ordnance Survey practice for the rest of the 19$^{th}$ century, and strongly influence those of the first half of the 20$^{th}$ century. They were also to put the Ordnance Survey at variance with those in Continental Europe and the British Empire.

As Seymour (1980) notes, Colby was unhappy about the quality of Ordnance survey maps even before he took over as its Director. Criticism of the quality had also come from the Master General of the Board of Ordnance, the Duke of Wellington. Most of the problems had their origins in the use of large numbers of poorly trained assistants and an over-reliance on sketching. A significant factor may also have been the system of payment, where surveyors were paid for each square mile mapped, in addition to a low basic salary. Colby recognised that by paying a higher basic salary, and making the payment for work carried out dependent on both quality and quantity, the result should be more accurate surveys.

The reform of survey practice introduced by Colby, what was known as 'Colby's System' (Close, 1926), was based on a rigid division of labour. In Colby's System, the field surveyor who carried out a chain survey did not plot the results of that survey. The man responsible for plotting the main lines of the survey was not involved in plotting any detail. Similarly, the observers of trigonometrical observations were not involved in the computation of those observations. As Close (1926) noted the observers 'worked quite blindly as to the results of their work'. In this system the surveying staff became expert in their own part of the operation, but there was an almost complete lack of flexibility. While this approach could be well suited to the 'large-scale survey of a civilised country; it would be quite unsuited to the topographical surveying of a tropical dependency' (Close, 1926).

Colby had the opportunity to develop his system during the Survey of Ireland between 1826 and 1839. The survey in Ireland was to be published at 1:10,560, while the survey in England and Wales had been intended for publication of maps at a scale of 1:63,360. This increase in publication scale clearly had implications for the standard of accuracy that the surveyors would be required to achieve. Colby laid down firm rules about how the survey was to be conducted. As Close (1926) notes 'the detail was surveyed almost entirely by chaining; traversing was not generally allowed'. The kind of sketching that had been used under Mudge had no place in Colby's system. Every field boundary was chained, together with all important features, even in towns chaining was used to survey all detail. The only features that it was permitted to survey by traverse were winding streams in steep valleys. Subsequently the rules were relaxed somewhat in upland areas away from cultivation. In urban areas the prohibition on traversing was to remain in force until 1897 (Close, 1926). The practical consequence of Colby's system was that there was no need for surveyors trained in all aspects of survey work. Inevitably, this will have had negative consequences for survey instruction more generally.

## 4. TRAINING OF OFFICERS

While Colby's reforms met the needs of the Ordnance Survey and its 1:10,560 survey work, they did not meet the needs of the Army more generally, where officers were called upon to carry out a wide range of survey duties. One problem was that, outside of the Ordnance Survey, there was no body of officers for whom survey work was their main duty. In consequence survey formed only a small part of a Royal Engineer's practical training. As a result 'the practical education of the Academy is far behind its theoretical instruction' (Sabine, 1839). As he was responsible for the Magnetic Office, Edward Sabine was in a unique position to be aware of the deficiencies of practical survey instruction. Sabine's duties included liaising with foreign organisations involved in measuring terrestrial magnetism, and in equipping and training British personnel who were to carry out observations as part of expeditions around the World. This put Sabine at the centre of a huge intellectual network stretching from the Americas to the East of Russia, and down to India and Australasia. Amongst his many contacts were Gauss, himself a notable surveyor, Herschel, Wheatstone, Beaufort, Walker (Director of the Survey of India), Airy, and the directors of foreign observatories, such as Kreil in Prague, Lamont in Munich and Mahlmann in Berlin. In addition Sabine was the 'Foreign Secretary' (the person who dealt with foreign language correspondents) for the Royal Society, the Royal Geographical Society and the British Association for the Advancement of Science. This put Sabine in a very powerful position, and someone who could expect to have his advice respected.

So what did Sabine recommend? The list is interesting both for what it contained, and for what it omitted. He recommended that cadets should be instructed in the use of:

1. All instruments required in geodesical operations

2. The transit, especially in its application to the determination of differences in longitude and latitude

3. Repeating circles and repeating theodolites

4. Reflecting circles and sextants

5. Barometer, especially in their application to the measurement of height

6. Magnetical instruments

What is interesting is that while the equipment listed would have enabled surveyors to locate their position on the Earth, the instruments would not have lent themselves to any detailed mapping of its surface. The plane table had, by this time, become no more than a historical curiosity for British surveyors, and a time when the Survey of India was producing some of its finest practitioners. This may, of course, reflected the interests of Sabine, whose work on geomagnetics required the accurate location of individual magnetic observations, not detailed mapping of areas.

The use of the sextant is of interest, as was to become, in the mind of Close, symbolic of all that was wrong about survey instruction in Britain in the 19$^{th}$ century. To most surveyors trained in the 20$^{th}$ century the sextant was an instrument used by maritime navigators. Very few will have been trained in its use, and almost certainly not as a piece of survey equipment. It therefore comes as a surprise to realise that, to 19$^{th}$ century British military surveyors, the sextant was a standard piece of surveying equipment. Close (1932) describes how, as a cadet in the School of Military Engineering, he had to practice taking observations with a sextant and an artificial horizon (usually a bowl of mercury). One of Close's first acts when appointed Instructor in Surveying at the School, was to abolish instruction in its use. It receives no mention in the *Text Book of Topographical and Geographical Surveying*, which Close wrote in 1905, and as the *Text Book* was to become the standard text for the instruction of generations of British military and civilian government surveyors, it is no accident that all memory of the sextant's use has been forgotten.

## 5. THE LACK OF A PROFESSIONAL BODY OF SURVEYORS

While Sabine was at the centre of a large network of scientist, mainly astronomers, apart from Gauss in Germany, and Lefroy in Canada, they were not men with a background or interest in surveying. While the work of the Ordnance Survey was regarded as important for national security and management, it did not enjoy the high reputation that the Survey of India was to enjoy. Although even with the Survey of India, it is noteworthy that the importance of the work of Everest on the Great Arc was recognised in France before it was recognised in Britain. A major factor in the relatively poor quality of British military survey training in the 19$^{th}$ century was the lack of a profession body of surveyors. Where in most other European military surveys an officer could be expected to spend his entire career within the survey department, in Britain survey was just one of the roles that a Royal Engineer officer would be expected to taken on. The Ordnance Survey was not seen as being a career path. A few officers, such as Clarke, did spend many years in the Ordnance Survey, but in Clarke's case that seems to have been due to an oversight on the part of the War Office. The effect of this lack of a coherent body of surveyors was to prevent the development of the kind of professional network that could be mobilised to affect changes in practice, and to influence policy.

Sir Charles Wilson, who was to be Director-General of The Ordnance Survey from 1886 until 1893, provides a good illustration of the career path that a Royal Engineer could be expected to follow. After instruction in the School of Military Engineering Chatham, Wilson was sent to Gosport in 1857 and employed on the town's defences. In February 1858 he was made secretary of the boundary commission which delimited the United States/Canadian boundary from Lake in the Woods to the Pacific Ocean, not returning to England until July 1862. After writing the report on the delimitation, he spent 18 months on the defences of the Thames and Medway. Wilson then volunteered to take part in the Ordnance Survey of Jerusalem. While in Palestine, Wilson also ran a line of levels to determine the height of the Dead Sea. From October 1866, Wilson spent two years with the Ordnance Survey in Scotland, including working on a Parliamentary Boundary Commission. From October 1868 to May 1869, Wilson was in Sinai conducting a survey, which was followed by nearly a year in the Ordnance Survey as an executive officer.

In 1870 Wilson was appointed the first Director of the Topographical Department of the War Office. In 1873 the Department became a branch of the Intelligence Department, with Wilson becoming an Assistant Quartermaster General. At that time, the Topographical Department was not engaged in original survey work, its role was to compile maps from existing source material to meet the demands of the War Office or the Government. In 1876, Wilson put in charge of the Ordnance Survey of Ireland, and in 1878 he was sent as British Commissioner on the demarcation of the Serbian frontier. This was followed in 1879 by an appointment as British Military-Consul General in Anatolia. As part of his duties, Wilson was involved in the reform of the Turkish Gendarmerie in the aftermath of the Russo-Turkish War of 1877.

In 1882 Wilson joined the British military force in Egypt, before return to the Ordnance Survey of Ireland in April 1883. In September 1884 he returned to Egypt to join Wolseley's Nile expedition to relieve Khartoum as Chief of the Intelligence Department. In July 1885, Wilson was back in Ireland, being appointed Director-General of the Ordnance Survey in November 1886.

By contrast, an officer, such as Andrew Waugh, posted to the Great Trigonometrical Survey of India in 1832 could expect to spend his entire career with the Survey, retiring as Director of the Survey in 1862. This continuity of service in a survey department encouraged the kind of specialism and professionalism that was found in survey officers in European survey departments. A Royal Engineer in Britain had to remain a generalist, and, this was to the detriment of survey training and practice in Britain.

## 6. STAGNATION

Close (1925), in a paper on Colonel Clarke, noted that ‘for a long period the history of the Ordnance Survey is from a scientific point of view but a melancholy recital of mediocrity’. Close dated that decline to the resignation of Clarke in 1881, but it could be argued that the real scientific work had been carried out long before 1881, and had culminated in the publication of Clarke’s work on the calculation of the triangulation network (Clarke, 1858). The practical work that underpinned Clarke’s mathematical adjustments had been carried out by Roy, Mudge and Colby by 1841, and strengthened by Yolland in the 1840s and early 1850s. Thereafter, the work carried out in Britain was concentrated on detail survey work for large-scale mapping. This was largely limited to 3$^{rd}$ order triangulation as a basis for the chain surveys. This was not intellectually demanding work, it just required patience and precision in the observations.

Very occasionally, more challenging work came along that required surveyors who had mastered higher level survey observations and computations. One such was the boundary survey along the United States/Canada border on which Wilson participated. However, these opportunities were few, and far between.

At the same time, demands on non-military surveyors hardly encouraged practitioners to take a deep interest in the development of the discipline. In part, this was a result of the decision to increase the scales of mapping carried out by the Ordnance Survey to 1:10,560, and later to 1:2,500. With such large scale mapping being made available by a government survey department there was little demand for survey work from land owners. The British cadastral system also worked to the detriment of professional surveyors. Even after registration of title was introduced, it was made voluntary, and, due to the cost, was largely ignored. When, at last, registration was made selectively compulsory, it was only on transfer, and based on ‘general boundaries’. In other words, the definition of the parcel, or parcels being registered was based upon written descriptions, not upon surveyed boundaries. With their exclusion from the process of land registration, it was difficult for surveyors to acquire true professional status. This lack of professional status was reflected by in a lack in profession training. In 1882 Clements Markham published a paper on the current state of survey training available in Britain. He listed some 38 institutions which offered training, together with their backgrounds and, in some cases, their instructors. However, all of the institutions listed were primarily schools of navigation for potential Merchant or Royal Naval officers. None delivered a syllabus that would have been recognised as suitable for someone wishing to follow a career in land surveying.

The lack of professional status and training was also reflected by a lack of survey related papers in the journals of the day. The Proceedings of the Royal Geographical Society had become the main outlet for survey related publications for want of other outlets. However, in the 1860s almost no papers on survey were published, except one by Buchan on barometric heighting (Buchan, 1868). In the 1870s the Proceedings published two papers, one by Wilson on his Surveys in Palestine and Sinai (Wilson, 1873), and one by Warren 'On the reconnaissance of a new or partially known country' (Warren, 1875). The Warren paper provides basic instruction in survey techniques and equipment based on his survey work in Palestine. The Warren paper is particularly significant in that, at the time, it was deemed useful to publish what was a fairly basic account of surveying. The assumption being, that this would be unfamiliar to readers of the journal. What also makes these contributions to the journal interesting was that, at about the same time, Watson was using Royal Geographical Society equipment to carry out a survey on the Upper Nile, and was to need the services of the Society in getting his observations computed (Watson, 1876). It seems clear, from Watson's experience, that Royal Engineer officers who served in Britain were only trained in plane survey and seemed not to know how to carry out and compute astronomical and geodetic observations. At the same date, officers serving in India would have been expected to carry out such work as part of their normal duties.

## 7. SURVEY TRAINING AND PRACTICE IN INDIA

In contrast to the stagnation of survey instruction and practice in Britain, the situation in India was much better. The firm foundations established by Watson were to be built on and developed during the 19th century. In part, this was necessary due to the lack of adequate training received by the surveyors before they reached India. Everest complained in 1830 that the training in Addiscombe, the East India Company's military college, was purely elementary and lacking in an adequate practical component (Phillimore, 1958, p.351). The solution adopted was a kind of apprenticeship, where a newly arrived officer would be attached to a field party led by an experienced officer. Another factor that had an impact on survey instruction after 1830 was the employment of Indians on the Survey. There could be no expectation that the Indian staff would have received prior instruction in survey, so suitable training would have to be provided. Arguably, however, the key factor that kept the Survey of India from the decline noted in Britain, was the decision of Everest not to follow Colby's System, and to expect surveyors to be competent in all areas of their work. Everest will have seen Colby's System in operation when he visited the Ordnance Survey in Ireland, but he must have found the approach too rigid for conditions in India.

In 1851 the *Manual of Surveying for India, detailing the mode of operations in the Revenue Survey of Bengal* was compiled by Smyth and Thuillier. This work, which went into a third edition in 1875, as the *Manual of Surveying for India, detailing the mode of operations in the Trigonometrical, Topographical and Revenue Surveys of India,* became the standard guide to the work of the Survey of India until superseded in the early 20th century by the *Survey of India Handbook of Topography* (Gordon, 1911). The third edition included an appendix, written by Andrew Waugh, on 'Instructions for Topographical Surveying' and a memorandum on the use of the plane table. It was inconceivable at that time that such a work would have been published in Britain, for the simple reason that no one would have seen a need for it. However, in the last quarter of the century the changing political situation was to start a re-evaluation of accepted method and a realisation the metropolitan power had much to learn from the experience of the Indian surveys. The fact that the Indian surveyors were able to affect changes in Britain is largely down to their ability to act as a network, supporting each other and influencing policy.

## 8. NEW DEMANDS

Following the 'Scramble for Africa', Britain was confronted by the problem of having theoretical control over large tracts of territory in a continent which was almost completely devoid of mapping. If these newly acquired territories were to be controlled effectively, they would need to be mapped. Of course, Britain was not alone in facing the problem of unmapped territory. France had, at least, made a start in North Africa, with mapping in Algeria, but most its territories were completely unmapped, as were those of Belgium, Germany and Italy. Even the old colonies of Spain and Portugal were virtually unmapped (Bartholomew, 1890). Of the 11.5 million square miles of Africa, Bartholomew estimated that detail survey covered only 200,000 square miles, topographic mapping some 440,00 square miles, detailed route surveys about 2.3 million square miles, general mapping about 4.8 million square miles, much of which he judged approximate, and some 3.8 million square miles was unexplored by Europeans.

The acquisition of extensive colonies in Africa in the 1870s sparked a debate in Britain about how best to meet the mapping needs of these new colonies. At the forefront of this debate was the Royal Geographical Society, which had not previously shown a great deal of interest in such matters (Collier and Inkpen, 2003). While the journal of the society had periodically reported on the progress of the Survey of India and the exploits of the Pundits, it had no formal role in surveying and mapping. In 1854 Captain Fitz Roy and Henry Raper had issued a report on surveying, which was published by the RGS as a pamphlet entitled *Hints to Travellers*. Additional material for the pamphlet was supplied by Admirals Smyth and Beechey, Colonel Sykes and Francis Galton. These were all leading figures within the RGS at the time that *Hints to Travellers* was published, and very influential in determining the policy of the Society. What is interesting to note that while four were naval officers with long-standing interests in marine charting and navigation, only one was an army officer, and his chief interests were meteorology and statistics. It is therefore not surprising that there was a bias towards navigational techniques in the pamphlet, at the expense of the more systematic survey methods which were more appropriate to map making on land.

Two further editions of the *Hints to Travellers* were published in the Proceedings of the Royal Geographical Society. The third edition, which appeared in 1871, was written by Back, Collinson and Galton, two naval officers and a scientist. It also contained a section on the use of the theodolite and altazimuth instruments by Colonel Walker, Superintendent of the Great Trigonometrical Survey of India. However, the techniques described were those suitable for fixing the observers position in the field, not for the mapping of extensive areas. That Walker seems to have been content to write just on position fixing seems rather strange given his experience in India. However, this was the first time an Indian surveyor was to be involved in advising on survey work, and it may simply represent all that the main authors asked him to supply. Future inputs from Indian surveyors were to be much more significant.

In 1879, Markham made a proposal to the Council of the Royal Geographical Society that it 'should organise a plan for the instruction of geographical students and others about to visit unknown or little known countries, so as to train them as scientific observer' (Markham, 1879). The Council accepted Markham's proposal and a course of training in surveying was established under John Coles, the Map Curator and former naval officer. Markham's course, like *Hints,* was not concerned with systematic mapping, being designed to permit the determination of position using methods best suited to navigation at sea. Despite its limitations, the Royal Geographical Society's course was to have a n almost complete monopoly in the training of non-military personnel who need to be able to execute survey work as part of their duties. The course was even taken by Army officers who had not learnt enough surveying as part of their training.

Until the 1880s there were relatively few survey officers serving on the council of the Royal Geographical Society, which was still largely naval dominated. Things started to change in 1878 with the election of Lefroy, an Artilleryman, but with an interest in practical astronomy and geomagnetism. In 1880, he was joined by H.E.L. Thuillier (uncle of H.R. Thuillier), and Godwin-Austen. Over the next few years Cooke, Warren and Walker joined the Council. In the 1890s the influence of surveyors was further strengthened by the elections of Darwin (son of Charles), Watson, Talbot, H.R. Thuillier, Everett and Holdich. Of these, Holdich's influence was by far the most profound, but he would have been much less successful without the support of the other surveyors.

The first serious attempt to address both the kinds of surveys to be conducted, and the kind of personnel needed to conduct those surveys, was that of Holdich (1891). In that paper Holdich recommended the adoption of the "Indian System" for use in Africa. This would involve triangulation by Europeans followed by a 'graphic system of mapping ……by means of chiefly native labour' (Holdich, 1891). He was quite clear that 'native labour' had a major role top play in the mapping of Africa 'indeed, I may express my conviction that it is quite hopeless to attempt to deal with the vast project we are considering on any other basis. Native labour must be the mainstay of the whole project'. He even went further by stating that even 'were European labour available, I should certainly prefer the native in native territory' (Holdich, 1891).

Problems with a lack of mapping had also been identified as a result of the need to carry out boundary surveys between the newly acquired British territories, and those of the other colonial powers. As Holdich (1891) noted, previously Britain had rounded "off her territories with great natural barriers of sea and mountain". All this had now changed, as the British territories in Africa had land boundaries totalling approximately 8,500 miles. As noted above, British surveyors had been involved in the United States/Canadian boundary surveys, and in some boundary demarcations in the Balkans. The former had mainly required the astronomical determination of the $49^{th}$ parallel (Anderson, 1876), while the latter mainly depended on the correct demarcation of watersheds**.** In both cases, this involved working in areas that were largely explored and inhabited. In Africa, the boundary demarcation parties often had to carry out surveys in areas that had were largely unexplored by Europeans and were frequently either sparsely inhabited or uninhabited. This meant that the surveyors had to cope with severe logistical problems, as well as with the difficulties of demarcations where the boundary had been delimited in the absence of any real knowledge of what existed on the ground (Collier, 2005).

At a meeting of the British Association in 1900, Holdich returned to the issue of mapping in Africa (Holdich, 1901), again to stress the need for locally recruited and trained labour to carry out the bulk of the work. The first colony in which Holdich's ideas was put into practice on a significant scale was the Gold Coast. It was no accident that the Gold Coast was also the first colony to be provided with complete medium scale topographic map coverage. Holdich managed to force through reforms of the Royal Geographical Society's course, in the face of fierce resistance from Markham, to ensure that its graduates would be competent to meet the real needs of the new colonies (Collier and Inkpen, 2003).

In practice, however, the most significant event for the reform of British survey training and practice was the Second South African War. The lack of existing mapping, and the inadequacies of the techniques used by British trained surveyors to meet the mapping needs were cruelly exposed. It was surveyors from India, like Close, who demonstrated what Indian techniques could produce, leading their adoption in the field. The survey of the Orange River Colony was the first systematic application of Indian techniques to mapping in Africa (an Indian surveyor had earlier been employed to conduct a plane table survey along the line of the British/German East African boundary).

On his return to Britain, Close was appointed Instructor in Surveying at the School of Military Engineering, where he reformed instruction along Indian lines. He also wrote the *Text Book of Topographical and Geographical Surveying* (1905), which was to serve as the standard work for the first half of the 20$^{th}$ century. Close was also to play an important role in the Colonial Survey Committee, which ensured that the newly established colonial survey departments adhered to the Indian model (Collier, 2006).

## 9. CONCLUSIONS

From being at the cutting edge of surveying practice in the early years of the 19$^{th}$ century, there was a steady decline in its originality under the 'dead hand' of the Colby System, and the lack of professional status of surveyors. In India, by contrast, surveyors belonged to a professional body dedicated to the technical advance of their subject. It was only when returning Indian surveyors started to play a role in scientific life in Britain that the necessary changes in teaching and practice were affected that were to fit British surveyors for work in the 20$^{th}$ century. In large part, their success was owed to their ability to act as a coherent group, something that had previously been lacking in British surveying.

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The author started his working life at the Directorate of Overseas Surveys, before taking a degree in Surveying and Geography from the University of Newcastle upon Tyne and a PhD at the University of Aston. Since 1981 he has been on the staff at the University of Portsmouth teaching courses in the mapping sciences. Since the early 1990s his research interests have been mainly focused on the history of survey and mapping. He has been a member of the British Cartographic Society since 1969, the Remote Sensing and

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1994 Innovative military mapping using aerial photography in the First world War: Sinai, Palestine and Mesopotamia 1914-1919, *Cartographic Journal* **31** 100-104.

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