Scientia Canadensis

Volume 39
Number/Numéro 1
2016/17

Canadian Journal of the History of Science, Technology, and Medicine
Revue canadienne d'histoire des sciences, des techniques et de la médecine

Editorial Board / Comité de rédaction

Mailing Address
c/o Canada Science and Technology Museums Corp.
P.O. Box 9724, Station T
Ottawa, ON K1G 5A3
CANADA

Editor's Note

The present issue represents the diversity and depth of the CSTHA community. In his article on magnetic surveys of North America, Matthew Goodman has combined instrument studies and geography to provide a new perspective on the work of John Henry Lefroy. Shifting from land to oceans, Michael Murphy has detailed the history of key technologies developed at the Bedford Institute of Oceanography from its earliest days in the 1960s to the 1980s. In his article, Brendan Cull has brought together the history of photography, botany and international expositions, based on his prize-winning talk at the 2015 CSTHA conference. Philip Enros has provided a historical/critical look at the development of our discipline in Canada with an article about the early years at the Institute for the History and Philosophy of Science and Technology (IHPST), 50 years after its founding in 1967. In addition, we are very pleased to offer thirteen book reviews demonstrating a wide range of studies of Canadian topics in the history of science and technology. Many thanks to our reviewers and the editorial team for bringing this issue together.

Ce numéro représente bien la diversité et la profondeur de la communauté de l'AHSTC. Dans son article sur les relevés magnétiques du territoire nord-américain, Matthew Goodman combine l'histoire des instruments scientifiques et techniques et la géographie pour proposer une perspective nouvelle sur les travaux de John Henry Lefroy. De la terre aux océans, Michael Murphy détaille l'histoire du développement de technologies clés à l'Institut océanographique de Bedford, de ses débuts dans les années 1960 jusqu'aux années 1980. Dans son article, Brendan Cull réunit l'histoire de la photographie, de la botanique et des expositions universelles, en s'appuyant sur les résultats de sa présentation primée à la conférence de l'AHSTC en 2015. Philip Enros propose quant à lui une histoire critique de l'Institut pour l'histoire et la philosophie des sciences et des technologies de Toronto, 50 ans après sa fondation en 1967. Ce numéro est complété par la publication de treize comptes rendus d'ouvrages portant sur des aspects variés de l'histoire des sciences et des technologies au Canada. Nous remercions chaleureusement les évaluateurs et l'équipe éditoriale pour avoir permis la réalisation de ce numéro.

On the cover / en couverture: *Detail, Paul Kane, Canadian, 1810-1871. Scene in the Northwest - Portrait, c. 1845-1846. Oil on canvas. Overall: 55.5 x 76 cm (21 7/8 x 29 15/16 in.). The Thomson Collection © Art Gallery of Ontario, 2009/507. Image © Art Gallery of Ontario. Détail, Paul Kane, Canadien, 1810-1871. Scene in the Northwest - Portrait, c. 1845-1846. Huile sur canevas. Dimensions: 55.5 x 76 cm (21 7/8 x 29 15/16 po.).*

Scientia Canadensis

Volume 39, Number/Numéro 1 (2016-2017)

Articles

Book Reviews / Comptes rendus

Guidelines for Authors

Scientia Canadensis is a peer-reviewed journal and invites submissions of original articles on the history of science, technology, and medicine. Please submit articles as Microsoft Word files to editor David Pantalony, dpantalony@techno-science.ca via email. Article manuscripts should not be currently under evaluation for publication by another journal.

Manuscripts articles may be written in English or French, and should not exceed 10,000 words. Please consult with the editor regarding word-limits for other types of content such as research notes, forums or roundtables. All manuscripts should contain the following elements:

- Title
- Author name(s)
- Author email address(es)
- Abstract (no more than 150 words)
- Keywords that broadly identify the article's subject
- Author bio appended to the end of the article

Please use Times Roman 12-point text and double-space the text using a page set to Word's "normal" margins. Graphics, tables, and figures are welcome: please note their recommended position in the body of the text (e.g. "Insert figure 1 here"), but please do not insert images into the manuscript. Save and attach all images as separate files. Images may be saved as JPG files. Line drawings or other vector-type images should be saved and submitted as EPS files. Please do not submit images in or as a Word file.

References should be formatted as consecutively numbered endnotes. Endnotes must be complete and uniform according to the *Chicago Manual of Style*. Book: Henry M. Tory, ed., *A History of Science in Canada* (Toronto: Ryerson, 1939), 5. Book chapter: Trevor Levere, "What is Canadian about Science in Canadian History?" in *Science, Technology, and Canadian History*, eds. R.A. Jarrell and N.R. Ball (Waterloo: Wilfrid Laurier Press, 1980), 14-22. Journal Article: Raymond Duchesne, "Historiographie des sciences et des techniques au Canada," *Revue d'histoire de l'Amérique française* 35, 2 (1981): 193-215. Subsequent reference: Tory, 3. Using two or more works by the same author: Tory, *A History of Science*, 3. If the reference remains the same but the page changes: Ibid., 4.

Directives aux auteurs

Scientia Canadensis est une revue qui publie des articles inédits évalués par les pairs ayant pour sujet l'histoire des sciences, des technologies et de la médecine. Les documents électroniques doivent être soumis en format Microsoft Word au rédacteur en chef David Pantalony, à l'adresse dpantalony@techno-science.ca. Les manuscrits ne doivent pas être en cours d'évaluation par une autre revue. Ils peuvent être rédigés en français ou en anglais et ne devraient pas excéder 10.000 mots. La longueur d'autres types de contenus, tels que les notes de recherches, les forums ou les tables rondes, sont déterminés après consultation avec le rédacteur en chef. Tous les manuscrits devraient contenir les éléments suivants :

- Un titre
- Les noms des auteurs
- Les adresses électroniques des auteurs
- Un résumé de l'article n'excédant pas 150 mots
- Une liste de mots clés identifiant le sujet de l'article
- Une courte biographie des auteurs annexée à l'article

Veuillez utiliser le format Times new Roman 12 à interligne double, en appliquant des marges de type « Normal » dans Word. Graphiques, tableaux et figures doivent être annoncés dans le texte (ex: « Insérer figure 1 ici »), mais sauvegardés dans des documents à part. Les images doivent être soumises séparément en format JPG. Les images de type vectoriel peuvent être soumises en format EPS. Dans les deux cas, elles ne doivent pas être insérées dans un fichier Word avant d'être soumises.

Les notes de bas de page doivent être numérotées consécutivement. Les références bibliographiques dans les notes de bas page doivent être complètes et uniformes, suivant les directives du *Chicago Manual of Style*. Livre : Henry M. Tory, ed., *A History of Science in Canada* (Toronto: Ryerson, 1939), 5. Chapitre de livre : Trevor Levere, « What is Canadian about Science in Canadian History? » in *Science, Technology, and Canadian History*, eds. R.A. Jarrell and N.R. Ball (Waterloo: Wilfrid Laurier Press, 1980), 14-22. Article de revue : Raymond Duchesne, « Historiographie des sciences et des techniques au Canada », *Revue d'histoire de l'Amérique française* 35, 2 (1981) : 193-215. Répétition d'une référence: Tory, 3. Citation de deux ou plusieurs ouvrages d'un auteur: Tory, *A History of Science*, 3. Si la référence demeure mais que la page change : Ibid., 4.

Scientific Instruments on the move in the North American Magnetic Survey, 1843–1844

Matthew Goodman

Abstract: *In 1843-4, John Henry Lefroy conducted a geomagnetic survey of Hudson's Bay Company territory in British North America. Lefroy and his instruments, guided by French Canadian voyageurs and Indigenous guides moved within the HBC network of forts and outposts. This paper complements and extends historical accounts of Lefroy's survey by examining how, and how well, Lefroy's instruments moved on this extensive survey. The recent material turn in the history and historical geography of science provides the framework for a closer reading of the spatial biographies of several of Lefroy's instruments. Focusing on their varying states of disrepair—and solutions to repair them—this paper not only recaptures the materiality of these instruments, but adds to our understanding of repair and maintenance in the history of survey science. Looking at instruments as objects to be carried and managed also helps illuminate the overlooked role of Indigenous and French Canadian voyageurs in scientific expeditions.*

Résumé : *En 1843-44, John Henry Lefroy a effectué une inspection du territoire de la Compagnie de la Baie d'Hudson (CBH) dans l'Amérique du Nord britannique. Lefroy et ses instruments se sont installés dans un réseau de forts et avant-postes de la CBH, guidé par de voyageurs canadiens français et de guides autochtones. Cet article complète et étend les récits historiques de l'exploration de Lefroy et examine en particulier comment les instruments de Lefroy ont été déplacés lors de cette enquête géomagnétique. Le tournant matériel récent dans l'histoire et la géographie historique des sciences fournit le cadre d'une lecture plus approfondie des biographies spatiales des plusieurs instruments de Lefroy. Mettant l'accent sur les instruments sur différents états de délabrement permet non seulement de ressaisir la matérialité de ces instruments, mais aussi de contribuer une meilleure compréhension de la réparation et de l'entretien dans l'histoire des sciences de l'exploration. Finalement, cet article contribue à éclairer le rôle souvent négligé des voyageurs autochtones et canadiens-français dans ces expéditions scientifiques.*

Keywords: John Henry Lefroy, magnetic crusade, scientific instruments, repair, geobiography

JOHN HENRY LEFROY IS WELL KNOWN to Canadian historians and historians of science alike (**Figure 1**). His role in helping to foster a scientific community in Canada during the time of his directorship of the Toronto Magnetic and Meteorological Observatory (1842-43, 1844-1853) has been remarked on in several different historical accounts, most notably those by Suzanne Zeller and Gregory Good. Zeller has also positioned Lefroy as one of a number of individuals of the early nineteenth century who can be described as "Humboldtian," or having

Matthew Goodman, "Scientific Instruments on the move in the North American Magnetic Survey, 1843-1844" *Scientia Canadensis* 39, 1 (2016-17): 1-26.

Figure 1*. Paul Kane, Canadian, 1810-1871. Scene in the Northwest - Portrait, c. 1845-1846. Oil on canvas. Overall: 55.5 x 76 cm (21 7/8 x 29 15/16 in.). The Thomson Collection © Art Gallery of Ontario, 2009/507. Image © Art Gallery of Ontario.*

operated within a Humboldtian network and paradigm, in their approach to doing science.[1] Zeller has positioned Lefroy in such a way largely because of his involvement in a magnetic survey of parts of what was British North America, Rupert's Land and the Northwest Territories, today collectively known as Canada, between May 1843 and November 1844. This survey was a constituent part of a wider geomagnetic project, known as the magnetic crusade—which was coordinated at and by Edward Sabine's magnetic department at Woolwich, England and Humphrey Lloyd's Dublin Observatory, Ireland. The magnetic crusade was in operation from 1839 to roughly 1854 and was made up by a combination of observation at fixed magnetic and meteorological observatories—both within and beyond the boundaries of the British Empire from Europe to South Africa to Australia—and by observation on a number of mobile surveys, of which Lefroy's was one.[2] The magnetic crusade was the most extensive and ambitious project of the early nineteenth century, a "combination such as the scientific world never before saw" according to Lloyd, who similarly expected that the results of such an enterprise would "correspond with the gigantic magnitude of the machinery."[3]

The most famous of the magnetic crusade's mobile surveys was arguably that of the expedition led by James Clark Ross to South Polar waters between

1839 and 1843. Lefroy's survey was in some respects an Arctic counterpoint to Ross's Antarctic voyage but it was also much more important than that statement suggests. Lefroy's survey was the only overland survey of the magnetic crusade sanctioned by the British government and the Board of Ordnance—two institutions critical to the organisation of the entire crusade—and it was motivated by the surprising discovery that "the highest isodynamic lines of the northern hemisphere were closed and irregularly elliptical curves, extending across the North American Continent nearly in a north-west and south-east direction, and having their central point, or the point of maximum of Force, approximately in 52° north latitude, and 270° east [90°W] longitude." Observations in the neighbourhood of this phenomena were, Sabine explained, "objects which presented themselves amongst the most important desiderata for our present knowledge, and as likely to have a peculiar value at a future period in respect to the Ætiology of the science [of terrestrial magnetism]" and research that "might serve to elucidate the laws of those secular changes, which, in our present ignorance of the causes of the earth's magnetism, seem even more mysterious than the apparently complex relations of contemporary phenomena."[4]

Much of this is already known, due largely to the scholarship of several Canadian historians. However, it is often the case that the story of Lefroy's survey is subsumed into wider historical narratives. For example, Zeller, who has probably provided the most robust accounts of Lefroy's survey, uses the survey in one instance to support a far-ranging history of the creation of a scientific community and legacy in Canada and in another Lefroy and his survey are positioned in relation to wider narratives of the Humboldtian traveller and Humboldtian networks.[5] In like manner, Ted Binnema utilises the story of the survey as one of a number of staging posts which help elucidate his history of the involvement of the HBC in a host of scientific knowledge-making enterprises from 1670 to 1870. For Binnema, "the geomagnetic survey also serves to illustrate as clearly as any aspect of the history of science in the HBC, that, although historians have often emphasised how scientists and companies acted as agents of empire, empires and companies were at least as likely to act as agents of science."[6] Trevor Levere's work on Lefroy is an exception here. While Levere has used Lefroy as part of a much wider and longer narrative of science in the Arctic, he has also provided one of the more detailed, if brief, studies of the materiality of Lefroy's survey.[7]

In several respects, this paper is motivated by the work of Levere and by the need to sharpen the focus on the magnetic, meteorological, astronomical, and mathematical instruments which travelled with Lefroy to the Canadian Arctic and to the need to do so within the framework of the recent "material turn" in historical geographies of science literature.[8] First, a history of the problems involved in organising and staffing the survey will be offered, together with a condensed outline of the route and timings of the survey as it eventually turned out. From this, the focus switches to the instruments that travelled with

Lefroy. These instruments can tell us a lot about the process of doing scientific survey work at this time and in this country. In their "moments of disrepair" the instruments shed light on how instruments were managed, adjusted, and made credible on the move.[9] Importantly, such stories also offer much needed insights into the history of repair and maintenance in the survey sciences. The third section goes on to explore the scientific instruments as objects that were carried and the French Canadian and Indigenous labourers who bore them through the North American wilderness. In doing so it is argued that such invisible labour ought not to be ignored in our understanding of the ways in which scientific instruments were managed on the move. The role of such individuals in guiding the survey will also be remarked upon in this section. Finally, the paper will conclude with a tentative attempt at applying the concept of "geobiography" to an analysis of some of the instruments that travelled with Lefroy in order to destabilise their traditional temporal biographies or life-cycles.

Origin of the Survey

Edward Sabine had initially wanted to carry out a magnetic survey himself in British North America in 1839 (**Figure 2**). He had contacted the Hudson's Bay Company (HBC) about this expedition and later wrote to Humphrey Lloyd in the spring of 1839 telling him that the HBC had offered him a canoe and that he had already planned his route from Montreal to York Fort via Lake Superior and on the way back to Quebec to observe at Moose Rain.[10] However, at this time both he and Lloyd were frantically trying to complete their report on the British Magnetic Survey. It had already caused Sabine many anguished days and nights trying to incorporate the frequent revisions of Lloyd in time for it to be printed.[11] Its publication had been postponed once in October 1838 ("our poor report, alas! Must be suspended") and Sabine was unwilling to allow this to happen again.[12] Sabine was forced to choose between his "Canadian project" and "our British Report" and, he wrote to Lloyd, he "sacrificed the first!" The HBC's cooperation had been just what Sabine had wished for but he would have to have been in Montreal on 1 May 1839 and this, he explained, he "cannot do so, without abandoning the B. Report, so, the step is taken & regrets are useless."[13] However, as Sabine later wrote, "the project of a North American magnetic survey…was not suffered to drop."[14] Instead, a new candidate for Sabine's "Canadian project" was sought.

Charles J. B. Riddell—the first director of the Toronto Observatory—was next identified for the role by Sabine in 1840 but, perhaps because it would have been too much of a loss for the nascent Toronto Observatory, this idea was vetoed by Lloyd.[15] Lieutenant Charles Wright Younghusband, Riddell's assistant at the Toronto Observatory, was the obvious candidate to embark on the survey but, when Riddell was invalided home to England at the beginning of 1841, Younghusband was forced to take over management of the observatory. Lefroy was at this time still the director of the St. Helena Magnetic and Meteorological

Observatory—another of the colonial observatories of the magnetic crusade—but had expressed in a number of letters to Sabine and Lloyd his desire for survey work.[16] He had been rebuffed in his requests for a St. Helena or a South African survey but in August 1841 he was contacted by Sabine over the prospect of taking over Sabine's "Canadian project," to which Lefroy dutifully and enthusiastically committed himself. Lefroy had never been considered the best observer employed on the magnetic crusade. "Poor Lefroy," Lloyd remarked in a letter to Sabine in May 1841, "will never make an observer" as he had "no tact in overcoming practical difficulties, even of the simplest kind."[17] He was, however, an organised, industrious, and fit soldier and, as we will see later, not as impractical as Lloyd had thought. At any rate, extreme accuracy, on the part of the instruments and the observer, was both "impracticable and unnecessary" on a mobile magnetic survey, and of secondary importance to portability and fortitude.[18] Lefroy arrived in Montreal on 15 September 1842 and Toronto on 23 October. Officially, Lefroy was employed on a permanent basis as the director of the Toronto Observatory with only a "special view to his employment on the survey" but it seems certain that it was Sabine's desire for a magnetic survey in North America which was the primary reason Lefroy was brought over from St. Helena. As Sabine had originally intended, the survey was carried out with the enthusiastic support of the HBC, due largely to its London governor, J.H. Pelly, and North American governor, George Simpson. The HBC provided canoe conveyance and personnel as part of its "Brigade for the northern department."[19]

The Survey: Its Course and its Actors

Lefroy took over the running of the Toronto Observatory from Younghusband upon his arrival and for the next six months. The work of the observatory had "fallen terribly in arrears," as Lefroy himself noted in his *Autobiography*.[20] Younghusband had struggled to keep up with the unremitting observations and reductions that were required at the observatory and the physical condition of the observatory was similarly dire. The dismissal of both Bombardier Thomas Menzies (for drunkenness) and his replacement Acting Bombardier John McNaught (for being untrained and unskilled in observatory work) together with Riddell's departure had left the Toronto Observatory severely shorthanded.[21] "All in all," Julian Smith has noted, "it seemed as though Lefroy had assumed a hopeless task."[22] In March 1843 Lefroy travelled to Boston to take charge of a set of new transportable magnetometers devised by Riddell and constructed by the instrument maker Thomas Jones, which had finally arrived from England. After returning to Toronto for three weeks Lefroy left once again, this time to Montreal, where he arrived on 22 April 1843.

The survey had not yet begun, but already certain instruments had suffered from the exigencies of travel. Between Toronto and Montreal, Lefroy, together with Henry, had to travel in a "common open country waggon [sic.], filled with straw, in a sharp frost," as navigation on Lake Ontario was not yet open. The effect of the jolting upon his instruments was "disastrous."[23] The Gambey and the Fox-type dip circles were "shaken to pieces," the Gambey "literally" so and the Fox "almost." The Gambey, Lefroy wrote to Younghusband from Montreal, consisted of little more than "loose parts lying about in a box" by the end of its transit. The theodolite was similarly shaken apart and, although Lefroy carried the barometers on his shoulders the entire way, "a little mercury" managed to escape one of them.[24] More problematically for Lefroy,

> Lloyd's static needles lost force from the effect of the jolting to such a degree as to entirely disconnect the subsequent observations from those intended to be the base series, taken at Toronto. The same remark applies to Fox's needle C, and a new base had to be taken for both, at Fort William (Station LXIX). The instruments were reinstated, as well as could be done, before starting.[25]

Lefroy was more sanguine in his assessment in his *Autobiography*, saying of the altered state of the instruments that "there was no help for it, and they were put in order again without much trouble."[26] However, Lefroy noted in his contemporary survey journal that, on the day the canoes launched from Lachine, he had "found such difficulty in turning Fox in azimuth as to fear a considerable injury to the axis" which he later discovered was due to the screws of the level coming through the copper plate and grating "upon the under."[27] Although the Fox had been "reinstated," it had not returned to its previous state; it now existed on the margins of a state of disrepair.

Before proceeding to the story of Lefroy's survey and an analysis of his instruments as they travelled it is necessary to pause and take stock of exactly what scientific instruments Lefroy took with him on his voyage. Trevor Levere has written a concise and highly informative account of the instruments Lefroy took with him on his survey, but the list he presents is limited to the main magnetic apparatus Lefroy carried and precludes a full appreciation of the extent of the meteorological, mathematical, and astronomical instruments also included in the survey inventory. The full list runs as follows:

1. One Declination Magnetometer and Bifilar, in one box, with canvas cover and straps complete with spare tube and suspension pins and spare therm[ometer].

2. Inclinometer, in box, with [*same as above*].

3. Declinometer (2, 4 inch & 1, 3 inch coll. needles), the box carrying also:
    - spare 3½ inch bars
    - 1 pair 2 inch bars
    - The brass table tops for the legs of inclinometer
    - A spare stirrup with revolving mirror made at Toronto, for vibrat[ing] all the smaller bars

4. Fox's dip circle complete, with two intensity needles A and C and one reversing needle B.

5. Gambey's dip circle, complete with a pair of Lloyd's needles and thermometer.

6. A theodolite.

7. A portable transit instr.

8. A repeating reflecting circle.

9. A small 4½ sextant, the property of Lieut. Younghusband.

10. An artificial horizon, with iron mercury bottle, also a box wood ditto.

11. Two Newman's iron cistern barometers nos. 33—119

12. One actinometer from observ[ator]y

13. One azimuth compass of the Committee's construction. 4 spare pivots.

14. One Kater's ditto.

15. Thermometer:

- 1 Newman's for boiling point of water.
- 1 ? registering in copper case, pierced and polished .
- 1 Newman's standard mercury.
- 3 Newman's merc[ury] max.
- 2 Newman's Spirit min[imum].
- 1 Newman's max with black bulb.
- 1 wet bulb Hygrometer, 2 therm[ometers].
- 1 Daniel's ditto, with ether
- 3 Therm[ometer]s merc[ury] purchased at Montreal, two of them max registering, one common mercury graduated to -35°.

15. Three cylinders capable of holding any of Newman's thermometers (standard excepted) polished copper, double in the lower part and pierced with holes so dispersed that those in the outer and inner case are not opposite.

16. A copper case to carry ditto.

17. Six year's meteorological forms from Professor Espy, for distribution.

18. One lanthorn [sic.] and fire lamps for illuminating the instr. at night. Also a few wax candles in canteen (cir. 400lbs).

19. Two of the Admiralty dip books (Capt. Ross's form), one half full.

20. Two Dip books for Fox.

21. 1 100 feet measuring tape.

22. A small Dollond common telescope.

23. One or two spare lots of legs, from the old transport[able] magnet[ometer].

24. A large box for stationery and miscall. stores.

25. Lind's wind gauge from the observ[ator]y.[28]

This is a much more considerable list than the one Lefroy later offered in his *Diary of a Magnetic Survey* (1883). The Diary list, which is Levere's source, does however offer up additional information on the makers of some of the instruments and Riddell's *Magnetical Instructions for the Use of Portable Instruments* (1844) gives some of their contemporary prices. Briefly: the Fox dip circle weighed 37lbs. in the box and cost £26 2s; the Gambey 27lbs.; the theodolite was made by Thomas Jones and weighed 10½lbs.; the declination magnetometer weighed 25lbs (the maker is not given but it was probably Jones) and cost £12; the original transportable declinometer was by Weber but subsequently replaced by the "much superior instrument made by Jones" under Riddell's instruction and cost £14;[29] the transportable bifilar was also made by Jones, weighed 22lbs. and cost £19 10s; the inclinometer mentioned above was an induction inclinometer of Lloyd's design and Jones's construction that weighed 18lbs. and cost £15; the committee from which the azimuth compass came was the Admiralty Committee and was constructed by John Barrow; and the repeating-reflecting circle was made by George Dollond and weighed 25lbs.[30] Lefroy, prior to the survey, estimated in a letter to George Simpson that altogether the instrumentation necessary to "obtain any magnetic results of value may be brought well within the compass of 50lbs. weight."[31] In reality, as the above demonstrates, Lefroy's magnetic apparatus alone weighed well over 50lbs. and together with the meteorological, mathematical and astronomical instruments Lefroy packed which were also required to obtain "magnetic results of value," Lefroy carried around 180lbs. of scientific instrumentation on the survey.[32] As Levere rightly points out in a footnote, the weight of instrumentation is "not a trivial point when everything had to be packed into canoes and carried across portages."[33]

The most sensitive and arguably the most important magnetic instruments Lefroy carried were those made by Jones. Thomas Jones (1775-1852) was an English instrument maker who had learned his craft as an apprentice to the eminent Jesse Ramsden in London. Jones supplied geomagnetic instruments for several surveys during the 1830s, including the biggest of them all: the magnetic crusade. This despite the fact that he was accounted something of a "knave" and, as Sabine wrote to Lloyd in early 1839 as the magnetic crusade was beginning to take shape, Jones could not be depended on "in regard to time, nor correct execution."[34] Lefroy was not enamoured with his work either. He found the "partitions and fittings too slight; too coarse, heavy…screws work loose, portions chip off etc.."[35] Henri-Prudence Gambey (1787-1847), the maker of one of the dip circles Lefroy carried, was much more highly regarded. Gambey worked in Paris where he engineered precision instruments for the Paris Observatory as well other physicists and astronomers on the continent and in Britain.[36] Robert Were Fox (1789-1877), who produced Lefroy's other dip circle, was a Cornish geologist, physicist and designer of geomagnetic apparatus. Together with Thomas Brown Jordan (1807-1890), Fox's drawing master and engineer, the pair constructed some of the most well-respected and sought out scientific instruments, notably the Fox-type dip circle (**Figure 2**), which was used on many naval scientific expeditions.[37]

Together with the instruments listed above, Lefroy outlined the other necessities for his journey, such as a gun and a rifle, canteens, cassettes, other luggage, portable inkstands, bedding, blanket, one-and-a-half gallons of wine, tobacco, tea, powder, shot and balls. Extra clothing for his assistant, Bombardier William Henry, was purchased at a total cost of £6 16s 0½d and included a pea coat, a red flannel shirt, a pair of shoes, a lowland Scotch cap, a grey cloth

Figure 2. Example of a Robert Were Fox dip circle made by W George of Falmouth, Cornwall, England, c.1840. Image courtesy of The Science Museum.

jacket, two chamois leather shirts and two chamois leather drawers.[38] Lefroy also gave red shirts to Baptiste and Roubillard, two of the voyageurs on the survey, "by way of uniform."[39]

Thus equipped, Lefroy and Henry were ready for their overland voyage of exploration. Lefroy was initially bullish about the prospect, writing to Sabine as Lefroy crossed the Atlantic aboard the Prince Regent that "no exertion of mine shall be wanting and so I confidently hope to be able to give you in 1844…as large a body of results as will in some degree answer the questions that must grow out of those Ross is obtaining at the opposite Pole."[40] Lefroy obviously saw this survey as a mirror of the triumphant Antarctic survey James Clark Ross had, by the time of this letter, almost completed. In reality, it was of secondary importance to Ross's attempt to map the mostly uncharted

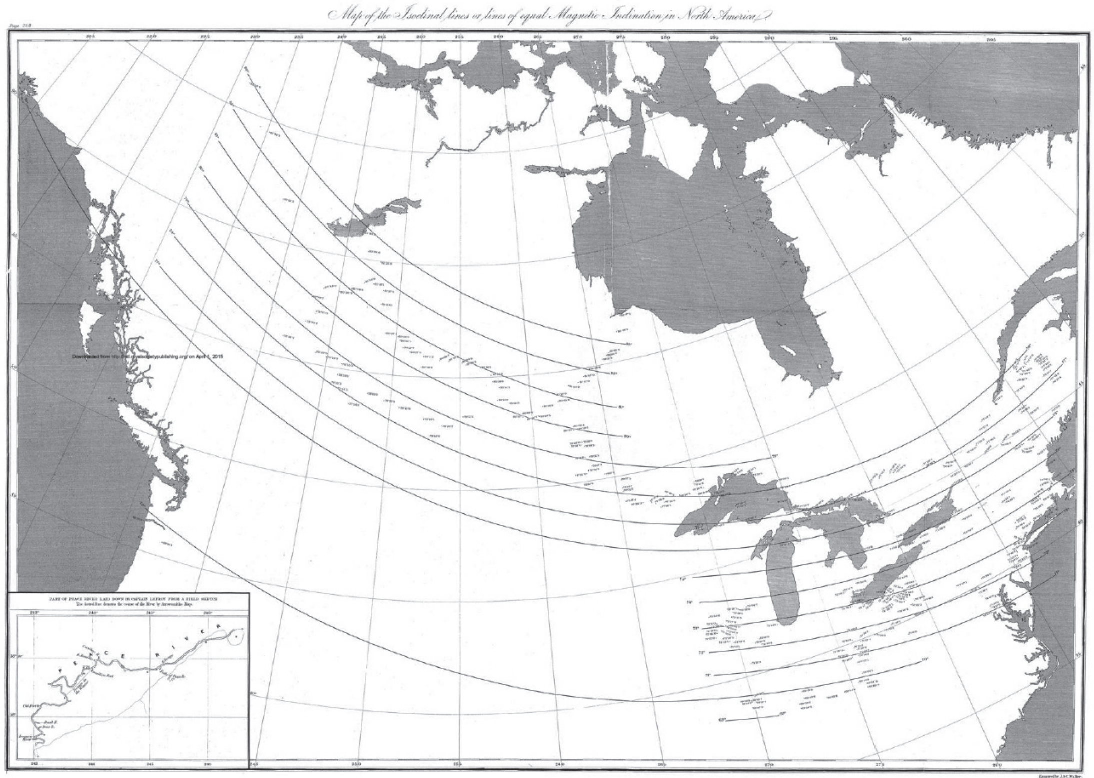


***Figure 3**. Map of the Isoclinal lines or lines of equal Magnetic Inclination in North America, in Edward Sabine, "Contributions to Terrestrial Magnetism, No. VII,"* Philosophical Transactions of the Royal Society *136 (1846): 258.*

magnetism of the Antarctic region, but the Canadian survey was still expected to be highly significant in exploring and confirming the "previously unsuspected characteristic of the magnetic system of the globe," namely that it was in these parts that the intensity of the earth"s magnetic force in the northern hemisphere had its focus.[41]

The first observations of the survey were made in the vicinity of Hudson's Bay House at Lachine on 30 April 1843.[42] The next day the canoes—"canots de maitre," able to accommodate 13 or 14 voyageurs and up to four passengers—departed from Isle d'Urval and headed up the Ottawa River. The course of Lefroy's route is traced in several accounts of his survey and so it is appropriate here to simply give a brief overall outline. Lefroy and company headed northwest. They navigated both Lake Superior and Lake Winnipeg, stopped at several important HBC outposts—e.g. York Factory, Norway House, Cumberland House—and traversed many difficult portages, the "Rat Portage" being probably the most infamous, on their way to Fort Chipewyan, which the party reached on 23 September 1843 and where they wintered until 5 March 1844. Along the way Lefroy and his assistant Henry had made magnetic and meteorological observations almost daily, as the weather allowed. At Fort Chipewyan, Lefroy and Henry established a temporary observatory in which, working 12-hour shifts each, they almost ceaselessly recorded magnetic and meteorological observations at hourly intervals during daylight hours and every 2 minutes during magnetic disturbances, from 16 October 1843 to 29 February 1844.[43] Leaving Fort Chipewyan on 3 March on snowshoes, three "trainaux" (sledges) and a cariole, Lefroy and his party trekked to Fort Simpson, where a second temporary observatory was also established from March to May 1844. When the ice broke on 25 May 1844, Lefroy headed instantly for Fort Good Hope, reaching there on 29 May. This was the farthest north they would reach, and the occasion on which they "touched the confines" of the Arctic Circle.[44] This was the apotheosis of Lefroy's survey. After this point, the party turned south and made their way to Montreal via several of the same HBC posts as they had visited on their way north. Lefroy and his party made their way (noisily) into Toronto on 18 November, before the survey ended on 25 November 1844 in Montreal. At the culmination of the survey, the party had covered close to 6,000 miles and observed at over 300 stations (**Figure 3**).

Initially, Lefroy travelled as part of the HBC "Brigade for the northern department," led by John Maclean. Lefroy was to be afforded two hours a day for observations (should the weather be conducive for such), four hours at each post they stopped at and twenty-four hours on days which coincided with the magnetic Term Days which the colonial and foreign observatories were all following simultaneously on Göttingen mean time.[45] After only a few days Lefroy's arrangement with the HBC Brigade was changed. Two voyageurs were placed at Lefroy's disposal—Edouard Genereux and Pierre Roubillon—"to carry the instruments over Portages, pitch [his] tent, and be otherwise useful" and Lefroy's canoe was "detached" from the Brigade in order to give him more time for observations. This new organisation was "an improvement on the previous arrangement" but only lasted until Fort William at the head of Lake Superior—reached at the beginning of June 1843.[46] Here, Lefroy's

> connection with the Hudson's Bay Company canoes was entirely dissevered. The large canoes, called Canots de maître, then went on no further than this point; the number and length of the portages precluding their further employment, a lighter canoe, called the Canot du Nord, came into use, one of which was appropriated to myself by the directions of Sir George Simpson, with a guide and a supply of provisions, and henceforward I commanded the disposition of my own time, subject only to the necessity of getting on.[47]

Lefroy had always felt that his and Henry's survey work made them a "constant source of anxiety" for the HBC as any "accident" on their part would have entailed lengthy delays for the time-conscious Brigade. After parting ways at Fort William, this anxiety was lifted but outside of the embrace of the Brigade, Lefroy and Henry were required to care for themselves, having to cook and carry more on the portages, which created their own time pressures.

Time was always a factor on the survey, whether with the Brigade or without. Lefroy described his initial routine in a letter to Younghusband shortly after the canoes had first departed Lachine:

> We start about ½ p 3 every morning, stop for breakfast about ½ p 7 when I observe for time and Var[iatio]n, and for dinner about ½ p 1. The other canoes proceed

> immediately after dinner, mine remains behind while I observe Gambey and Fox. This takes about 2 hours, we then follow, and overtake them after they have encamped, usually about 8 oclock—take supper and lie down until the cry of lève! lève! turns us out before three in the morning. The discomfort of this mode of travelling is chiefly a want of time for washing, dressing and so on.[48]

It is not clear from the above whether Lefroy and Henry observed Gambey and Fox for the full two hours or whether this included the time needed to set up and take down the instruments. As a point of interest, Lefroy noted once that he (along with, probably, Henry or others) "packed up the instr., struck the tent" and was afloat in the canoe "in less than 40m from the last observ."[49] Lefroy was also required to observe on Term Days, which lengthened the time of instrument adjustment. Term Days were prescribed by Lloyd and occurred one day each month. On such days, all observatories or magnetic surveyors participating on the British magnetic scheme were to simultaneously observe their magnetometers and inclinometers on six-minute cycles for an entire 24-hour period, all set to Göttingen mean time. For Lefroy and company to set up and adjust the transportable magnetometers and induction inclinometer instruments on these days required approximately two hours.[50]

Lefroy's comments to Younghusband seem to have described an average day of observation. At other times, observations could take up almost the entire morning. For instance, on 19 September 1843, Lefroy reported having spent from 0715 to 1125 making observations.[51] It was also not uncommon for observations to be taken at dinner time for one to three hours.[52] When daylight shortened, evening observations had to be made by candlelight, something not easily achieved. Wind and rain were two of the most frequent barriers to observation outdoors by candlelight. For instance, Lefroy "decided not to keep" the Term Day of 20 September 1843 because by then the nights were "so long, so much candle light in the open air would have been necessary and so much chance of wind etc. as to make it unadvisable."[53] On a separate occasion Lefroy did not observe in the evening because he had "strained [his] eyes considerably in examining the axles of Fox's needles" during the day.[54] Early in the survey it seems that Lefroy also used the evenings for observational practice as, on 14 May 1843, he described feeling "uncommonly savage at the cry of Leve! Leve! about ¼ to 4, [as he] had been practising lunars until past 12 o"clock."[55]

Despite the fact that Lefroy and Henry had parted company with the Brigade at Fort William in June, they were still subject to time pressures and the need to complete their navigation north to Fort Chipewyan before winter. On 10 July 1843, Lefroy reported that he could not complete all the observations he had wanted to on stopping in the afternoon because they needed to keep moving while the wind allowed it. Lefroy complained that "were it not for an occasional detention I could not easily keep my head above water."[56] Lefroy was the more aggrieved as well because, he wrote, "we had a tolerably pretty spot also. A level floor of smooth granite running out from a sandy beach which was covered with a beautiful wild pea, while a thicket of aspen spruce and willow screened us on one side from the wind." Such an excellent example of the temporary and fleeting sites used for observation were to be cherished because often (as, for instance, Lefroy encountered later the same day) the spots they halted at were "very bad." A "wet and sandy beach where the surf dashed within a few feet of the tent" for example, or a beach of shingles, or on the "swampy soil" of the Long Portage.[57] These individual and continually changing sites had to be negotiated by Lefroy and Henry in the context of changing weather conditions and, importantly, the changed and ever-changing condition of the magnetic and meteorological instruments they carried.

Instruments: Moving, Changing, Changed

Lefroy's instruments changed dramatically over the course of the survey. This was of course to be expected "under the circumstances of a long land journey."[58] Even so, the catalogue of injuries Lefroy's instruments suffered and the repairs that had to be undertaken along the way were extensive. Changes in the state of the instruments Lefroy carried occurred for a number of reasons. First, there were many seemingly mundane accidents. The thermometer which worked in tandem with the inclinometer, which Lefroy was carrying with the intention of trying to "unite the broken column, fell from pocket on stooping for something, and broke."[59] Lloyd's needles were almost lost twice in the space of a couple of days. On one occasion a "Mr Ross" "let them fall into the stream just before encamping" after which they "floated down, but the canoe recovered them about 3 miles down."[60] Two days later, Lefroy dropped the same needles out of his Macintosh pocket at a portage.[61] That the readings made by Lloyd's needles later seemed anomalous would suggest that these needles had suffered a loss of magnetic strength as a result of their falls and brief river excursion, although Lefroy in his journal believed that "no cause can be given for such an occurrence."[62] At another time part of the Fox-type dip apparatus was dropped by Henry in his rush to shoot at a moose which had suddenly appeared. Although no injury seems to have occurred by this, it does remind us that making observations was not always the main priority on the survey.[63]

Some of the most significant accidents and breakages occurred with the meteorological instruments Lefroy carried, which is perhaps unsurprising given that these were some of the most fragile. A spirit thermometer "fell from the place on which it had been supported all night, and got broken."[64] Both of the barometers were similarly put out of use: no. 11 was simply "broken in the canoe," and no. 119 broken because it "had been so placed in the canoe that the cistern end projected a little, unobserved, beyond the gunwale, and on approaching the shore it came violently in contact with the overhanging stem of a tree."[65] The loss of both barometers was a "sad disappointment" to Lefroy.[66] Previous to their final demise, one of the barometers had also been used by a French Canadian child as rock-throwing target practice: "well he was not an Indian," Lefroy drily observed in his journal, "or it had been a 'gone' barometer."[67] Newman's maximum registering thermometer no. 10 was broken at the first "carrying place," i.e. a portage, only a few days after the survey had first embarked.[68] A second "New. Max therm." was broken not long after, "in the water, apparently by the force of the current."[69] Before the canoes had even launched from Lachine, Lefroy's servant, had "let the box of thermometers fall from the hand cart on which it was going down, on to the stones, breaking two thirds of the contents." Only one hygrometer and "one or two" thermometers managed to escape this "most unfortunate piece of clumsiness."[70] It is not entirely clear if Lefroy had a chance to replace all of the broken thermometers before the survey properly launched.

In addition to the above accidents, several of the mathematical and astronomical instruments were also damaged or changed. For instance, the circle of the theodolite was "much bent" by a fall at the François River.[71] The brass plummet was also "abstracted…from the Theodolite box" by a group of Chipewyan children which Lefroy "endeavoured in vain" to recover.[72] One of the glasses of the artificial horizon was smashed when Henry dropped it at a portage.[73]

Finally, there were also the many and varied ways in which Lefroy's magnetic instrumentation was damaged and changed as it moved through the different sites and settings of the North American survey. A couple of these incidents have been related above but there were several more instances along the way. After stopping and setting up instruments on 20 June 1843, Lefroy was surprised by the occurrence of a stray calf blundering into his instruments. Lefroy was attempting at the time to observe the meridian altitude of the sun but instead observed the calf knock over his Gambey dip circle and smash the cover "to pieces."[74] By this unfortunate accident the Gambey was "rendered for the time unserviceable," Lloyd's needle A "which was on it at the moment, was ruined," and a deviation of the survey's route to take in the Red River settlement, and lower Fort Garry specifically, was required in order to affect repairs.[75]

There were four particularly precious instruments which travelled with Lefroy: the three transportable magnetometers and the induction inclinometer. These were precious because they measured the earth's magnetic force in absolute, rather than relative terms, and were the instruments employed on magnetic Term Days to observe simultaneously with all observatories on the British magnetic scheme. They were to be set up only at particularly long stoppages along the way at forts, and within the temporary observatories at Fort Chipewyan and Fort Simpson. Precious as they might be and as infrequently used as they were in comparison to the other instruments, they also suffered. On two separate occasions when the transportable magnetometers were set up, they were blown down. The declinometer, used to measure the variation of the magnetic force, escaped largely unharmed from its fall, although the theodolite in use alongside it had its vertical and its horizontal limbs bent and "bruised."[76] On the occasion when the transportable bifilar magnetometer was blown over, both its suspension tube and thermometer were broken.[77]

Damage to the limbs, or the body of the apparatus, were not the only problems to afflict the magnetic instruments. The needles by which they operated also continually suffered. The most frequently recorded trouble was that of the needles contracting rust because of extended "exposure" to the environment. Axles were also frequently put out of shape. On 24 July 1843, Lefroy reported on the state of his eight needles at this early point in the survey. Rust had not yet set in but already Lloyd no. 2 had a "sensible bend at the shoulder of the front axle"; Fox C's back axle shape was not good; Gambey 1's sides were "not quite straight lines"; and the polish on half of them had already begun to wear away.[78] Fox A seems generally to have "worked with very tolerable freedom, not as a positively good one, but not as a positively bad one" although some irregularity was noticed with the weight at 4.0 grams seemingly "due to a bruise on the axle." Fox B "did not work freely" and "ceased to vibrate almost instantly"; and Fox C was so often found to be irregular in its force that Lefroy "condemned the axle and substituted a spare axle for it" in August 1843.[79] Two new Lloyd's needles were forwarded to Lefroy in 1844 at Norway House but "they proved to be about 0.2 inch too long for the [Fox] dip circle, and were never used."[80] This marginal but significant error speaks to Jutta Schickore's studies of imperfection in microscopes and how in the early nineteenth century, i.e. the period the magnetic crusade covered, "the individual differences between instruments" or in this case, needles, "produced by the very same maker came into the fore."[81] Repair and maintenance by the user was now the assumed method of ensuring that a particular device was in perfect-working order. Lefroy could not achieve this with these replacement needles. However, thanks largely to a network of HBC outposts and his own occasional labour, Lefroy managed to repair his instruments following breakages en route.

Fixes

Histories of maintenance and repair are still largely to be written.[82] It is a topic of "growing interest for geographers," but these efforts have tended to fall outside the realm of the history of science.[83] According to Fraser MacDonald and Charlie Withers "we have paid too little attention to fallibility and to how truth claims about science and exploration were made despite, not because of, the instruments used."[84] As Schaffer rightly pointed out in 2011, "some histories of broken instruments and their fixes might help."[85] The previous section was an answer to the first part of Schaffer's request, and the following speaks to the latter.

In writing his post-factum Diary, Lefroy hoped to demonstrate in part "the perplexities of a magnetic observer out of reach of skilled mechanical assistance."[86] To some extent, this is true. There were no (human) Foxes, Gambeys, Lloyds or Newmans at large and on hand to help in the places to which Lefroy and his instruments travelled in British North America and the Northwest Territories. Lefroy could and did rely on his own reasonable personal knowledge of the mechanics of his instruments. He filed, straightened, remounted, and sometimes recycled instruments in order to restore their ability to observe, measure, and record. For instance, when the Fox-type dip circle "became partially broken from the shank" when in use, Lefroy "endeavoured, apparently with success to fix [the problem] with Blowpipe" after which he was able to continue observing the Fox.[87] Later, in September, when Henry broke one of the glasses of the artificial horizon, Lefroy "was obliged to take the back glass of the actinometer and cut it for a new glass."[88] The actinometer became, in the mobile, isolated, context of the Northwest Territories, not only an instrument but a resource, a recyclable object. This incident perhaps also speaks to the hierarchy of instrumentation in Lefroy's survey: what could be bastardized and what could not be spared. If we think back too to the incident in which the calf damaged the Gambey dip circle, an incident which diverted the course of the survey, it is clear that certain instruments were too important to be left in a state of disrepair. Some instruments, however, could be entirely foregone. For instance, several of the barometers and thermometers were also smashed and broken—some quite early in the course of the survey—but Lefroy only mentions procuring one replacement Dollond spirit thermometer from a Mr Swanston at Fort William at the end of May 1843.[89]

Although Lefroy did indeed manage the state of several of his instruments by his own hand and resources, he also relied in great part on the network of HBC forts through which the survey passed and, specifically on the armourers or blacksmiths that worked in these places. The most notable of these occurrences was at Fort Garry, a.k.a Stone Fort, within the Red River settlement, which Lefroy and company reached on 28 June 1843. The party remained at Fort Garry until 4 July in order to have repairs to the dip circle and other articles effected.[90] The "tangent screw of azim[uth] limb of inclinometer" which was "crooked and occasioned irregularity in the motion" was repaired; the "footscrew of vibration box [was] straightened from bend caused by fall at L. Huron"; the "vertical limb of theodolite which was bent by [the same] fall as above [was] flattened; and Lefroy "allowed the armourer to try to straighten the bent axle of Lloyd no.1, it being quite useless in that condition." For this the armourer "first took out the temper [and] afterwards rehardened it." For this last fix Lefroy wrote that the armourer "appears to have succeeded."[91] Lefroy also stated that the armourer's repairs to the dip circle were "very neatly executed." Once again however the humble wagon proved to be a dip circle's nemesis as, when it was moved from lower Fort to upper Fort Garry (where Lefroy was residing) "it was shaken to pieces by 21 miles transport in a cart without springs" even though it was packed in appropriately. Lefroy "had to take it all to pieces and tighten all the screws," an operation which did not seem to require much time as Lefroy was observing the dip later the same day.[92]

This stop was a deviation from the original intended route of travelling from Fort Alexander to Norway House, a fact which demonstrates the importance of certain HBC outposts and the knowledge that skilled mechanical assistance was sometimes, though not always, within reach during the survey.[93] In certain respects, comparison can be made with Lefroy's time in St. Helena, where Lefroy also felt as if he had been "thrown only on one's own resources." This despite the fact that there were workmen in the colony who were not only capable of repairing instruments but who were willing and able to "pick holes in the coat of a London artist" and make alterations to instruments to improve their functionality, such as occurred with Lefroy's anemometer.[94] Prior to departing for St. Helena, Lefroy had expected that the blacksmiths on the island were capable only of "rough work, but not fine or nice work."[95] In this supposition Lefroy seems to have been proved wrong. Such blacksmiths and armourers were the invisible maintainers of the material parts of the magnetic crusade, given that they were responsible for the upkeep and continual evolution of the physical space of colonial observatory complexes around the world.

A Multiplicity of Hands: Indigenous and Other

The labour of Fort armourers is not the only example of the invisible work behind maintaining Lefroy's survey. Both the French-Canadian voyageurs and Indigenous guides who accompanied Lefroy are also often overlooked in accounts of Lefroy's survey. Thinking about the materiality of the survey—of the non-human actors—is, perhaps ironically, one of the means by which these individuals can be brought into focus because this perspective illuminates the multiplicity of different hands through which these instruments passed on the survey and pays due attention to the fact that although this survey is remembered as Lefroy's survey, it was dependent and contingent upon the capacity of a number of other individuals, from Lefroy's servant, to his assistant Henry, to the various French Canadian voyageurs and local Indigenous guides who carried the fragile instruments and kept them as safe as possible given the arduous travel circumstances. As Lefroy rather rudely put it in a letter to his mother prior to the survey,

> You cannot think what an anxious business has been the conveyance of so many Instruments safely from Toronto by land, and with every care several of them have suffered a good deal—nor will my uneasiness upon this score be soon relieved for the canoes are unloaded every night, and every night will put it in the power of a clumsy voyageur to ruin my hopes.[96]

These "clumsy" voyageurs were men such as Edouard Genereux, one-eyed Pierre Roubillon, Pierre Blondin, Narcisse Arel, and Baptiste Ayot—the "Sancho Panza of the party"—among others.[97] There were also a number of Indigenous men who participated in the safe passage of the survey and its instruments, such as Laurent Tewakewassin and "Louis," both Iroquois, Baptiste Sateka, and two Chipewyans, Gougro—who went "by the agreable [sic.] name of the "Man-Eater""—and Assagai.[98] It was the role of these individuals in particular to carry the entire material inventory of the survey over portages—which ranged from one or two miles to twelve miles in length and could take up to two days to traverse. Lefroy explained the process in a letter to his sister Isabella in October 1844:

> When we arrive at such a place, the canoe is unloaded, taken out of the water, carried across by land, by two of the men, and then the loading carried over to it…The canoe weighs about 400lbs, and two men have to carry it on their shoulders. I have a box

> weighing 100lbs. Someone has the pleasure of carrying that, and so of everything. 180lbs is considered a full load, if compact. They have to go and return as often as necessary until every thing is carried… I always carry something, more indeed than most gentlemen in this country, for the sake of example, and because I have many small separate packages requiring constant care and watchfulness.[99]

Lefroy was always keen, in his memoirs and in his letters, to point out that he carried a "tolerable burden, even for a bourgeois," which included "gun, barometer, dish, haversack with books and axe" at these crossing places.[100] By this admission, however, it would seem that Lefroy did not carry the bulk of his instruments. The instrument he did carry, a barometer, was for the majority of the survey broken. I think it is important to note that the vast majority of the time in which the instruments were carried on the survey it was by the hands of someone other than Lefroy for a couple of reasons. It is true, as MacDonald and Withers and Dunn and Naylor have all pointed out, that using instruments is, as much as anything, a story of training and disciplining the user to manipulate technology. Instrument use was an embodied practice which bred dexterity and regularity in both the user and the object.[101] It is also true, I would argue, that we ought not to dismiss the dexterity, sensitivity, and skill with which voyageurs and Indigenous guides unloaded, carried—sometimes for many miles across steep and swampy ground—and reloaded the hundreds of pounds' weight of instrumentation which made up Lefroy's survey on hundreds of occasions, sometimes incessantly on the days they encountered many small portages. As we have seen on several other occasions, the scientific equipment which travelled on this survey was often extremely fragile and liable to break at even the slightest of rough treatment. Lefroy made it clear in the letter to his mother above how easy it would have been for a "clumsy" voyageur to ruin the hopes of his survey. But, in the hands of a competent voyageur or Indigenous guide, instruments were safely moved and thus their state of existence—whether broken or usable—stabilized. They did not "use" the instruments, but they managed them in arguably as important a way as Lefroy did.

Alongside their management of the state of the instruments, the survey crew also managed the state of the canoes in which Lefroy and the instruments mostly travelled. There are numerous references in Lefroy's field journal to the fact that frequent stops were required for "gumming" of the canoe. The canoe was an important space for the survey. It was both carrier and carried. It provided a space for Lefroy and Henry to sleep following the exhausting ritual of Term Day observations and, occasionally, it was made into a space from which to observe while moving, as Lefroy did with the actinometer on 25 August 1843, although he did not consider the observations "so good as a shore one."[102]

In his recent book on the history of the relationship between the HBC and science, Ted Binnema has explained how, "aboriginal people routinely served not only as trappers, but also as guides, couriers, and hunters for traders throughout the HBC territories."[103] The aboriginal people of Lefroy's survey fulfilled all three of these roles, but Lefroy largely noted their prowess as guides. Even when Laurent—Lefroy's first guide—"got completely bewildered" for a time "among the archipelago of small low-wooded islands, all singularly alike, which fills the centre of the Lake of the Woods"—the wonder, Lefroy wrote, was

> not that the Iroquois lost his way, but that they should know it at all: that over a line of some three thousand miles these Indians know every stone and stump, and are able to guide a canoe without compass through intricate channels in which a European eye is lost at once.[104]

For navigation, Lefroy had only John Franklin's route maps—which had been made during Franklin's journey of 1819 and which while "very creditable" to the officers that made them, "were at the best imperfect"—as well as astronomical and mathematical instruments such as sextant and azimuth compass, and Indigenous and HBC guides, upon whom Lefroy greatly relied. "Native expertise" had similarly been the context in which several attempts to find the Northwest Passage were made as the local knowledge of Indigenous peoples was "impeccable" because they had "travelled widely" and had a "pretty fair idea of neighbouring topography for many days" travel" as Levere has argued.[105]

Conclusion

The point of illustrating the amount and frequency of the breakages that occurred to Lefroy's instruments during the survey is not to try to demonstrate that the survey was a failure or that Lefroy was an incompetent surveyor. Both are false. Lefroy's survey was an extraordinary feat of scientific endeavour that collected magnetic observations from more than 300 stations across British North America and beyond. His survey remained the "main standard and reference for magnetic observations in western North America for the next three decades" and Lefroy himself was labelled a "highly trustworthy traveller, and one accustomed to rigorous and exact observations" by the Austrian author and magnetic researcher Carl Weyprecht in 1874.[106] Considering the fragility of most of the instruments, the extreme environment and climate through which Lefroy and company bore them, and the several different modes of transport by which they travelled—wagon, canoe, cariole, horse, sledge, on backs and in hands—the instruments survived remarkably well and, as has been said, remained sufficiently workable to make a voluminous amount of credible observations.

Davis Baird has argued that "many instruments hide the very materiality they are made from."[107] Without the breakages that occurred along the way, this would have been true of Lefroy's instruments. The only other references to the instruments in Lefroy's journals except for those made in moments of disrepair are simple statements such as "Obsd with Fox" or "Observed dip with both of Gambey's needles." To use an oft-cited remark of Bruno Latour's, "scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become."[108] Or, as Stephen Graham and Nigel Thrift have observed, "things only come into visible focus as things when they become inoperable."[109] This is when the materiality of Fox, Gambey, the magnetometers, and the meteorological instruments becomes tangible and graspable. The point of looking for and exploring instruments in varying states of disrepair is then to recapture a semblance of their materiality and, following Schaffer, to understand how instruments were managed in altered states and to increase an awareness of the importance of repair and maintenance in mobile scientific practice and how this was "dependent on relations between makers, users, and travellers."[110] To this last point I would also add, in the specific context of Lefroy's survey, that focusing on instrument failure and repair also illuminates the particular network of HBC outposts through which Lefroy and his party travelled and in which instruments and magnetic needles were mended and reanimated.

"Each needle has its personal history" wrote Lefroy in his post factum Diary.[111] Arguably, this could be taken further to say that each needle—even each instrument—has also a personal geography. We might call this an instrument's "object biography," "spatio-temporal life," or "social-spatial biography."[112] Just as Pike distinguishes the "geographical notion of entanglements" to demonstrate that brands and branding are inescapably intertwined with spatial associations and connotations and, crucially, that "such attachments shape and are shaped by the agents involved," so we ought similarly to pay attention to the geographical entanglements involved in the biographies of Lefroy's instruments.[113] Caitlin DeSilvey's favourite term for this, and perhaps my own too, is an object's "geobiography."[114]

A geobiography, as Pauli Tapani Karjalainen describes it, is "the expression of the course of a life as it relates to the places lived."[115] It is part of understanding objects, artefacts, scientific instruments, as more of a "process rather than a stable entity," and that the "provisional identity" of a thing can depend in large part on "where they are in their geobiography."[116] For one example of this, we might profitably turn to the dip circle. Levere has rightly pointed out that a traditional, temporal biography of the dip circle in the long nineteenth century reads largely as one of conservatism and stability of design—as indeed was the case for other magnetic instruments in this period. To read the geobiography of a nineteenth-century dip circle is to read a much more unsettled and uneven biography of the object.

As I have written elsewhere, the Gambey dip circle that Lefroy took with him to North America had previously been used during the British Magnetic Survey, 1833-38. As part of this survey, the Gambey was not only an instrument of observation but of experimentation and standardisation too in the particular spaces of London's Regent's Park and Westbourne Green.[117] Briefly, the Gambey was employed at these sites as an instrument against which to critique English-made dip circles and through which to calibrate and develop these same circles. These parks were shaped as spaces of site-specific experimentation by the Gambey and by extension helped shape what the Gambey—a French instrument—ironically embodied in this time and place: the emergence of British specialism in the art of terrestrial magnetic observation and the construction of instruments accurate and reliable enough for it to be a credible pursuit. The perspective of this work in many ways follows the precedent set by Jenny Bulstrode's persuasive and cogent study of the geographical entanglements—of Cornwall and Cornish mines—attached to the construction, popularisation, and distribution of Fox's dip circle in the early 1830s.[118]

In like manner, reading the geobiography of Lefroy's instruments, most notably the dip circles, we are able to discern the frequently changing and ultimately changed significance of such apparatus as they related to the places of the survey. As has been demonstrated, the dip circles were frequently rendered unusable or untrustworthy during their time in the often harsh North American environment. And, as has also been shown, these instruments were put back together by local HBC armourers or by Lefroy himself using what resources he could muster in the places he found himself in, and maintained as much as possible in their reconstructed states by Indigenous guides and French Canadian voyageurs. In other words, what the Gambey and the Fox, or indeed several of the other instruments, came to represent, was the physical manifestation of the combination of skills and knowledges of British and continental instrument makers together with local craftsmen, facilitated by Indigenous labour. Seen in this way, these instruments represent a disruption to the traditional dichotomy of the centre and the periphery, the metropole and the wilderness, in which terms nineteenth-century imperial science is sometimes framed. The geobiography of Lefroy's instruments shows that the passage of Lefroy's survey was one taken through hybrid spaces and, in passing through, these instruments were themselves made hybrid.

Matthew Goodman is a PhD Candidate at the University of Glasgow in the School of Geographical and Earth Sciences. His work focuses on the history and geography of the early nineteenth-century magnetic crusade with a particular emphasis on the materials and administration necessary to construct this worldwide scientific scheme.

Endnotes

1 See Gregory Good, 'Between Two Empires: the Toronto Observatory and American Science before Confederation," *Scientia Canadensis: Canadian Journal of the History of Science, Technology and Medicine* 10, 1 (1986): 34-52; Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (McGill-Queen's University Press, 2009); and Zeller, 'Humboldt and the Habitability of Canada's Great Northwest," *Geographical Review* 96, 3 (2006): 382-398, especially 388-391.

2 For a small offering of histories of the magnetic crusade see, John Cawood, 'The Magnetic Crusade: Science and Politics in Early Victorian Britain," *Isis* 70, 4 (1979): 492-518; John Cawood, 'Terrestrial Magnetism and the Development of International Collaboration in the Early Nineteenth Century,"

Annals of Science 34, 6 (1977): 551-587; Christopher Carter, 'Magnetic Fever: Global Imperialism and Empiricism in the Nineteenth Century," *Transactions of the American Philosophical Society* 99, 4 (2009): i-169; Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Science History Publications, 1978); Vidar Enebakk, 'Hansteen's Magnetometer and the Origin of the Magnetic Crusade," *The British Journal for the History of Science* [hereafter *BJHS*]47, 4 (2014): 587-604; Gregory Good, 'Between Data, Mathematical Analysis and Physical Theory: Research on Earth's Magnetism in the 19th Century," *Centaurus* 50 (2008): 290-304; Ann Savours and Anita McConnell, 'The History of the Rossbank Observatory, Tasmania," *Annals of Science* 39, 6 (1982): 527-564; Jessica Ratcliff, 'Travancore's Magnetic Crusade: Geomagnetism and the Geography of Scientific Production in a Princely State," *BJHS* 49, 3 (2016): 325-352.

3 Humphrey Lloyd to Charles J.B. Riddell, 30 December 1839, Royal Society Library and Archives [hereafter RS] Manuscripts General [MS] 119/4 (Vol. I).

4 Edward Sabine, 'Contributions to Terrestrial Magnetism. No. VII," *Philosophical Transactions of the Royal Society of London* 136 (1846): 237-336, 238. Emphasis added.

5 Zeller, *Inventing Canada*; and Zeller, 'Humboldt and Habitability."

6 Ted Binnema, *Enlightened Zeal: The Hudson's Bay Company and Scientific Networks, 1670-1870* (Toronto: University of Toronto Press, 2014): 200

7 Trevor H. Levere, *Science in the Canadian Arctic: A Century of Exploration, 1818-1918* (Cambridge: Cambridge University Press, 1993); and Trevor H. Levere, 'Magnetic Instruments in the Canadian Arctic Expeditions of Franklin, Lefroy, and Nares," *Annals of Science* 43 (1986): 57-76.

8 See, for example, Diarmid A. Finnegan, 'The Spatial Turn: Geographical Approaches in the History of Science," *Journal of the History of Biology* 41 (2008): 369-388; David N. Livingstone, 'The Spaces of Knowledge: Contributions towards a Historical Geography of Science," *Environment and Planning D: Society and Space* 13 (1995): 5-34; David N. Livingstone, *Putting Science in its Place: Geographies of Scientific Knowledge* (Chicago and London: University of Chicago Press, 2003); David N. Livingstone and Charles W. J. Withers, eds, *Geographies of Nineteenth-Century Science* (Chicago and London: University of Chicago Press, 2011); Richard C. Powell, 'Geographies of Science: Histories, Localitites, Practices, Futures," *Progress in Human Geography* 31, 3 (2007): 309-329; and Simon Naylor, 'Introduction: Historical Geographies of Science – Places, Contexts, Cartographies," *BJHS* 38, 1 (2005): 1-12.

9 Simon Schaffer, 'Easily Cracked: Scientific Instruments in States of Disrepair," *Isis* 102, 4 (2011): 706-717

10 Sabine to Lloyd, [?] April 1839, RS:MS/119/66 (Vol. I).

11 Sabine to Lloyd, 8 April 1839, RS:MS/119/49 (Vol. I).

12 Sabine to Lloyd, 23 October 1838, RS:MS/119/58 (Vol. I).

13 Sabine to Lloyd, [?] April 1839, RS:MS/119/66 (Vol. I).

14 Sabine, 'Contributions VII," 239.

15 Lloyd to Sabine, 27 April 1840, The National Archives, United Kingdom, [hereafter TNA] BJ/3/10/151.

16 See, for example, Lefroy to Sabine, 19 October 1840, TNA BJ/3/81/18.

17 Lloyd to Sabine, 15 May 1841, TNA BJ/3/11/201.

18 Riddell to Lloyd, 26 October 1843, RS:MS/119/39 (Vol. II).

19 Binnema, 213

20 John Henry Lefroy, *Autobiography of General Sir John Henry Lefroy*, ed. Lady Lefroy, printed for private circulation (n.p., n.d.): 63. Reducing the data accrued from both the mobile surveys and the fixed magnetic observatories was extremely labour-intensive. As such, only a small part of it was ever reduced in the 19th century, much less analysed, but these data would prove useful in 20th century reductions.

21 Julian A. Smith, 'Humboldt, Sabine and the "Magnetic Crusade:" The Founding of the Toronto Observatory," a research report completed under contract to the Canadian Museum of Science and Technology (1989): 31-32.

22 *Ibid.*, 34.

23 Lefroy, *Autobiography*, 64.

24 Lefroy to Charles Wright Younghusband, 25 April 1842, in George F. G. Stanley, ed., *John Henry Lefroy: In Search of the Magnetic North. A Soldier-Surveyor's Letters from the North-West, 1843-1844* (Toronto: Pioneer Books, the MacMillan Company of Canada Limited, 1955): 6.

25 John Henry Lefroy *Diary of a Magnetic Survey of a Portion of the Dominion of Canada chiefly in the North-Western Territories, Executed in the Years 1842-1844* (London: Green and Co., 1883): 2.

26 Lefroy, *Autobiography*, 64.

27 Lefroy's manuscript journal is in Yale University Library, and I have used a microfilm copy found in Library and Archives Canada, John Henry Lefroy MG24-H25, microfilm reel M-2314, *Journals of Sir John Henry Lefroy*, 2 Vols, Vol. I, [hereafter JLVI], 5, 1 May 1843; and 11, 2 May 1843.

28 List and specification of articles taken by Lieut. Lefroy on the magnetic survey, to the northwest, Lachine, 30 April 1843, TNA BJ/3/35/15.

29 Lefroy, *Diary*, 1.

30 All weights from Lefroy's *Diary*, 1; and all prices from Charles J. B. Riddell, *Magnetical Instructions for the use of Portable Instruments adapted for Magnetical Surveys and Portable Observatories* (London: W. Clowes & Sons, 1844): 98-99.

31 Lefroy to George Simpson, Governor-in-Chief of Rupert's Land, forwarded to Colonel Sabine, Montreal, 25 September 1842, quoted in A. D. Thiessen, 'The Founding of the Toronto Magnetic Observatory and the Canadian Meteorological Service," Part V, *Journal of the Royal Astronomical Society of Canada* 35 (1941): 141-150, 146.

32 Lefroy, *Diary*, 1.

33 Levere, *Magnetic Instruments*, 66, f. 39.

34 Anita McConnell, 'Jones, Thomas (1775-1852)," *Oxford Dictionary of National Biography* [*ODNB*], Oxford University Press [OUP], 2004 [http://www.oxforddnb.com/view/article/15096, accessed 20 July 2017]; Sabine to Lloyd, 16 March 1839, RS:MS/119/61 (Vol I.)

35 Lefroy to Sabine, 20 May 1843, TNA BJ/3/35/24.

36 Paolo Brenni, '19th Century French Scientific Instrument Makers I: H-P. Gambey," *Bulletin of the Scientific Instrument Society* 38 (1993): 11-13.

37 Denise Crook, 'Fox, Robert Were (1789-1877)," *ODNB*, OUP, 2004 [http://www.oxforddnb.com/view/article/10042, accessed 20 July 2017]; Anita McConnell, 'Jordan, Thomas Brown (1807-1890)," *ODNB*, OUP, 2004 [http://www.oxforddnb.com/view/article/15123, accessed 20 July 2017].

38 'List," TNA BJ/3/35/15.

39 JLVI, 22, 9 May 1843.

40 Lefroy to Sabine, received 10 August [1842], TNA BJ/3/35/7.

41 Sabine, 'Contributions VII," 238.

42 The dates and places of Lefroy's survey can be found in Lefroy, *Diary*; Lefroy, *Autobiography*; and Thiessen, Part V, 149-150.

43 Lefroy to Younghusband, 13 December 1843, quoted in Stanley, *John Henry Lefroy*, 69.

44 Lefroy, *Diary*, v.

45 George Simpson to the Gentlemen in charge of Districts and posts in the Service of the Honorable Hudson's Bay Company, 26 April 1843, in Thiessen, Part V, 148.

46 Lefroy, 5 May 1843, *Diary*, 61.

47 Lefroy, 1 June 1843, *Diary*, 79.

48 Lefroy to Younghusband, 20 May 1843, quoted in Stanley, *John Henry Lefroy*, 13.

49 JLVI, 138, 20 July 1843.

50 Lefroy, 21 June 1843, *Diary*, 90.

51 JLVI, 253, 19 September 1843.

52 JLVI, 30, 14 May 1843; and 62, 11 June 1843.

53 JLVI, 256, 20 September 1843.

54 JLVI, 122, 12 July 1843.

55 JLVI, 31, 14 May 1843.

56 JLVI, 118, 10 July 1843.

57 *Ibid.*; and swampy ground from JLVI, 136, 19 July 1843.

58 Lefroy, *Diary*, 38

59 JLVI, 150, 26 July 1843.

60 JLVI, 17, 7 May 1843.

61 JLVI, 21, 9 May 1843.

62 JLVI, 43A, 24 May 1843.

63 JLVI, 254, 19 May 1843. The moose got away.

64 JLVI, 61A, 11 June 1843.

65 JLVI, 41, 22 May 1843; Lefroy, 16 June 1843, *Diary*, 87.

66 Lefroy to his mother, 6 June – 1 July 1843, quoted in Stanley, *John Henry Lefroy*, 27.

67 JLVI, 42A, 24 May 1843.

68 JLVI, 15, 6 May 1843.

69 JLVI, 33, 15 May 1843.

70 Lefroy to Sabine, received 10 August [1842], TNA BJ/3/35/7.

71 JLVI, 49A, 30 May 1843.

72 JLVI, 248, 16 September 1843.

73 JLVI, 220, 2 September 1843.

74 JLVI, 79, 20 June 1843.

75 Lefroy, 20 June 1843, *Diary*, 89. To an extent, this accident was fortuitous. Had the calf not blundered in and broken the Gambey, Lefroy would not have altered his route to take in the Red River Settlement and would then not have bumped into Sir George Simpson, North American Governor of the HBC. It was Simpson at the Red River would advised Lefroy to head not for Moose Factory as originally intended but instead to make for Fort Chipewyan and overwinter there. See Lefroy, *Autobiography*, 74; or John Henry Lefroy and Sir John Richardson, *Magnetical and Meteorological Observations at Lake Athabasca and Fort Simpson…and at Fort Confidence in Great Bear Lake* (London: Her Majesty's Stationery Office, 1855): ix-x.

76 JLVI, 34A, 16 May 1843.

77 JLVI, 150, 26 July 1843.

78 JLVI, 145, 24 July 1843.

79 Lefroy, *Diary*, 30, 31.

80 Lefroy, *Diary*, 20.

81 Jutta Schickore, 'Ever-Present Impediments: Exploring Instruments and Methods of Microscopy," *Perspectives of Science* 9, 2 (2001): 126-146, 136.

82 For some attempts to do so though, see Schaffer, 'Easily Cracked"; David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (London: Profile, 2008); and Simon Werrett, 'Recycling in Early Modern Science, *BJHS* 46, 4 (2013): 627-646.

83 See Caitlin DeSilvey, 'Object Lessons: From Batholith to Bookend," in *The Wiley-Blackwell Companion to Cultural Geography*, eds. Nuala C. Johnson, Richard H. Schein, and Jamie Winders (Chichester, Wiley-Blackwell, 2013): 146-158. DeSilvey gives a concise summary of the kinds of things these works have focused on, from Cornish harbours to post-Katrina New Orleans.

84 Fraser MacDonald and Charles W. J. Withers, 'Introduction: Geography, Technology and Instruments of Exploration," in *Geography, Technology and Instruments of Exploration*, eds Macdonald and Withers (Farnham: Ashgate, 2015): 1-14, 10.

85 Schaffer, 'Easily Cracked," 708.

86 Lefroy, *Diary*, 30.

87 JLVI, 48A, 29 May 1843.

88 JLVI, 220, 2 September 1843.

89 JLVI, 50A, 31 May 1843.

90 Lefroy, 29 June 1843, *Diary*, 94.

91 JLVI, 101, 1 July 1843.

92 JLVI, 104, 3 July 1843.

93 Lefroy to his mother, 6 June – 1 July 1843, in Stanley, *John Henry Lefroy*, 31.

94 Lefroy to Sabine, 31 August [1840?], TNA BJ/3/81/16; and Lefroy to Sabine, 17 November 1840, TNA BJ/3/81/20.

95 Lefroy to Sabine, [1839?], TNA BJ/3/81/2.

96 Lefroy to his mother, 25 April 1843, in Stanley, *John Henry Lefroy*, 4. Emphasis added.

97 Lefroy, *Autobiography*, 75.

98 JLVI, 237, 11 September 1844; and Lefroy to his mother, 30 September 1843 – 2 January 1844, in Stanley, *John Henry Lefroy*, 65.

99 Lefroy to his sister, Isabella, 18 October 1844, in Stanley, *John Henry Lefroy*, 129.

100 Stanley, *John Henry Lefroy*, xx. Emphasis in original.

101 MacDonald and Withers, 'Introduction," 9-10; Richard Dunn, 'North by Northwest? Experimental Instruments and Instruments of Experiment," in *Geography, Technology and Instruments of Exploration*, 57-75; and Simon Naylor, 'Weather Instruments all at Sea: Meteorology and the Royal Navy in the Nineteenth Century," in *Ibid*., 77-96.

102 JLVI, 204, 25 August 1843.

103 Binnema, 31.

104 Lefroy, 18 June 1843, *Diary*, 88; Lefroy to his mother, 6 June – 1 July 1843, in Stanley, *John Henry Lefroy*, 28.

105 Levere, *Science and the Canadian Arctic*, 4.

106 Smith, 'Humboldt," 36. Weyprecht quoted by Smith from Dictionary of National Biography, II, 841.

107 Davis Baird, *Thing Knowledge: A Philosophy of Scientific Instruments* (Berkeley: University of California Press, 2004): 19.

108 Bruno Latour, *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, Mass. and London: Harvard University Press, 1999): 304.

109 Stephen Graham and Nigel Thrift, 'Out of Order: Understanding Repair and Maintenance," *Theory, Culture and Society* 24, (2007): 1-25, 2, quoted by DeSilvey, 'Object Lessons," 150.

110 Schaffer, 'Easily Cracked," 710.

111 Lefroy, *Diary*, 18.

112 'Socio-spatial biography" is a term found in Pike, A., 'Placing Brands and Branding: A Socio-Spatial Biography of Newcastle Brown Ale," *Transactions of the Institute of British Geographers* 36 (2011): 206-222; 'Spatio-temporal" is a term found in Hill, J., 'Travelling objects: The Wellcome Collection in Los Angeles, London and Beyond," *Cultural Geographies* 13 (2006): 340-366

113 Pike, 'Placing Brands and Branding," 206

114 See DeSilvey 'Object Lessons," 147.

115 Pauli Tapani Karjalainen, 'On Geobiography," in *Place and Location: Studies in Environmental Aesthetics and Semiotics III*, ed. V. Sarapik and K. Tüür (Tallinn: Estonian Literary Museum): 87-92, 87

116 DeSilvey, 'Object Lessons," 147.

117 Matthew Goodman, 'Proving Instruments Credible in the Early Nineteenth Century: The British Magnetic Survey and Site-Specific Experimentation," *Notes and Records of the Royal Society* 70, (2016): 251-268.

118 Jenny Bulstrode, 'Men, Mines and Machines: Robert Were Fox, the Dip-Circle and the Cornish System," (Unpublished MA thesis, University of Cambridge, 2014).

Early Canadian Botanical Photography at the Exposition universelle, Paris 1867

Brendan Cull [1]

Abstract: Sites et végétaux du Canada *was an early photographic experiment in botanical illustration. Presented at the 1867 Paris exposition, the album's 35 albumen prints were part of the Canadian displays. The photographs were a collaborative effort between Joseph-Charles Taché, Canada's Executive-Secretary at the exposition; Louis-Ovide Brunet, a Catholic priest and botany professor at the Université Laval; and Livernois & Cie, a Québec City photography studio. Previous work has considered the album as the aesthetic accomplishment of Jules-Isaïe Benoît dit Livernois, excluding Taché and Brunet from the art historical narrative. In this paper, I consider the album's political and botanical contexts, and viewership, to more clearly situate the album in the visual culture of early Canadian science. In its representation of Canadian landscapes and native-plant specimens, the album effectively employed photography to present Canada as a centre of cutting-edge scientific investigation.*

Résumé : *« Site et végétaux du Canada » était une expérience pionnière en illustration botanique. Présenté dans la pavilion canadienne à l'exposition de Paris en 1867, l'album présentait 35 impressions d'albumine. Les photographies résultaient d'un effort collaboratif entre Joseph-Charles Taché, Secrétaire-exécutif du Canada à l'exposition, Louis-Ovide Brunet, prêtre catholique et professeur de botanique à l'Université Laval, et Livernois & Cie, un studio de photographie de la ville de Québec. Les recherches passées considérait l'album comme un accomplissement esthétique de Jules-Isaïe Benoît dit Livernois, excluant la contribution de Taché et Brunet de leur narration. Je prends en compte les contextes botanique et politique, et celui de la publique pour mieux situer l'album dans la culture visuelle de la science canadienne naissante. En effet, dans sa représentation, l'album a efficacement employé la photographie pour présenter le Canada comme un centre d'investigation scientifique de pointe.*

Keywords: **Botany, Photography, Botanical Illustration, Joseph-Charles Taché, Louis-Ovide Brunet, Livernois et Cie., History of Botany, 1867 Exposition universelle**

NESTLED WITHIN THE PHOTOGRAPHY EXHIBITS presented by the Province of Canada[2] at the 1867 Exposition universelle d'art et d'industrie in Paris, France, an album of botanical photographs offered a unique perspective on the landscapes and plant species in the vicinity of Québec City to the international audience that attended the event. As part of the larger Canadian display (seen in **Figure 1**), Ovide Brunet's *Sites et végétaux du Canada* was viewed within a space that also contained lumber, geological specimens, fine art, bookbinding, and approximately two hundred other photographs. While the Canadian contributions to the Paris exposition were included physically within the

Brendan Cull, "Early Canadian Botanical Photography at the Exposition universelle, Paris 1867" *Scientia Canadensis* 39, 1 (2016-17): 27-50.

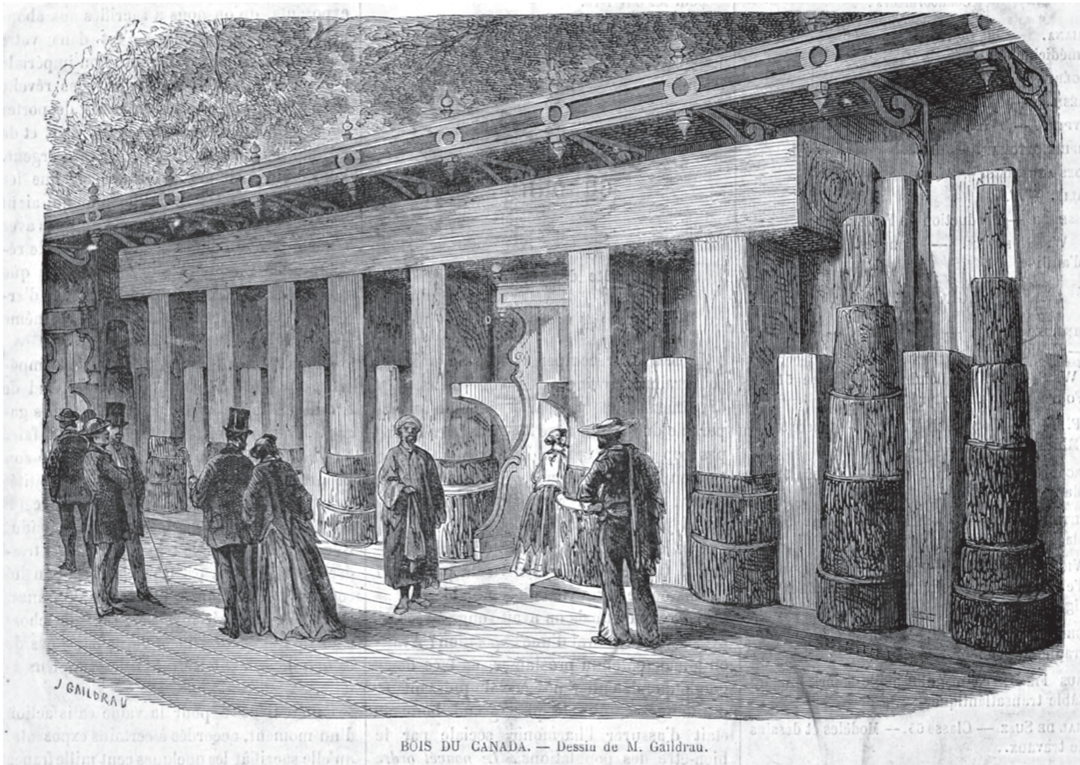


Figure 1. *M. Gaildrau, Bois du Canada. L'Exposition Universelle de 1867 Illustrée 1, no.18 (Paris, Bureaux: d'abonnements, 1 July 1867): 288. From: Hathi Trust Digital Library, https://babel.hathitrust.org/cgi/pt?id=gri.ark:/13960/t55f26f5p;view=1up;seq=294 (accessed 6 April 2017).*

exhibition space devoted to "Britain and its Colonies" and described in the catalogues and reviews about the British displays, these objects asserted a distinctly Canadian character and narrative through their emphasis on Canadian landscape imagery, natural resources, and industry, especially by highlighting the emerging country's plant assets.

Published in 1866, on the cusp of Confederation when "Canada" consisted of Canada East and Canada West, *Sites et végétaux du Canada* (**Figure 2**) was the brainchild of Joseph-Charles Taché (1820-1894), the Executive-Secretary for Canada at the 1867 Exposition universelle in Paris.[3] It was created through a collaboration between Louis-Ovide Brunet (1826-1876), a Catholic priest and Université Laval botany professor, and the Atelier photographique de Livernois & Cie., both of Québec City. Little has been known about this project apart from facts about its basic physical makeup and a brief analysis which connects it to the work of the Livernois photography studio. There are two copies of the album known to the author. The only complete version, which has received some attention from historian Michel Lessard,[4] is preserved in the archives of the Musée de la civilisation in Québec City; an incomplete copy is held in the library at Université de Montréal.[5] More a portfolio of loose pages than a bound book of photographs, the Québec album, composed of twenty-five sheets of heavy card onto which thirty-five albumen prints are pasted, provides

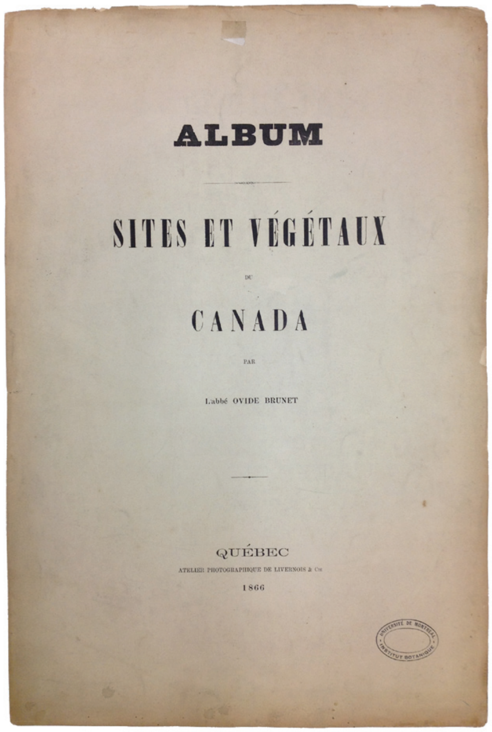


Figure 2. *Title Page from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

a foundation for the current study. The second copy, which has been previously overlooked, contains eighteen plates and twenty-nine photographs.[6] Along with providing a complete description of the physical makeup of both albums, I explore *Sites et végétaux du Canada* as a case study to understand more clearly the connections between it and the study of plants as part of nineteenth-century scholarly research. This analysis examines botanical photography and its use in the dissemination of information about Canada's flora in the Canadian display at the 1867 Exposition universelle in Paris. Through the nascent technology of photography—used as a tool of botanical illustration—*Sites et végétaux du Canada* presented Canada as a centre of cutting-edge scientific experimentation.

Early Intersections of Botany and Photography

Botanical study became a global enterprise in the nineteenth century. Plant taxonomy, physiology, geographical range, and economic applications drove data collection and classification efforts in this emerging area of science. As Suzanne Zeller notes in *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation,* botany formed an important part of a growing interest in assessing the economic and technological potential of Canada East and Canada West; plants became important to Canada's image. Zeller also observes that botany was employed as a template for interpreting and forecasting British North American progress. Ideas connecting botanical theory to human cultural development, over space and through time, circulated throughout the nineteenth century in the hope of forming a scientific measure of progress and development.[7] At this moment as well, new printing technologies—including colour lithography, photography, and the steam press—arrived in North America, enabling the inexpensive publication of visual information, making the combination of text and images increasingly present and accessible.[8] Photography offered realism, accuracy, and exact reproducibility, qualities of great interest to those invested in sharing art and science. Thus, the study of botany and the practice of photography simultaneously exploded in popularity during the nineteenth century.

Many of photography's inventors and early proponents actively engaged in producing photographic images of botanical subjects. Such an immediate entwining was the result of common interests amongst practitioners of botany, photography, and illustration. As Larry J. Schaaf explains in *Out of the Shadows: Herschel, Talbot and the Invention of Photography*, key figures in the early history of photography experimented with botanical imagery. Thomas Wedgwood (1771-1805) and Humphry Davy (1778-1829) worked towards recording images on paper and leather using silver nitrate, but ultimately failed to fix these images. While they were mainly interested in the reproduction of paintings and profiles using his method,[9] Schaaf points out that they also produced camera-less images of plants. Joseph Nicéphore Niépce (1765-1833) invented an early photographic process which produced printing plates on pewter through the long exposure of bitumen of Judea to sunlight. He intended the technology to be used as an illustrative medium and travelled from France to London to find a patron for his invention, which he called *héliographie*. While Schaaf concedes that it is not clear what Niépce's intentions were for his process, Franz Bauer (1758-1840), a noted and respected botanical illustrator at the Royal Botanic Gardens at Kew, known for his highly detailed scientific artwork, was a great advocate of Niépce's invention.[10]

Following the public announcement of the method developed by Louis Jacques Mandé Daguerre (1787-1851) for capturing a unique image on a silver-coated copper plate in 1839, Andreas Ritter von Ettingshausen (1796-1878), an Austrian academic, became interested in the application of the daguerreotype in science. Having learned the process from Daguerre himself, he took the information back to his home country, where he displayed his images for colleagues at the University of Vienna and the general public. In 1840, he photographed a cross-section of clematis stem using a microscope and artificial lighting.[11] The resulting daguerreotype depicted a magnified (if distorted) image of the cell structures of this plant specimen.[12]

Anna Atkins (1799-1871) created the very first photographically illustrated book, entitled *Photographs of British Algae: Cyanotype Impressions,* in 1843. It was composed entirely of botanical photograms (camera-less images). Using the cyanotype process invented by John Herschel (1792-1871), Atkins placed specimens of algae on sensitized paper, creating negative images directly from the specimens themselves. The result was a unique image in which the plant form appears as a white shape on a deep blue background.[13]

William Henry Fox Talbot (1800-1877) publicly displayed examples of his "photogenic drawings" of plants in exhibitions, published them in scientific journals, sent them to leading botanists, and included one as an illustration in his famous treatise on the use of photography, *The Pencil of Nature* (1844-1846). Talbot was vocal about the potential he saw in photography for botanical study. Graham Smith, in his article, "Talbot and Botany: The Bertoloni Album," highlights Talbot's enthusiasm as he shared his ideas about botanical photography with his scientific contacts, prominent figures in the rapidly expanding field of botany. Around 1839, Talbot sent early photogenic drawings to Antonio Bertoloni (1775-1869), based in Bologna, and to William Jackson Hooker (1785-1865), at the Royal Botanic Gardens at Kew in London, with the suggestion that his process could be useful for sharing information, reproducing the form of plants, and solving the problem of transporting botanical specimens, since plants could be left behind, and lightweight, thin paper photographs could be carried home.

The reception of Talbot's botanical photography was mixed. In an exchange of letters, Bertoloni and Talbot actively discussed the identification of the plants depicted in his photogenic drawings, employing them as a taxonomic tool. However, the legibility of the photographic image was a frustration for botanists. Hooker, according to Smith, was less than impressed with the lack of detail in Talbot's images as a method of collecting information from nature, suggesting instead that his process could more effectively be used to reproduce botanical drawings.[14] These photogenic drawings, as Talbot explained in the text that accompanies Plate VII, *Leaf of a Plant*, from *The Pencil of Nature*, were produced by placing the plant directly onto a sensitized sheet of paper, securing the specimen under a clear glass plate, and exposing it to light. By repeating the procedure, the tonal values could be reversed to create the final positive print.[15] While this method had the advantage of reproducing plant specimens to size, Talbot's photogenic drawings were ultimately unsuccessful because they were not effective at capturing the kind of detail that botanists, like Hooker, expected of botanical illustration.

Scholars of botanical illustration have suggested that experiments in botanical photography slowed following these early experiments.[16] However, despite initial pushback from botanists, including Hooker, photography remained an intriguing means of depicting plants. In "Given time: biology, nature and photographic vision," Steve Garlick notes the conceptual and scientific qualities that made photography an appealing medium for the depiction of flora in the nineteenth century. He suggests that photography's ability to fix a moment in time was seen as an asset in the examination of specimens, which were often ephemeral, and would degrade as a consequence of desiccation or pressing: photography allowed the viewer to assess short-lived qualities of a plant long after the original specimen was lost.[17] This was in line with the goals of a notion that emerged during the nineteenth century, what Lorraine Daston and Peter Galison term, "mechanical objectivity," by which they refer to "new methods aimed at automatism: to produce images 'untouched by human hands,' neither the artist's nor the scientist's. Sometimes but not always, [in the nineteenth century] photography was the preferred medium for these 'objective images.'"[18] Machines became emblematic of certain virtues, which were deemed important to scientific research, with restraint being an important feature of avoiding subjective interpretations. Kelley E. Wilder expresses this idea in her book, *Photography and Science*, stating that, to the nineteenth-century observer, photography "was mechanical, and so indefatigable. It was indiscriminate, and therefore objective. It was optical, and consequently, reliable."[19]

The inability of photography to capture fine detail and produce readable images continued to frustrate photographers as technologies improved. The wet-plate collodion process, introduced in 1851, was an improvement on previous paper- and metal-based media in terms of clarity and reproducibility. Glass plates provided a transparent and durable surface onto which a photo-sensitive emulsion could be applied. The resulting negatives were used to create an unlimited number of finely detailed prints on paper. Despite this, as Elizabeth Eastlake pointed out in her essay "Photography," published in *The London Quarterly Review* in April 1857, there were limitations to the prevailing technology for imaging plants in general:

> The colour green, both in grass and foliage, is now his [the photographer's] great difficulty. The finest lawn turns out but a gloomy funeral-pall in his hands; his trees, if done with the slower paper process, are black, and from the movement, uncertain webs against the white sky,—if by collodion, they look as if worked in dark cambric, or stippled with innumerable black and white specks; in either case missing all the breadth and gradations of nature.[20]

Eastlake's criticism, when applied to botanical illustration, raises a number of concerns. In keeping with Hooker's complaints about camera-less images, the contemporary photographic technologies at hand struggled to achieve images comparable to hand-rendered artworks capable of reproducing colour (especially green) and tonal range, both important to capturing the characteristics of plant specimens. Nevertheless, by the mid-1860s, photography had advanced as an imaging technology. Despite its lack of colour, the clarity and detail achievable with the wet-plate collodion process enabled better opportunities for illustrating plants. A little over two decades after the initial experiments of Talbot, Atkins, and von Ettingshausen, Taché approached Brunet to create *Sites et végétaux du Canada*.

The Album in the Literature

Previous inquiry into the creation and reception of *Sites et végétaux du Canada* is limited to two works by Michel Lessard: an article entitled, "Focus sur les villas et les fleurs: Deux primeurs signées Livernois" and a book, *Les Livernois, photographes*.[21] In both, Lessard refers exclusively to the album at the Musée de la civilisation in Québec City and focuses on the authorship of the images, connecting the photographs to the larger work of the Livernois family and their successful photography business in Québec City. More specifically, Lessard attributes the images to Jules-Isaïe Benoît dit Livernois (1830-1865) but notes that the publication was completed in 1866 by Jules' wife, Élise Livernois (née L'Hérault dit L'Heureux, 1827-1896), and son-in-law, Louis Bienvenu (?-1876), following Jules' untimely death.[22]

In his brief article in *Cap-aux-Diamants: la revue d'histoire du Québec*, Lessard provides a general impression of the variety of images, which make up the album. He reports:

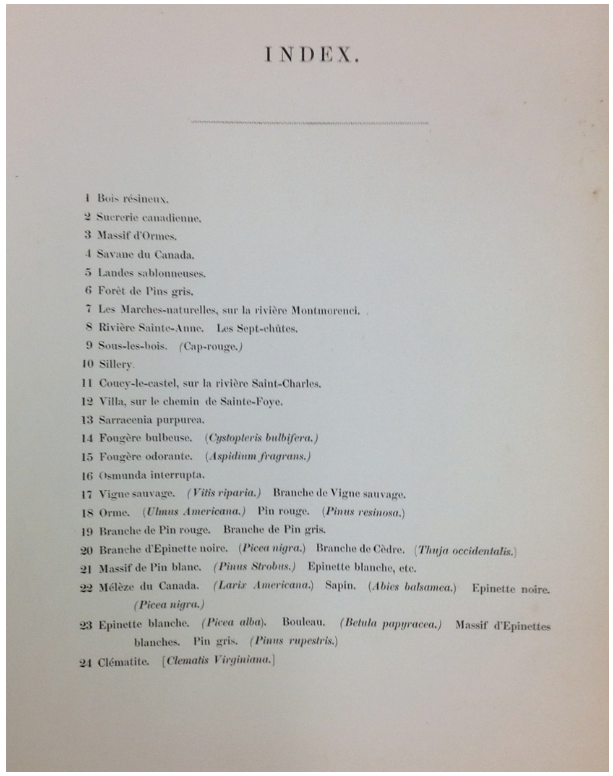
> L'Album: Sites et végétaux du Canada, de l'abbé Ovide Brunet, comporte 24 planches de 43cm par 35cm comprenant 34 épreuves de différents formats ilustrant [sic] des massifs d'arbres, des phénomènes géomorphologiques comme les marches naturelles de la rivière Montmorency, des variétés de plantes dont quelques fougères, des jardins de villas, la tradition acéricole dans une mise en scène naïve réalisée en plein été dans un théâtre de clercs en soutane. Plusieurs vues sont prises sur le terrain; d'autres ont été l'objet de montages en studio.
>
> [The Album: Sites et végétaux du Canada, by Abbé Ovide Brunet, contains 24 plates, measuring 43 cm by 35 cm, with 34 photographic prints of various sizes, illustrating stands of trees, geomorphological phenomena such as the natural steps of the Montmorency River, various species of plants including ferns, villa gardens, the tradition of maple syrup production in a natural setting staged in full summer by priests in cassocks. Several photographs are taken on location; others were constructed in the studio.][23]

Lessard's analysis of the photographs centres on their aesthetic value. He emphasizes the connection between Livernois' images of plants and those of "the early light painters," highlighting the work of Talbot and pointing to similarities in the simplicity of composition. He also notes the accomplishment of the Livernois photography studio in creating the first photographic herbarium in Canada.[24] However, this concise treatment of *Sites et végétaux du Canada* does not consider the botanical context within which this album was produced. As a result, Ovide Brunet is acknowledged only in passing, as the man who commissioned the photographs, and Taché is not mentioned. In the section that follows, I provide a detailed description of the two existing albums to enable a better understanding of their physical and conceptual makeup. I also connect the images with contemporary challenges and trends in photography.

The Québec City Album

The only known complete version of *Sites et végétaux du Canada* is housed at the Musée de la civilisation in Québec City. The archival collection to which it belongs (the *fonds* d'archives du Séminaire de Québec) also includes resources related to Ovide Brunet's personal and professional life. Since this album contains all of the images described in its index, and because Lessard has previously written about this version, it offers a baseline for comparison.

The basic components of the Québec City album can be broken down into four elements: 1) cover, 2) title page, 3) index, and 4) plates. The cover appears to be original and is made of red fabric-covered cardboard with red crosshatch-textured leather on the corners and spine. The album is not currently bound, and there is no indication of glue or sewing on the edges of the title page, index, and plates. The title, which appears in gilt lettering along the spine and on a leather title insert on the front of the cover does not include accents and reads, "SITES ET VEGETAUX DU CANADA PAR L'ABBE O. BRUNET." Green endpapers line the inside of the cover, which was originally fastened around the contents of the album using four ribbon ties, one set on the top and bottom, and two along the right side (opposite the spine); only three of the four ties are extant.[25] The presence of this type of fastening suggests that



INDEX.

1 Bois résineux.
2 Sucrerie canadienne.
3 Massif d'Ormes.
4 Savane du Canada.
5 Landes sablonneuses.
6 Forêt de Pins gris.
7 Les Marches-naturelles, sur la rivière Montmorenci.
8 Rivière Sainte-Anne. Les Sept-chûtes.
9 Sous-les-bois. *(Cap-rouge.)*
10 Sillery.
11 Coucy-le-castel, sur la rivière Saint-Charles.
12 Villa, sur le chemin de Sainte-Foye.
13 Sarracenia purpurea.
14 Fougère bulbeuse. *(Cystopteris bulbifera.)*
15 Fougère odorante. *(Aspidium fragrans.)*
16 Osmunda interrupta.
17 Vigne sauvage. *(Vitis riparia.)* Branche de Vigne sauvage.
18 Orme. *(Ulmus Americana.)* Pin rouge. *(Pinus resinosa.)*
19 Branche de Pin rouge. Branche de Pin gris.
20 Branche d'Epinette noire. *(Picea nigra.)* Branche de Cèdre. *(Thuja occidentalis.)*
21 Massif de Pin blanc. *(Pinus Strobus.)* Epinette blanche, etc.
22 Mélèze du Canada. *(Larix Americana.)* Sapin. *(Abies balsamea.)* Epinette noire. *(Picea nigra.)*
23 Epinette blanche. *(Picea alba).* Bouleau. *(Betula papyracea.)* Massif d'Epinettes blanches. Pin gris. *(Pinus rupestris.)*
24 Clématite. *[Clematis Virginiana.]*

Figure 3. *Index from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

the title page, index, and plates were likely never bound to the cover. In this sense, the "album" is, more correctly, a portfolio. However, as the title page refers to the work as an album (see **Figure 2**), I shall continue to use the term in this article.

The title page and index are printed in black letterpress, on the same sheet of paper, which is folded in half, along its width, with the text appearing on the recto of each resulting page. The title page identifies the project as "ALBUM SITES ET VÉGÉTAUX DU CANADA PAR L'abbé OVIDE BRUNET." The Atelier photographique de Livernois & Cie. is credited within the publisher's information, listed along with the place and date of publication, "Québec 1866." The index (**Figure 3**) presents a numbered list of twenty-four plates, along with the corresponding titles for each of the thirty-five photographs that comprise this version of the album.

While the index lists twenty-four plates (which here refer to the pages as a whole, with photographs, page numbers, and captions), this album actually contains twenty-five because the two photographs listed as the images on plate 8 (entitled *Rivière Sainte-Anne* and *Les Sept-chûtes*, respectively) actually appear on two separate plates, both labeled "8." The plates are numbered on the top right corner when viewed in portrait orientation. They are made of thick card and measure 14 inches by 21 inches (approximately 35 cm by 53 cm), with the exception of the two plates labelled "8," which are smaller, 13 inches by 16 inches (approximately 33 cm by 40.5 cm). The size, orientation, and proportions of the photographs differ from plate to plate. The number of photographs pasted onto each plate varies as well: plates 1-16 and 24 each contain one photograph; plates 17-21 have two photographs; plate 22 includes three; and plate 23 has four. Image captions are printed in letterpress under each image. They include place or plant names in French. The plants are identified using French-Canadian common names and many are also labeled with Latin binomial nomenclature. The photograph captions printed on the plates correspond to the ones in the index.

The Montréal Album

A second version of *Sites et végétaux du Canada* is currently housed in the Bibliothèque des livres rares et collections spéciales at Université de Montréal, as part of the "Collection botanique." It is likely that the album came to be part of this collection through the institution's historical and academic connections with Université Laval. The fact that Université de Montréal was originally a satellite campus of Laval would account for the album's presence in the botanical collections of the university.[26]

Like the Québec City version, this album consists of a cover, title page, index, and plates. However, the current cover is not original, and six of the plates listed in the index are missing. It consists of plates 1-2, 4-6, 8, and 13-24, which follow the order and organization presented in the index. The plates are approximately the same size in both albums.[27] In contrast to the album in Québec City, the Montréal version contains a single plate, labeled "8," with smaller prints of both photographs listed in the index.

The existence of a second album and letterpress title page, index, captions, and page numbers in both, suggests a high monetary investment in the project. This, in turn, implies that more than one album might have been printed to maximize the overall cost of printing. It is unclear, at this point, whether any other copies of *Sites et végétaux du Canada* were made or have survived.

The Origins of the Album

The idea of a photographic album featuring Canadian botany appears to have been the brainchild of Joseph-Charles Taché, the Executive-Secretary for Canada at the 1867 Exposition universelle in Paris. It is important to reiterate that, when planning began, Confederation was on the horizon and "Canada" still consisted of Canada East and Canada West. The title page bears the date 1866 and the origins of this project are recorded in Ovide Brunet's journal. On 23 August 1866, Brunet received a letter from Taché asking him to have photographs of plants, shrubs, and trees (in isolation and in groups) made for the Canadian display in Paris. From the beginning, Brunet advocated the inclusion of landscape images in the project, writing, "Je me propose de faire exécuter les choses suivantes: 1. une savane, 2. une forêt, 3. une érablière, 4. une pinière, 5. massif d'ormes, 6. aster et solidago, et autant d'arbres isolés que possible. [I propose to have the following photographs made: 1. a bog, 2. a forest, 3. a sugar maple bush, 4. a pine forest, 5. stand of elms, 6. aster and solidago (goldenrod), and as many individual tree specimens as possible]."[28]

These additions to Taché's initial request reflect Brunet's academic interest in the geography of Canadian botany. In her analysis of Canadian scientific practices of the mid-nineteenth century, Suzanne Zellar notes a burgeoning international interest in biogeography, following work by Alexander von Humboldt (1769-1859), Augustin Pyramus de Candolle (1778-1841), and William Jackson Hooker on the physical distribution of plants across geographic space.[29] Brunet's own interest in geography, as it applied to the study of Canadian flora, is clear in many of his writings. For example, his first academic publication, entitled *Voyage d'André Michaux en Canada depuis le Lac Champlain jusqu'à la Baie d'Hudson* (published in 1861), traced the location of plants described by French botanist André Michaux (1746-1802) in *Flora Boreali-Americana* (1803). Drawing from Michaux's notes, herbarium specimens housed at various institutions in Paris, and a manuscript at the library of the American Philosophical Society in Philadelphia, Brunet outlined the geographic ranges of common and rare plants throughout the British North American possessions and around Hudson Bay.[30] This theme is clear in the addition of various botanically relevant sites to the project. However, if elements of both Taché's and Brunet's vision for the project can be seen in the photographs that ultimately ended up in *Sites et végétaux du Canada*, it is clear that the Livernois studio also had a major impact. Below, I describe the photographs, highlighting how they interact within the album and relate to the broader work of its creators.

The Photographs

Sites et végétaux du Canada can be divided into two parts, thematically. The first half, plates 1-12, showcases images of landscape. An outstanding feature of these photographs is the presence of trees, which function to frame scenes, provide variety, or serve as focal points themselves. Each of these photographs is composed in order to include whole tree specimens. The second half, plates 13-24, presents images of plant specimens both *in situ* (outdoors) and *ex situ* (in the studio environment). They depict a number of different ways of illustrating plants in their entirety or in parts. Within this thematic split, further analysis suggests that the thirty-five images in the album can be divided into five distinct groups based upon the treatment of their subject matter. The photographs from the Montréal album, reproduced for the first time here, illustrate the various ways plants are represented in *Sites et végétaux du Canada*. I have selected images that have not appeared in previous publications.

The first group is composed of four photographs that highlight natural habitats in the vicinity of Québec City, with emphasis on the geographies of the sites depicted. These include a coniferous wood (*Bois résineux*), a bog (*Savane du Canada*), a sandy ridge (*Landes sablonneuses*; see **Figure 4**), and a jack pine forest (*Forêt de Pins gris*). Each of the photographs in this group focuses on an expansive landscape, punctuated by plants and large, mature trees. These images are the direct result of Brunet's enthusiasm for a geographical approach to botany.

The second group contains nine images of human interactions within the Canadian landscape. There is a focus on leisure and grand estates in these photographs, which include a tableau of maple-sugar making (*Sucrerie canadienne*; **Figure 5**) and a rural farming scene (*Massif d'Ormes*). This section also includes an image of two men standing on the naturally occurring limestone steps of the Montmorency River (*Les Marches-naturelles, sur la rivière Montmorenci*); two photographs of river and waterfall scenes (*Rivière Sainte-*

Figure 4. *Landes sablonneuses. Albumen print, approximately 200 x 320 mm, cardboard mount 350 x 530 mm. Plate 5 of Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

Figure 5. *Sucrerie canadienne. Albumen print, approximately 200 x 320 mm, on a cardboard mount approximately 350 x 530 mm. Plate 2 from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

Anne and *Les Sept-chûtes*); and, finally, four photographs of country estates, set within the forest (*Sous-les-bois (Cap-rouge)*, *Sillery*, *Coucy-le-castel, sur la rivière Saint-Charles*, and *Villa, sur le chemin de Sainte-Foye*). Brunet noted the creation of *Sucrerie canadienne* in a journal entry from August 1866.[31] However, Jules Livernois died in 1865 and it is not clear from the journal who created many of the photographs that Brunet envisioned for the album. We do know that the four images of the country estates were used to illustrate an essay, entitled "Our Country Seats," published in 1865 in the third series of *Maple Leaves*, by James MacPherson Le Moine (1825-1912). These are attributed to Jules Livernois.[32] Overall, the photographs in this group emphasize the beauty and utility of the countryside close to Québec City, for leisure, work, and habitation, accentuating the established forests of the landscape.

The third group presents five plant specimens, either whole or in part. These photographs—of *Sarracenia purpurea* (**Figure 6**), *Fougère bulbeuse (Cystopteris bulbifera), Fougère odorante (Aspidium fragrans)*, *Osmunda interrupta*, and *Branche de Cèdre (Thuja occidentalis)* – each depict plant material placed against a white background, in the style of herbarium vouchers, which preserved pressed plant specimens, mounted on card and with accompanying botanical information. They reflect a more traditional treatment of plant images, referencing established conventions of Western botanical illustration and botanical photography. Lessard connects the aesthetic of these specimen photographs in *Sites et végétaux du Canada* to the work of "early light painters," such as Talbot and Atkins. The comparison is understandable. The image from the album reproduced in Lessard's *Les Livernois, photographes*, which launched the current investigation, at first glance appears to be a camera-less image. However, upon closer inspection, a tell-tale shadow behind the specimen reveals that this and similar photographs in *Sites et végétaux du Canada* were not made by placing the plants directly onto light-sensitive photographic paper, but rather were taken with a camera. The resulting image is not a record of the plant's shadow, but of the light reflected off its surface, thus allowing the photographer to capture botanical information, including form, surface morphology, venation, and texture.

This difference in process would have been significant for Brunet, since he was an adept artist who created illustrations for some of his own publications. During an educational tour of Europe in 1861-1862, which was a requirement of his promotion to Chair of Natural History at Université Laval, Brunet became familiar with the work of prominent figures in the history of Western botanical illustration, including Pierre-Joseph Redouté (1759-1840).[33] The botanical images produced by Redouté and his circle were precise, set against a blank background, full colour, and visually striking. While photography was limited to a monochromatic palette, the images on plates 13-16 and 20 of *Sites et végétaux du Canada* reflect those characteristics of Redouté's work that could be achieved within the medium. The manner in which these photographs are composed, with the leaves and stems intact but with no roots at the base,

Figure 6. *Sarracenia purpurea. Albumen print, approximately 250 x 300 mm, cardboard mount 350 x 530 mm. Plate 13 from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

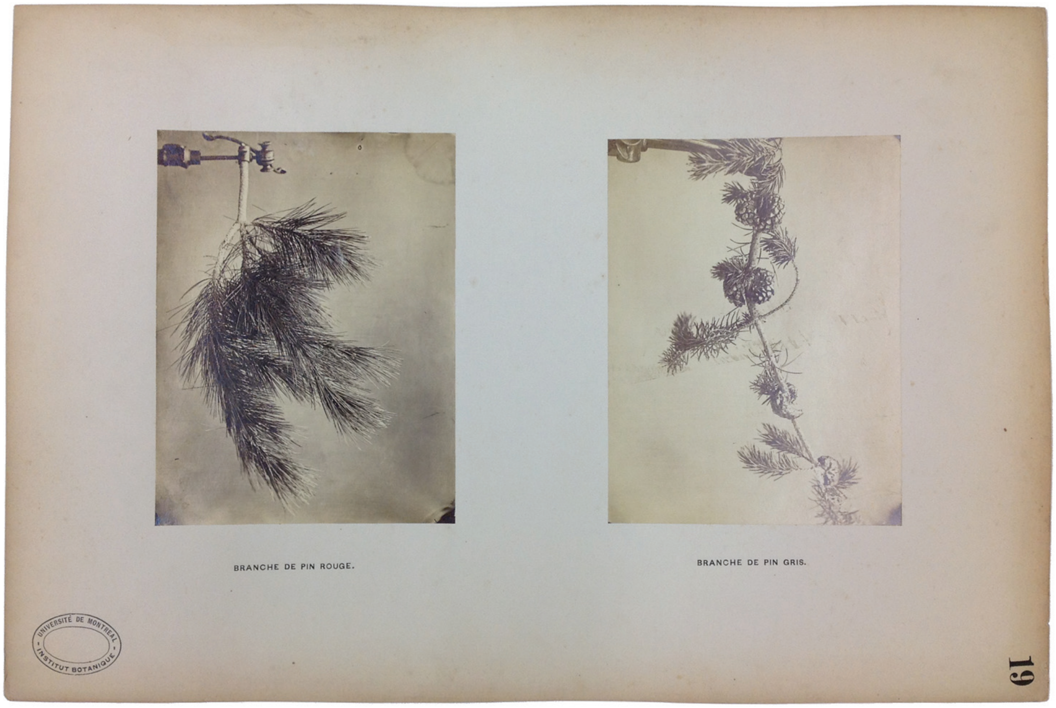


Figure 7. *Branche de Pin rouge and Branche de Pin gris. Albumen prints, each approximately 150 x 200 mm, on a cardboard mount 350 x 530 mm. Plate 19 from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

closely emulates the way in which Redouté chose to depict herbaceous plant specimens.

A fourth group of six photographs is comprised of "studio portraits" of plant specimens presented on metal armatures (possibly retort stands commonly used in the laboratory) against an unadorned backdrop. Those include *Branche de Vigne sauvage*, *Branche de Pin rouge* and *Branche de Pin gris* (**Figure 7**), and *Branche d'Épinette noire (Picea nigra)*. Others are shown on simulated architectural props: *Vigne sauvage (Vitis riparia)* is attached to a wall painted to look like an exterior façade, and *Clématite [Clematis Virginiana]* (**Figure 8**) has been wrapped around a balustrade that sits in front of a painted backdrop. All of the photographs in this group showcase the three-dimensionality of the plants, while also demonstrating how they drape over objects (especially the vines) or simulating how they might appear on a tree (as in the individual branches on retort stands). Combining some of the conventions of botanical illustration employed by artists such as Redouté, these photographs also reflect an experimental approach to the depiction of these specimens.

The fifth group includes eleven images of trees, taken outside and set against the sky. Distinct from the first and fourth groups, which also depict trees and tree limbs, photographs in this group focus on one or more whole specimens in natural surroundings. *Orme (Ulmus Americana)* and *Pin rouge (Pinus resinosa)*,

Figure 8. *Clématite [Clematis Virginiana]. Albumen print, approximately 140 x 200 mm, on a cardboard mount 350 x 530 mm. Plate 24 from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

Massif de Pin blanc (Pinus Strobus) and *Épinette blanche, etc.*, *Mélèze du Canada (Larix Americana)*, *Sapin (Abies balsamea)* and *Épinette noire (Picea nigra)* (**Figure 9**), and *Épinette blanche (Picea alba)*, *Bouleau (Betula papyracea)*, *Massif d'Épinette blanches* and *Pin gris (Pinus rupestris)* all clearly communicate the growth form of the trees depicted. Each is taken from a low angle to maximize the contrast between tree and sky.

The photographs in this group employ one of the weaknesses of early photography to botanical advantage to delineate overall physical form. Nineteenth-century critics of photography complained that when the sky was properly rendered in a photograph, the landscape was left dark and underexposed; correct exposure of the landscape left the sky completely white due to the insensitivity of early photographic emulsions to the colour blue.[34] The sky in this last group of images in *Sites et végétaux du Canada* is overexposed and blank; however, this feature helped to isolate trees from their environment, enough to obtain clear images of their shapes, much like the blank backgrounds employed in more traditional depictions of trees in botanical illustration.

Ultimately, along with the skill of the Atelier photographique de Livernois & Cie. photographers, Taché's vision for the project and Brunet's botanical eye can be seen in the photographs. Their respective contributions are clear in the thematic organization of the images, with the inclusion of Canadian landscapes

Figure 9. *Mélèze du Canada (Larix Americana) (right), Sapin (Abies balsamea) (centre) and Épinette noire (Picea nigra) (left). Albumen prints, each approximately 150 x 200 mm, on a cardboard mount 350 x 530 mm. Plate 22 from Ovide Brunet, Sites et végétaux du Canada, Québec: Atelier Photographique de Livernois & Cie, 1866. Approximately 350 x 530 mm. Image reproduced courtesy of Université de Montréal. Bibliothèque des livres rares et collections spéciales. Collection Botanique, QK 201 B785 1866 / CSz.*

and plants, and in the ways in which the botanical specimens are depicted with reference to established conventions of botanical illustration. This analysis of content and composition complicates a strictly aesthetic view of the album. At the same time, more research is required better to understand the role of the Atelier photographique de Livernois & Cie. in the album's creation, beyond its role as a publisher and, potentially, a supplier of images from a catalogue of previous work. Having laid out the album's visual program, I now turn to an analysis of the photographs within the larger Canadian display to which it belonged.

Sites et végétaux du Canada at the Exposition universelle, 1867

To understand how *Sites et végétaux du Canada* was viewed by those who attended the Exposition universelle in Paris, it is necessary to situate the album, physically and intellectually, within the Canadian displays. From 1 April to 4 November 1867, it was viewed within the vast oval exhibition hall erected on the Champ-de-Mars in Paris, France. Within this building, designed by Frédéric LePlay (1806-1882), each of the participating nations was provided with a triangular space, which was further subdivided into "groups" based upon the type of objects presented. Photography, contained in "Apparatus and Application of the Liberal Arts," was located between "Works of Art," and displays which contained "The Common Arts" and "Industrial Products."[35]

Sites et végétaux du Canada was exhibited within a specific area designated for Canadian photography. In her essay, "Canada in Paris: Krieghoff and the Universal Exhibition 1867," Arlene Gehmacher observes that photography was "a substantial display for Canada, comprising over two hundred works by eight of its most respected photographers of the day, including William Notman, Alexander Henderson, Livernois & Cie., Ellison & Co., Samuel McLaughlin, and J. Smeaton."[36] The reception afforded these photographs was positive. In a review published in *The Photographic Journal*, the *Illustrated London News*, and the official British *Reports on the Paris Universal Exhibition, 1867. Vol. I.,* Charles Thurston Thompson (1816-1868) described the quality of the photographic displays of various nations, specifically reporting that the contributions of Canada were "quite" equal to those of well-established centres of photography such as England and France.[37] As a noted photographer employed at the Department of Science and Art at the South Kensington Museum, Thompson's remarks on Canadian photography were significant endorsements.[38] Having viewed the displays himself, he described many of the images in the exhibition, providing insight into their contents. Of the photographs exhibited by Canada, he wrote:

> *Canada*.—Henderson, A., Montreal, has a very large collection of Canadian views, especially from the neighbourhood of Quebec and on the Ottawa River. These photographs must convey a good idea of the splendour and picturesque character of Canadian landscape. Some of them have been produced instantaneously. Notman, W., Montreal, exhibits large and small portraits of great merit. He also contributes some skating scenes on the St. Lawrence, seal-stalking amongst the ice, and the caribou-stalking in the middle of the wild and romantic country between St. Urbain and Lake St. John. Mr Notman's photographs leave little to be desired. Mr. McLaughlin, photographer to the Board of Works, Canada, exhibits views of Quebec and Montreal—scenes of the timber trade on the Ottawa, timber-yards of Quebec, falls of Montmorency, and delicious wood scenery taken both in summer and in the spring, when the ice, melting under the rays of the sun, gives a peculiar and striking feature to the picture—also public buildings at Ottawa—all excellent photographs. *Livernois, of Quebec, contributes photographs from historical paintings, engravings, plans, and portraits, illustrative of the history of Canada; also a collection of forest trees and plants, and detailed parts for study. He also exhibits some good landscapes* [emphasis added]. Smeaton, J., of Quebec, exhibits interesting views of the miners at work, at rest, and travelling in the gold-fields of the river Chaudière, near Quebec they give a graphic portraiture of a miner's life and of the splendid wild scenes of the native forests in Canada. Ellison and Co., Quebec—Views of Quebec and its environs, autumnal scenes of Canada, &c.[39]

His description of Canada's contributions, which reached different audiences in three noteworthy publications, provides a jumping off point for further analysis. Thompson viewed the album's imagery as didactic ("for study") and connected these photographs to a larger international interest in Canadian flora. This raises the question whether the pages of *Sites et végétaux du Canada* were not bound in order to display more than one plate at a time, thereby encouraging comparative study of the specimens depicted.

World's fairs were important venues for Canadian science. Objects such as *Sites et végétaux du Canada* reflected national interest in advertising the scientific wealth of Canada to the world. In *Histoire des Sciences au Québec: de la Nouvelle-France à nos jours*, Luc Chartrand, Raymond Duchesne, and Yves Gingras claim that these international events helped to demonstrate, especially for the government, that the work of the Canadian science establishment had broad applications. Discussing the inclusion of geological objects in Canada's displays at the 1851 Great Exhibition of the Works of Industry of All Nations, they note that the critical and popular success of such items was a key legitimizing factor for Canadian science within Canada itself and argue that the involvement of institutions, such as the Geological Survey of Canada, provided economic opportunity. Through the celebration of Canada's natural wealth, with the hope of securing further investments and markets, government displays were a public-relations boon, since the country could be viewed as "enlightened and progressive" because of its interest in the sciences.[40] As a result, scientific participation of this kind continued into the 1867 exposition. In this light, *Sites et végétaux du Canada* can profitably be viewed as a product of Canadian science.

Indeed, the mineral wealth displayed internationally by the Geological Survey of Canada was not the only natural resource showcased and endorsed by the government. Plants, especially trees, were an important feature of Canadian international exhibits. Canada was known for a series of "timber trophies," which highlighted lumber from local tree species, at the world's fairs of 1851, 1855, and 1862.[41] Lumber also figured prominently in the Canadian exhibits in Paris in 1867. An impressive display of massive wooden columns, a collection of aesthetically pleasing native woods, and a catalogue of woody plants comprised the largest part of the Canadian court. As seen in an illustration from *L'Exposition Universelle de 1867 Illustrée* (see **Figure 1**), trees and wood products were afforded great prominence.

Brunet's involvement in the exposition was extensive. In the *Reports of the United States Commissioners to the Paris Universal Exposition, 1867,* an anonymous author wrote:

> The Canadian exhibit attracted much attention by the size of the hewed timbers of fir and pine, and the beauty of the specimen slabs of the walnut, maple, oak, ash and other forest trees. This collection was prepared under the direction of the Abbé Brunet, and was accompanied by a complete descriptive catalogue, forming a pamphlet of 64 pages. A gold medal was awarded by the jury.[42]

As indicated in the French government's catalogue of the exposition, Brunet contributed a "Collection de bois avec herbiers et épreuves photographiques d'arbres et de massifs d'arbres [collection of wood with herbaria and photographic prints of trees and stands of trees]."[43] With Brunet's botanical influence evident throughout, a discussion of the relationship between *Sites et végétaux du Canada* and the displays as a cohesive unit is warranted.

Gehmacher confronts a similar contextual challenge in her study of a large, nine-paneled and ornately framed installation of paintings, also displayed at the Exposition universelle in 1867, entitled *Timber Depot, Quebec,* by Cornelius Krieghoff (1815-1872) and William Scott (1831-1904). Relating the subject matter of these paintings, which depict events in the lives of lumbermen, to the overall program of the industrial section of the Canadian exhibits, she argues that they connect with an overall focus on the lumber industry. Gehmacher notes that the huge artwork, despite being a group of framed oil paintings, was placed amidst the photographs and in close proximity to Brunet's grand displays of Canadian wood. She wonders if this positioning resulted from the perceived documentary qualities of Krieghoff's work.[44] A consideration of Canada's photography displays suggests that this may have been a thematic choice. Such an analysis informs our understanding of both *Timber Depot, Quebec* and *Sites et végétaux du Canada.*

The juxtaposition of photographs and paintings of trees, plants, and landscapes, and Brunet's collection of the genuine articles, developed an overall visual narrative that promoted botanical Canadiana. I use the term "botanical Canadiana" here to refer to objects, which were used to associate the history and character of Canada with forestry, forests, plants, and botany. In this way, Canadian flora became intimately linked with the image Canada wished to present to the world. The display offered a narrative of scientific and economic ambition, demonstrating the historical and cultural connections to botany in Canada through artworks, such as *Timber Depot, Quebec* by Krieghoff and Scott, photographic projects, including *Sites et végétaux du Canada,* and the timber display put together by Brunet.

Prompted by Gehmacher's question why *Timber Depot, Quebec* was not exhibited amongst the oil paintings of the Canadian section, I suggest that the subject matter of Canada's photographic display also reveals a larger thematic organization. Each of the photographers mentioned in Thompson's review exhibited scenes of the Canadian landscape, highlighting toil within the forests—lumberjacks (as in McLaughlin's work), miners (Smeaton), and hunters (Notman)—or outdoor recreational activities, especially in the photographs of Henderson, Notman, Livernois, and Ellison. The placement of these photographs together, alongside Brunet's impressive display of wood, created a visual representation of Canada, one that emphasized both the nation's resources and their exploitation. Each item within the larger display performed a rhetorical role in shaping this image of Canada. In this way, the painting installation by Krieghoff, with its ornate wooden frame of local wood by Scott, easily ties in, thematically and conceptually, with the wood specimens and photographic imagery around it. The images and objects that relate to this narrative of botanical Canadiana, are gathered together to tell a story of Canada's rich natural resources, through landscapes and plants, depicted in traditional media and through the nascent technology of photography. *Sites et végétaux du Canada* fits snugly within this narrative, between the aesthetic expression of *Timber Depot, Quebec* and the economic/scientific value represented by the wood samples.

Photography and the Visualization of "Canada"

The inclusion of *Sites et végétaux du Canada* in the Canadian displays speaks to the importance of photography in the visualization of "Canada" in the mid to late-nineteenth century. For Taché, Brunet, and the Atelier photographique de Livernois & Cie., the wet-plate collodion process allowed them to highlight local landscapes, botanical assets, and natural history and present them as typically "Canadian" on an international stage. Considered thus, *Sites et végétaux du Canada* may be viewed as a claim on Canadian scenery and flora by Taché and Brunet for its insertion into the larger history of art and science in Canada. As Joan M. Schwartz has argued in her work on photography as a tool of the "geographical imagination," photography had a profound effect "on strategies of seeing, engaging, and understanding the world—on the process by which people have come to know the world and situate themselves in it; by which they have pictured landscape, invested it with meaning, and articulated their relationship to it."[45] In "Science and Sentiment: The Work of Photography in Nineteenth-Century North America," she further asserts that, in the struggle to define Canadian borders and the geographical concept of "Canada" itself, photographs "were created and conscripted to preserve natural wonders and exploit natural resources, survey boundaries and settle diplomatic disputes, study ancient civilizations and subjugate native peoples, justify Manifest Destiny and celebrate empire."[46] Framed within this body of work, *Sites et végétaux du Canada* can be seen as a visual statement constructed by Taché, Brunet, and the Atelier photographique de Livernois & Cie. about "Canada" at a critical juncture in time. It presents the sites and vegetation of their local environments as representative of the natural wealth and scientific potential of Canada writ large.

Sites et végétaux du Canada was not created in a vacuum. Placing it within various contexts and exploring its connections to nineteenth-century art, science, politics, and economy, broadens our understanding of this photographic project's origins. This case study paves the way for a more detailed investigation of this complex, collaborative project and the relationship between photography and scientific research in Canada during the nineteenth century. Further work is required to tease out the intricacies of such an analysis. Exploring the relationship of the album's photographs to other contemporary botanical practices, such as the creation and collection of plants for herbarium vouchers and catalogues, would provide a broader scientific context for this project. Drawing upon research of scholars such as Ann B. Shteir,[47] a comparison with nineteenth-century Canadian hand-rendered botanical images, including the pressed-plant arrangements of Catherine Parr Traill (1802-1899), prints by Agnes Fitzgibbon (1833-1913), and painted illustrations by women such as Millicent Mary Chaplin (1790-1858) and Fanny Bayfield (1813/14-1891), would shed light on the influence of gender and the professionalization of science on the production of botanical images in the nineteenth century.

Ultimately, *Sites et végétaux du Canada* is representative of wider trends in nineteenth-century botany and photography. At the moment that this album was created, at the height of the wet-plate collodion era and on the verge of Confederation, photography served as a promising visual tool for sharing the botanical wealth of the landscapes explored by Taché, Brunet, and the Atelier photographique de Livernois & Cie. In considering the physical plants and their locations alongside their visual representation, we catch a glimpse into one facet of Canadian botanical illustration during the 1860s. Seen as part of the larger displays of Canada at the 1867 Exposition universelle in Paris, *Sites et végétaux du Canada* effectively employed photography to present Canada as a centre of cutting-edge scientific investigation.

Brendan Cull is a PhD candidate in the Department of Art History and Art Conservation at Queen's University, Kingston. He holds a bachelor of science degree in biology, a bachelor of education degree, and a master's degree in Art History from Queen's University. His doctoral research focusses on the intersection of art and science during the early history of Canadian photography and botany.

Endnotes

1 I am indebted to each of the generous and knowledgeable archivists, librarians, and researchers I have had the privilege of interacting with and learning from, both in person and online, during my research. This project would not have happened without you. I would like to specifically thank Joan M. Schwartz, my graduate supervisor in the Department of Art History and Art Conservation at Queen's University, and Colleen Skidmore (University of Alberta) for their guidance throughout this process. I am also very grateful for the kindness and encouragement received from David Pantalony as I put this article together. I would like to thank the anonymous reviewers who helped make this paper stronger. This research was funded by the Social Sciences and Humanities Research Council's Joseph-Armand Bombardier Canada Graduate Master's and Doctoral Scholarships.

2 Throughout this paper the terms "Canada" and "Canadian" are used as they would have been understood by the creators of *Sites et végétaux du Canada*, living in British North America in 1866 when this project was conceived and created. The "Canadian" displays at the 1867 Exposition universelle are representative of the pre-Confederation colonies of Canada East and Canada West (later known as Québec and Ontario), since the displays were planned and the Exposition universelle began prior to 1 July 1867. Nova Scotia had its own exhibits at the Exposition and was listed separately from "Canada."

3 Thank you to Jacques Cayouette, Research Scientist at Agriculture and Agri-Food Canada, for generously sharing his collection of resources related to Brunet and, in the process, helping to clarify Brunet's relationship to Taché.

4 Michel Lessard is the only person to have written about this album prior to the current study. He describes its contents and interprets some of its images in the article, "Focus sur les villas et les fleurs: deux primeurs signe es Livernois" *Cap-aux-Diamants: la revue d'histoire du Que bec* 3, no. 2 (1987): 7. He also includes a brief mention of the project in *The Livernois Photographers* (Québec: Musée du Québec-Québec Agenda, 1987), 85 and 150-151.

5 The Québec version is currently in the collections of the Musée de la civilisation in Québec City (MCQ: PH2000-9863 to PH2000-9897, formerly ASQ: album 171-G). The Montréal copy is held in the Library of the Université de Montréal and has been labeled "sites et végétaux du canada : album." It is missing Plates 3, 7, 9, 10, 11, and 12 (UdeM: QK 201 B785 1866 / CSz).

6 It is unclear if Lessard was unaware of the Montréal album since he asserts that the Québec version is "[un] exemplaire unique" (a single or unique copy) in "Focus sur les villas et les fleurs: primeurs signe es Livernois."

7 Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Montréal: McGill-Queen's University Press, 2009), 257-259.

8 Jim Burant, "The Visual World in the Victorian Age," *Archivaria* 19 (Winter 1984-1985): 114.

9 Wedgwood's article, published in the *Journals of the Royal Institution* (Volume 1, 1802) was entitled "'An Account of a method of copying Paintings upon Glass, and making Profiles, by the agency of Light upon Nitrate of Silver,' invented by T. Wedgwood, ESQ. With Observations by H. Davy."

10 Larry J. Schaaf, *Out of the Shadows: Herschel, Talbot and the Invention of Photography (New Haven, CT: Yale University Press, 1992)* 25-26, 30-31.

11 This whole-plate daguerreotype of a "Section of Clematis" taken on 4 March 1840 sold at auction at Christie's London in 2004 for £139,650, well above the estimate of £90,000-120,000. Lot 7, Sale 6900, London, 19 May 2004. For more information, see: http://www.christies.com/lotfinder/Lot/andreas-ritter-von-ettingshausen-1796-1878-section-4278477-details.aspx.

12 Ann Thomas, "Chapter 4: The Search for Pattern," *Beauty of Another Order: Photography in Science* (New Haven, CT: Yale University Press, 1997), 97-98.

13 Larry J. Schaaf and Anna Atkins, *Sun Gardens: Victorian Photograms* (New York: Aperture, 1985). Carol Armstrong and Catherine Zegher, eds., *Ocean Flowers: Impressions from Nature* (Princeton: Princeton University Press, 2004).

14 Graham Smith, "Talbot and Botany: The Bertoloni Album" *History of Photography* 17, no. 1 (1993): 40.

15 Plate VII of Talbot's *Pencil of Nature* depicts a positive impression of a photogenic image of a fern, that was placed directly onto a sensitized paper, pressed down using a glass plate, exposed to light and then removed to reveal the image. The process is repeated with the resulting image negative to produce the positive image (in which the shape of the plant is dark and the background is light). William Henry Fox Talbot, *The Pencil of Nature* (London: Longman, Brown, Green and Longman's, 1844-1846), plate VII. For current scholarship on Talbot's images of plants, see also: Schaaf, *Out of the Shadows*, 47. Anthony Burnett-Brown, Michael Gray, and Russell Roberts, *Specimens and marvels: William Henry Fox Talbot and the invention of photography* (London: Aperture, 2000), 10. Graham Smith, "Talbot and Botany: The Bertoloni Album," *History of Photography* 17, no. 1 (Spring 1993): 40.

16 Anne Secord, "Talbot's First Lens: Botanical Vision as an Exact Science," in *William Henry Fox Talbot: Beyond Photography*, eds. Mirjam Brusius, Katrina Dean and Chitra Ramalingam (New Haven, CT: The Yale Center for British Art and The Paul Mellon Centre for Studies in British Art, 2013), 60.

17 Garlick, "Given time: biology, nature and photographic vision," *History of the Human Sciences* 22, no. 5 (2009): 98.

18 Lorraine Daston and Peter Galison, *Objectivity* (New York: Zone Books, 2010), quote on 42-43. For more on the broader history of photography as an aid to seeing, see Martin Kemp, *The Science of Art: Optical Themes in Western Art from Brunelleschi to Seurat* (New Haven, CT: Yale University Press, 1990).

19 Kelley E. Wilder, *Photography and Science* (London: Reaktion, 2009), 18.

20 Lady Elizabeth Eastlake, "Photography," *The London Quarterly Review* 101, no. 202 (April 1857): 252.

21 Lessard published his book in both French and English. In this paper, I quote from the English version: The Livernois Photographers (Québec: Musée du Québec-Québec Agenda, 1987). See also: *Les Livernois, photographes*. Québec: Musée du Québec-Québec Agenda, 1987.

22 Lessard, *The Livernois Photographers*, 85.

23 Lessard, "Focus sur les villas et les fleurs," 7. Translation by Brendan Cull. Lessard's reporting on the number of plates and photographs is incorrect here. His information seems, in part, to be derived from the index, which lists a total of 35 photographs on 24 plates. The Québec album actually contains an extra plate, not listed in the Index. He corrects this error in *The Livernois Photographers*. The plates are also slightly larger than he describes.

24 Lessard, *The Livernois Photographers*, quote on page 150. Lessard, "Focus sur les villas et les fleurs," 7.

25 Email correspondence with archivist Peter Gagné at the Musée de la civilisation in Québec City, 31 August 2015. Gagné reports that, "The cover is not leather. It's apparently fabric-covered cardboard, with leather corners and a leather title insert with gilded lettering. It has 3 out of the 4 original ribbon ties: 1 each at the top and bottom and two on the right, where it opens."

26 Email correspondence with Éric Bouchard, librarian at the Bibliothèque des livres rares et collections spéciales at the Université de Montréal, 1 April 2015. Bouchard explained that from 1876 to 1920 the Université de Montréal was a branch of the Université Laval. Additionally, the album forms part of the collection of l'Institut botanique of the Université de Montréal, formed in 1920.

27 Email correspondence with Éric Bouchard, librarian at the Bibliothèque des livres rares et collections spéciales at the Université de Montréal, 13 April 2015. Bouchard explained that, "Les planches mesurent 14'' X 21''. Elles sont bien volantes, mais toutes contenues dans un album entoilé bleu (demi-cuir à coins de même couleur) portant au dos l'inscription suivante : « Brunet = SITES ET VEGETAUX DU CANADA – ALBUM »."

28 Arthur Maheux, "Louis Ovide Brunet," *Le Naturaliste Canadien* LXXXVIII, no. 12 (December 1961): 324, 329. For a biography of Taché, see: Jean-Guy Nadeau, "TACHÉ, JOSEPH-CHARLES," *Dictionary of Canadian Biography Online*, accessed 16 February 2017, http://www.biographi.ca/en/bio/tache_joseph_charles_12E.html.

29 Zeller, *Inventing Canada*, 184, 188-189.

30 Ovide Brunet, *Voyage d'André Michaux en Canada depuis le Lac Champlain jusqu'à la Baie d'Hudson* (Québec: Bureau de l'Abeille): 1-27. Brunet's article was later translated into English. See: Ovide Brunet, "Michaux and his Journey in Canada," trans. Thomas Sterry Hunt, *The Canadian Naturalist and Geologist* 1, no. 5 (Montréal: Dawson Brothers, 1863): 325-337.

31 On 29 August 1866, Brunet notes that "J'allai à St-Augustin où je fis photographier la sucrerie de M. Brosseau [I travelled to St-Augustin where I had photographs of Mr. Brosseau's sugar bush made." Maheux, "Louis Ovide Brunet," 329.

32 This observation is based upon the version of *Maple Leaves. Third Series. Canadian History and Quebec Scenery* (Quebec: Hunter Rose & Co., 1865), which resides in the W. D. Jordan Special Collections (Lorne Pierce Collection) at Queen's University.

33 Ovide Brunet, "Journal de voyage en Europe de l'abbé Ovide Brunet en 1861-1862," in *Le Canada français* second series, no. XXVI, ed. Arthur Maheux (1938-1939): 684.

34 Lady Elizabeth Eastlake, "Photography," *The London Quarterly Review* 101, no. 202 (April 1857), both quotes on page 252.

35 Henry Cole, "Appendix E to Mr. Cole's Report," *Reports on the Paris Universal Exhibition, 1867. Vol. I. Containing the report by the Executive Commissioner, and appendices.* (London: George E. Eyre and William Spottiswoode, 1868): 51-55.

36 Arlene Gehmacher, "Canada in Paris: Krieghoff and the Universal Exhibition 1867," *Journal of Canadian Art History 24* (2003): 34.

37 C. Thurston Thompson, "Official Reports of the French Exhibition: Class 9. Photography. Section II," *The Photographic Journal* 12, no. 186 (15 October 1867): 120.

38 Anthony J. Hamber, "Thompson, Charles Thurston (1816–1868)," *Oxford Dictionary of National Biography*, 2004, http://www.oxforddnb.com.proxy.queensu.ca/view/article/27259.

39 Thompson, "Official Reports of the French Exhibition," 123 (emphasis added).

40 Chartrand, Duchesne, and Gingras write, "Ce succès à Londres contribue à persuader les membres du Parlement que la participation de la Commission géologique aux manifestations internationales constitue à la fois un moyen idéal d'attirer sur les richesses naturelles de pays l'attention des investisseurs étrangers et de faire savoir au monde entier ce qu'un gouvernement «éclairé et progressiste» fait en faveur des sciences." Luc Chartrand, Raymond Duchesne and Yves Gingras, *Histoire des sciences au Québec: de la Nouvelle-France à nos jours*, nouvelle édition (Montréal: Les Éditions du Boréal, 2008), 138-139.

41 For current research into Canada's timber trophies at international exhibitions, see: Elsbeth A. Heaman, *The Inglorious Arts of Peace: Exhibitions in Canadian Society during the Nineteenth Century* (Toronto: University of Toronto Press, 1999), 141-181. For nineteenth-century responses to Canada's timber trophies, see: Henry Youle Hind, ed., *The Canadian Journal: A Repertory of Industry, Science, and Art, and a Record of the Proceedings of the Canadian Institute* 1 (1852): 38. Anonymous, *Canada at the Universal Exhibition of 1855. Printed by order of the Legislative Assembly.* (Toronto: John Lovell, 1856), 278-279. Anonymous, *The Record of the International Exhibition,* 1862 (London: William Mackenzie, ca. 1862): 114.

42 Anonymous, *Reports of the United States Commissioners to the Paris Universal Exposition, 1867. Published under Direction of the Secretary of State by Authority of the Senate of the United States, Volume I,* edited by William P. Blake (Washington: Government Printing Office, 1870): 152.

43 "Classe 41. - Produits des Exploitations et des industries forestières," Exposition Universelle de 1867 à Paris. *Catalogue général publié par la Commission Impériale. 5e Livraison. Produits (bruts et ouvrés) des industries extractives (groupe V.-classes 40 à 46.), Volume 5* (Paris: E. Dentu, 1867): 309. The same reference (in English, French, German, and Italian) can also be found in "Class XLI," *Catalogue of the British Section: containing a list of the exhibitors of the United Kingdom and its colonies, and the objects which they exhibit: in English, French, German, and Italian: with statistical introductions and an appendix in which many of the objects exhibited are more fully described.* (London: Printed for Her Britannic Majesty's Commissioners and sold by Spottiswoode and Co., New-Street Square, 1867): 250.

44 Gehmacher, "Canada in Paris," 35.

45 Joan M. Schwartz, "Photographic Archives and the Idea of Nation: Images, Imaginings, and Imagined Community," in Costanza Caraffa and Tiziana Serena (eds.), *Photographic Archives and the Idea of Nation* (Berlin-Munich-Boston: De Gruyter, 2015), 38.

46 Joan M. Schwartz, "Science and Sentiment: The Work of Photography in Nineteenth-Century North America," in Craig E. Colten and Geoffrey L. Buckley (eds.), *North American Odyssey: Historical Geographies for the Twenty-First Century* (Lanham, MD: Rowman & Littlefield, 2014), 228. See also: Joan M. Schwartz, "'Records of Simple Truth and Precision': Photography, Archives, and the Illusion of Control," in Francis X. Blouin and William G. Rosenberg (eds.), *Archives, Documentation, and Institutions of Social Memory: Essays from the Sawyer Seminar* (Ann Arbor, MI: University of Michigan Press, 2006), 61-83; reprinted from *Archivaria* 50 (Fall 2000): 1-40.

47 See: Ann B. Shteir, *Cultivating Women, Cultivating Science: Flora's Daughters and Botany in England 1760 to 1860* (Baltimore: The Johns Hopkins University Press, 1996).

The Origins of the Institute for the History and Philosophy of Science and Technology

Philip Enros

Abstract: *An effort to establish programs of study in the history of science took place at the University of Toronto in the 1960s. Initial discussions began in 1963. Four years later, the Institute for the History and Philosophy of Science and Technology was created. By the end of 1969 the Institute was enrolling students in new MA and PhD programs. This activity involved the interaction of the newly emerging discipline of the history of science, the practices of the University, and the perspectives of Toronto's faculty. The story of its origins adds to our understanding of how the discipline of the history of science was institutionalized in the 1960s, as well as how new programs were formed at that time at the University of Toronto.*

Résumé : *Un effort soutenu en vue d'établir des programmes d'études en histoire des sciences s'est déroulé à l'Université de Toronto durant les années 60. Les discussions initiales ont eu lieu en 1963 et, quatre ans plus tard, l'Institut d'histoire et de philosophie des sciences et des technologies a été créé. A la fin de l'année 1969, l'Institut recrutait des étudiants à la maîtrise et au doctorat. Cette activité impliquait une interaction entre la discipline émergente qu'était l'histoire des sciences, les pratiques de l'Université et les perspectives de la faculté de Toronto. La reconstitution de ses origines à Toronto nous permet de comprendre comment la discipline de l'histoire des sciences s'est institutionnalisée dans les années 60 ainsi que la manière dans les nouveaux programmes étaient formés à l'époque à l'Université de Toronto.*

Keywords: Institute for the History and Philosophy of Science and Technology, history of the history of science, history of science programs in Canada, history of the University of Toronto, John Abrams

THE UNIVERSITY OF TORONTO'S BOARD OF GOVERNORS approved the creation of an Institute for the History and Philosophy of Science and Technology in 1967. That year is commonly taken to mark the beginning of the Institute. However, the emphasis on 1967 tends to obscure the fact that efforts to establish programs in the history of science took place over an extended period of time, beginning in 1963. And it would take another two years before the Institute began to offer its own degree programs in 1969. This article traces the activities over that six-year period which gave rise to and shaped the Institute, Canada's first graduate program in the history of science.

The Presidential Advisory Committee

The creation of the Institute for the History and Philosophy of Science and Technology began with an informal meeting of six University of Toronto staff in the fall of 1963: Vincent Bladen, dean of the Faculty of Arts and Science

Philip Enros, "The Origins of the Institute for the History and Philosophy of Science and Technology" *Scientia Canadensis* 39, 1 (2016-17): 51-73.

and a political economist; Maurice Careless, chair of the History Department; Tom Easterbrook, chair of the Department of Political Economy; James Ham, professor of Electrical Engineering; John Hamilton, dean of the Faculty of Medicine; and Moffatt St. Andrew Woodside, vice-president academic.[1] All had an interest in the history of science, although none were active participants in the field. Soon three other faculty joined the group: John Abrams, a newly appointed associate professor in the Department of Industrial Engineering; Thomas Goudge, chair of the Philosophy Department; and, Norman Hughes, dean of the Faculty of Pharmacy. They were somewhat more knowledgeable about the history of science with Abrams being the most familiar with the subject. He had taken a number of graduate courses in the history of science at University College London during 1949-51 and was a member of several relevant organizations including the History of Science Society and the Canadian Society for the Study of the History and Philosophy of Science.[2] Goudge worked in the philosophy of biology and had written *The Ascent of Life*, which had won the Governor General's Literary Award for Non-Fiction for 1961. Hughes had taken a special interest in the history of medical science, and his faculty offered courses in the history of both medicine and pharmacy. In addition to these three individuals, there was some thought given to adding Marshall McLuhan, who was "exceedingly interested" in the area. But it was decided that it would be better to consult with him at a later stage.[3]

Woodside reported on the meeting to the University's president, Claude Bissell, recommending a Presidential Advisory Committee on the History and Philosophy of Science. The use of such committees was a typical way at that time of moving forward with issues. The committee was to examine the desirability and feasibility of establishing such studies and how they should be organized. Bissell approved and named Woodside its chair.[4] The latter had, only a few months earlier, been appointed vice-president academic. He had a long association with the University, graduating from it in 1928 with a BA in classics and winning a Rhodes Scholarship. Woodside had taught ancient history at Toronto, and served as Dean of the Faculty of Arts from 1952 and Principal of University College from 1959.

The committee was not the first attempt to advance the history of science at the University of Toronto. A decade earlier, the Special Committee on the Humanities had recommended a chair in the history of science.[5] Arising out of concerns with the status and future of the humanities, the Special Committee —which included Woodside and Goudge, with Harold Innis chairing—had considered injecting "more humanistic studies into the honour courses in the natural sciences and the social sciences."[6] It felt that the study of the history of science could help achieve that goal. There was far from unanimous support, however, for this view. Several departments, including Geology, Mathematics, Physics, and Zoology disagreed, arguing that it would be difficult to find the right person for the chair, that it was a subject more suited to graduate study, and that courses in history of science might turn out to be more scientific

Figure 1. Moffatt St. Andrew Woodside, with Northrup Frye to his left. Photo credit: Fednews, Toronto. Source: University of Toronto Archives.

than humanistic in nature. The recommendation was not implemented, which suggests the Woodside committee may have been seen as an opportunity to deal with unfinished business.

The members of the committee were also not the first Toronto faculty to find the history of science appealing. For many decades, several scientific staff had taken an interest in the history of their disciplines. Anatomy professor James Playfair McMurrich (1859-1939), for example, had authored a study of Leonardo da Vinci's work on anatomy in 1930.[7] McMurrich, along with several other Toronto faculty—including George Wrong, head of the History Department—had been founding members of the History of Science Society in 1924, of which McMurrich would later become President.[8] Faculty interest at

Toronto had also resulted in a variety of courses in the history of science, which had been offered over a long period of time.[9] When Woodside's committee was formed, over a dozen of these courses were listed in the University's calendars. For example, a philosophy of science course was available to undergraduate engineers, a history of biological science to both undergraduates and graduates in Zoology, and a course in the historical development of mathematical thought to graduate students in Educational Theory. The situation of the history of science at Toronto before the 1960s reflected the general state of the history of science prior to the Second World War: it was an emerging field with scientists as its main participants (their basic interest then being in legitimizing science), and university courses in the subject depended on the enthusiasm of individual faculty.[10]

At the University of Toronto, the renewed engagement with the history of science took place in a context quite different from that of a decade earlier. In the postwar period, science underwent a rapid expansion, and had secured a general prestige and public faith in its development. The University also had a greater capacity for starting up new programs of study. With growing funding in the 1960s, the scale of operations at the University of Toronto had begun to greatly expand with increasing student numbers, new and reformed undergraduate and graduate programs, higher levels of research activity, and a building boom.[11] Bissell assessed the sixties as "a decade of institutional growth so great it often amounted to institutional transformation."[12]

There was also a shift underway in the study of the history of science. After the Second World War, the practice of the history of science, particularly in the US and the UK, began a transformation into a separate academic specialization.[13] Building on the expansion of universities at that time, it became better established. There was a rapid growth in graduate programs in the field, particularly in the late 1950s and early 1960s. By 1965, 15 doctoral programs in the history of science could be found in the US.[14] With this growth came a change in the profile of its practitioners. Individuals trained in the history of science, using the methodologies of history, displaced scientists. Some of the members of the Woodside committee—Abrams, Hughes and likely Goudge—were well aware of this development.

A final difference from the 1950s was that interest in building a program in the history of science at the University of Toronto no longer originated in concern about the humanities. While departments like Philosophy and History were still interested, it was the professional faculties who were particularly keen. This was mainly due to their belief that students ought to know about the heritage of their chosen professions. Hughes, for example, argued for an integrated program in the history of science and certain professions.[15] He believed that each "professional person should know something of the historical background of his calling." A similar view, of course, had earlier stimulated the interest of scientists in the history of science.

The first meeting of the Presidential Advisory Committee was held on

November 7, 1963. Members quickly agreed that the University should offer courses in the history and philosophy of science.[16] They stressed that when referring to 'science' they also included technology. This was not a common practice at the time and may have been due to the presence of engineers and economists on the committee, as well as the fact that Toronto was the university of Harold Innis and Marshall McLuhan.[17] The latter's Centre for Culture and Technology had been expressly created for him earlier that year.

The committee identified a number of issues: the demand for history and philosophy of science, how the subject should be organized, and the need to recruit staff. They decided that they should seek advice from some of the subject's leading scholars. Woodside invited Bernard Cohen of Harvard and Charles Gillispie of Princeton to visit Toronto in January to meet with the committee. Cohen was unable to accept, but wrote: "It is very exciting to know that the University of Toronto may be planning a real effort in the area of history and philosophy of science, a move which would certainly be welcomed by many segments of our profession."[18] Gillispie was able to travel to Toronto and spent a January day in Toronto with the committee, which reported "a complete and exceedingly profitable discussion with him."[19]

In advance of meeting with Gillispie, committee members shared information. Hughes distributed material on the programs in history of science and in history of pharmacy at the University of Wisconsin. A major effort in these areas had commenced there in 1947, growing to become the "first full-fledged" department of the history of science in the United States.[20] Hughes also tried to set up a meeting with Ernst Stieb, a Toronto alumnus who had completed a doctorate in the history of science and pharmacy at Wisconsin and was currently on its faculty. But that did not work out. Ham circulated news about final-year undergraduates at the University of Cambridge now being able to devote their studies to the history and philosophy of science.[21] And Abrams, with Woodside's approval, talked with several participants at the December meetings of the History of Science Society and the Society for the History of Technology in Philadelphia. There he spoke with several "old friends", including Marshall Clagett, Derek de Solla Price, Gerald Holton, Thomas Kuhn and Joseph T. Clark, about how the field was organized at their universities and the challenges they faced.[22] Abrams reported that the history of science was growing in the US, that it was advisable to have a group of scholars rather than just one individual in the field, and that "serious courses" should be offered. By "serious" he meant that they needed to be based on research, graduate study, and adequate library resources. The history of science was also viewed as being more than the history of specific disciplines. It involved cross-fertilization among the disciplines as well as the interaction between science and society.[23]

The committee now felt it had enough information to move forward. At its meeting on March 19th, attended also by Ernest Sirluck, the dean of the School of Graduate Studies, the members decided to prepare a report for Bissell. They had concluded that the priority was to appoint qualified scholars, and set aside earlier questions about demand, believing that it would appear once "proper work" in the history and philosophy of science was established.[24] In the same vein, they decided that it was unnecessary to compile a list of existing courses in the University because they were "quite different in character from courses in the history of science." Reflecting Abrams' comments about serious courses, they viewed the history of science as a newly developing discipline, where "the 'amateur' has rapidly been giving way to the true professional, educated in the methods of historical or philosophical investigation."[25]

The committee's report to Bissell did not consider it necessary to rationalize why the history and philosophy of science was needed at Toronto. Perhaps advocating on the basis of George Sarton's new humanism or of James Conant's vision of general education was outmoded by the early 1960s. Indeed, Bernard Cohen was then arguing that "it is surely no longer necessary to justify the study of the history of science."[26] The committee limited itself to saying that the subject was essential to the study of civilization and that the University of Toronto should establish these studies "not because other universities are doing so, but because such studies are valid, important and productive of intellectual advance."[27]

The committee's report to Bissell made several recommendations. It suggested appointing at least two and ideally four qualified scholars, one of whom would be a senior scholar. These staff could be appointed in various faculties but should be given cross-appointment in History or Philosophy or Political Economy so as not to be isolated from other staff with historical or philosophical interests. The new staff might ultimately be organized into a centre or a department. In the meantime, the committee would remain in existence in order to support and advise them. The report also recommended that the work of the staff be not necessarily limited to undergraduate instruction. The committee believed that the "discipline should be allowed to develop in its own way."[28]

Presumably Bissell responded by asking for a budget, for the committee met in October to review a proposed budget. The members suggested a total of $42,000 with $20,000 for a senior appointment, $10,000 each for two other faculty, and the remaining $2,000 to cover the group's expenses. The committee also suggested consulting with the University Librarian to see if $8,000 could be found from his budget for books. The committee cautioned the President that "good scholars in this discipline are scarce and that the demand is great and becoming greater."[29] Bissell authorized a search for a senior person who would then recommend additional staff and guide the establishment of the history and philosophy of science at Toronto.[30]

Goudge advised Woodside that the senior appointment should be someone competent in both the history and the philosophy of science.[31] He suggested individuals such as Mary Hesse, Norwood Hanson, Stephen Toulmin, and Thomas Kuhn. Other committee members also made nominations. On December 2, 1964, the committee met to consider a list of twenty candidates. The committee decided to approach Hanson, a philosopher of science and a recent hire at Yale. Earlier he had built a large program in the history and philosophy of science at Indiana University and had been involved in establishing the subject at the University of Cambridge.[32] Woodside wrote on December 7th to sound him out. Hanson replied that while he would have to be offered more than $20,000, he was attracted by the opportunity of setting up a new program. He offered to visit Toronto in order to further explore possibilities with the committee.[33]

Hanson flew himself to Toronto and was there in late January 1965.[34] He met with the committee and with Bissell to discuss the University's plans. Goudge found his presence "robust, hard-driving and stimulating."[35] Hanson was enthusiastic about what might be done at Toronto, writing afterwards to Woodside:

> … your ideas concerning the history and philosophy of science are the most mature and reasonable I have encountered in a long time. My resolutions are firm now; I mean to help all I can in your admirable efforts to establish Toronto as THE center for advanced research and teaching in H+P of S.[36]

Hanson promised to prepare a report on his ideas. He also enlisted Stephen Toulmin's input and urged Toronto to consider recruiting him.

Hanson argued that Toronto's program would fit best in the School of Graduate Studies.[37] The program "should begin as an attack on 'frontier' problems in the history and philosophy of science," he wrote. This would not be a "one-man 'humanities' operation." It required recruiting staff "of the highest caliber" rather than "just a gaggle of interested amateurs, ex-scientists, or very inexperienced PhDs." Hanson's vision was ambitious. He estimated it would require over $180,000, including a director at $23,500, four senior staff at $20,000 each, support staff, and other expenses. The result, he claimed, would place Toronto at the "pinnacle of studies in the 'humanities of science'." The University's "humanists will at last come to recognize the centrality of the scientific adventure within the history of Western thought" and its scientists "will begin discussing, as they rarely can do now, the conceptual consequences of their own disciplines, the sociological impact of what they are doing, the historical roots of the laboratory work they hold dear." The program's studies would "naturally percolate downwards" and transform undergraduate studies. Attached to Hanson's report was a supplementary note by Toulmin. He believed that the proposed program at Toronto should be broader in scope than simply history and philosophy to encompass the "whole range of ways in which science interacts with its larger human environment." Toulmin urged the hiring of one or two scholars working on the "economic, political or sociological aspects of science."

Woodside's committee met in late February to consider Hanson's report. They were "enthusiastic about his proposals," agreeing in particular that the program should start at the graduate level. But they thought it impossible to find the amount of funding required.[38] Goudge noted in his diary that the committee was "rather staggered" by Hanson's proposed budget.[39] Nonetheless, they decided to seek from Bissell clarity about a maximum budget. They also agreed that if the amount was insufficient for Hanson's plan, they would inform him and invite Toulmin to Toronto. A week later, Bissell told Woodside that the committee could count on $100,000 a year.[40] Woodside shared this with Hanson and Toulmin, and invited the latter to meet with the committee in Toronto. Toulmin declined, deciding to accept a position at Brandeis University instead.[41]

The committee now had doubts that a prominent scholar could be attracted to Toronto. However, they still liked Hanson's scheme and decided to approach three other candidates: Gerd Buchdahl at Cambridge, Alistair Crombie at Oxford, and Thomas Kuhn at the Institute for Advanced Studies, Princeton. Abrams called Kuhn who declined because he had just recently joined Princeton.[42] Crombie also turned down the opportunity, saying that he couldn't move his children at that time.[43] And Buchdahl similarly declined because of his children's schooling as well as his publishing commitments.[44]

When the committee next met in November, it was clear that they needed to approach their objective in a new way.[45] The members proposed launching several initiatives aimed at making a "definite beginning" in the study of the history and philosophy of science at Toronto. One was to review existing assets at Toronto and consolidate them. Bissell suggested making use of William E. Swinton, who was due to retire as Director of the Royal Ontario Museum in June 1966. Bissell wanted to use Swinton's "authority as a scholar and his persuasiveness as a lecturer to advance the interest of the History of Science."[46] Swinton was later named the Centennial Professor in the History of Science, with the task of giving a series of lectures. Another effort was to form in early December 1965 a Toronto Section of the Canadian Society for the Study of the History and Philosophy of Science. Swinton was elected president, and Abrams secretary.[47]

In addition, the committee proposed a lecture series, inviting outside scholars. A hoped-for side-benefit would be that some of them might find Toronto attractive enough to join the University. Ultimately the committee concluded that it was not positioned to pursue these activities. A different organization was wanted, a smaller, active one headed by someone knowledgeable in the history and philosophy of science. The members believed the ideal candidate was Abrams, who had expressed interest in helping advance the project.

Woodside asked the Faculty of Applied Science and Engineering if Abrams could take on this task. The next, and last, meeting of the Presidential Advisory Committee took place on December 6th and recommended the creation of a new committee.[48] A week later, Abrams met with Bissell who agreed to form a new presidential committee oriented to building on Toronto's resources. Bissell gave it $2,000 to cover expenses.[49]

The Committee on History and Philosophy of Science

John Abrams had joined the University of Toronto in July 1963. Prior to that he was chief of operations research at the Defence Research Board in Ottawa.[50] It is not known why he left the Board. It has been suggested that he had reached his ceiling or that he might have been unhappy with the policies of the Diefenbaker government.[51] Bissell, who knew him fairly well—they had been neighbours in Ottawa—suspected that it was "because he was more interested in increasing human understanding than in developing weapon sophistication."[52] Some things are known: the department he joined, Industrial Engineering, recruited him because it wanted to establish a graduate program, and the move meant a cut in salary.[53]

Although Abrams devoted most of his time to operations research and was not active in history of science scholarship, he had a longstanding interest in it. Born in San Francisco, he obtained a PhD in astrophysics in 1939 from the University of California, Berkeley. After service with the Royal Canadian Air Force during the Second World War, where he became involved in operations research, he taught university for a few years. Abrams became interested in the history of science while teaching a general-education science course for non-science majors at Wesleyan University. He joined Canada's Defence Research Board in 1949 and was given a scholarship.[54] He spent the next two years in London, splitting his time as a liaison to the Royal Navy and a student in the history and philosophy of science at University College London, the major centre for such studies in the United Kingdom at that time. His notebooks show he took almost all of the 14 courses available there, from scholars such as Herbert Dingle, Alistair Crombie, and Angus Armitage.[55] Abrams returned to Canada in 1951, continuing to keep in touch with the field.

Given his interests and experience, it is not surprising that Abrams was asked to be the chair of the new Committee on the History and Philosophy of Science. One of the challenges facing the Presidential Advisory Committee, given its members' busy schedules, had been finding time to meet.[56] The individuals in Abrams' group did not occupy senior administrative posts, and they were half as many in number. Besides Abrams, the group included Maurice Careless, chair of History, who had also served on Woodside's committee; G.R. (Pat) Paterson from the Faculty of Pharmacy, who had founded the Canadian Academy of the History of Pharmacy in 1955; James M.O. Wheatley, a philosopher of science; and, Edward A. Sellers, chair of Pharmacology in the Faculty of Medicine. The group's task was to take practical steps to foster the subject in the University. It acted quickly, meeting three times and reporting back to Bissell before the end of March 1966.

Bissell approved the group's plans, which included proposals on course offerings, appointments of historians and philosophers of science, and library requirements.[57] Bissell also bolstered Abrams' position by arranging a cross-appointment to the History department, revealing that history of science was perceived to be largely rooted in the discipline of history. Careless, who had been very engaged in establishing history of science at Toronto, was glad to make the appointment. However, he also believed the subject was best pursued in a separate unit and not as part of the History department.[58] Careless's position shows that history of science was considered at Toronto, at least by History, to be an interdisciplinary field, albeit one which was beginning to produce its own specialists.

Abrams' cross-appointment triggered a decision by Arthur Porter, chair of Industrial Engineering, to not promote Abrams to the level of professor. Abrams was bitter, feeling that this broke a gentleman's agreement he had with Porter when he had joined the department.[59] Bissell advised Abrams to accept the situation for now "with the expectation that we would establish asap a Department of History and Philosophy of Science" to which he "would be appointed as Professor, probably as Acting Chairman and possibly as Chairman."[60] The following year Abrams was promoted to Professor in both Industrial Engineering and History.

The first item on the committee's plan of action was to circulate a questionnaire to university faculty. It had a dual purpose: to inform faculty of what the committee hoped to accomplish, and to gauge their interest in participating in its activities.[61] Over two hundred faculty (about 15% of the total) replied that they would be interested in attending public lectures or faculty-student and graduate seminars.[62] In addition, a survey of departments in the Faculty of Arts and Science revealed that 70% of them thought that there would be interest among their students in the history of science.[63]

The questionnaire prompted the University Librarian to reply that the existing collection would need "heavy reinforcement over a period of years" in order to support graduate study. The Library began to take steps to do just that. It applied for a grant from the Canada Council to improve its collection in the history of science, receiving $10,000 in 1967.[64] It also acquired, that year, a major collection of Charles Darwin material. And in the same year, the Library offered to store Stillman Drake's large collection of Galileana.[65]

Another initiative was a public lecture series, funded with a $6,000 grant from the university's Varsity Fund.[66] Derek de Solla Price from Yale University gave the first lecture in October of 1966 on "The Mythology of Science" before an audience of 140. Another ten historians of science, almost all of them from other universities, gave public lectures during the 1966-67 academic year. The afternoon lectures were followed by meetings with graduate students and faculty. The series was judged to have been an enormous success and continued for several years, into the 1970s.[67]

Abrams' committee also initiated some courses in the history of science. A beginning was made when the Council of the Faculty of Arts and Science approved a course in June 1966. Bissell was in attendance at the Council meeting, supporting the decision and declaring it to be "long overdue."[68] The course was a first-year Religious Knowledge option. These one-hour-a-week options had originated as a way of allowing the University's church-federated

Figure 2. *Claude Bissell, with Omond Solandt to his right, 1969. Photo credit: Robert Lansdale. Source: University of Toronto Archives*

colleges to offer religious instruction. The secular University College offered its students a variety of choices to meet this requirement. The history of science option began in 1966-67 as History 116 and was taught by Abrams, attracting 40 students.[69] He modeled it on a non-credit, survey course for adults he had given in the University's extension division in 1964 and 1965.[70] In addition to the undergraduate course, Abrams led a weekly graduate seminar that used both the visiting lecturers in the public lecture series and University faculty. History and Philosophy sponsored the seminar, which attracted some 20 graduate students from a wide variety of departments: mathematics, history, philosophy, architecture, physics, medicine, pharmacy, languages and literature, and social work.[71]

Abrams' committee also pursued Bissell's commitment to establish a dedicated department. Dean of Arts and Science Albert D. Allen organized a meeting in October 1966 with departmental chairs from History (Careless), Philosophy (Goudge), and five science departments to discuss this possibility. While there was "sympathy and support," there was doubt about the suitability of undergraduate studies in the history and philosophy of science.[72] In line with Hanson's advice, the group believed that an institute should be created within the School of Graduate Studies. Sirluck, who was also at the meeting, thought that was feasible. The School was already home to a number of graduate centres and institutes, many of them recently created in the University's favourable environment for interdisciplinary studies.[73] Sirluck saw these units as ways of permitting "horizontal, multidisciplinary specialization to run in parallel with the vertical, disciplinary specializations of the traditional departments."[74] Abrams' committee agreed and sought Bissell's approval. He met with Abrams and Sirluck on December 16, 1966.[75]

At the meeting, Abrams also asked to make two appointments in the history of science. Despite all the activity to build up and upon interest at the University, the Abrams' committee held firm to the view that a group of specialists was needed to supervise graduate studies and undertake research. Probably in preparation for the October discussion at Arts and Science, Abrams had put together a tentative budget of about $50,000 based on two full-time and two half-time staff.[76] Abrams would soon have some candidates for the full-time positions. For the hope that the public lectures series might turn up some scholars willing to move to Toronto was to be realized.

The second speaker in the series was Stillman Drake. His lecture, "The Scientific Personality of Galileo," was given on October 28, 1966 and was well received. He and Abrams must have discussed the possibility of a position at Toronto, because soon after Abrams raised the issue with Bissell. Drake had never had an academic appointment. After a bachelor's degree in philosophy and some graduate work in mathematics at UC Berkeley in the early 1930s, Drake had worked in the financial sector. Outside this employment, he had become a renowned Galileo scholar. Harvard had tried to recruit Drake a few years earlier, but he had then felt unable to leave his employer, a San Francisco-based investment-banking firm.[77] Clearly things had changed by late 1966. Drake found the situation at Toronto attractive. He thought the University had a "particularly enlightened attitude" concerning interdisciplinary studies. He appreciated the resources available there through the Centre for Renaissance and Reformation Studies and the Centre for Medieval Studies.[78] The position would allow him to spend more time on his research. The presence of a friend —Kenneth May, a mathematician and historian of mathematics hired in July 1966—was as well "no small factor" in bringing him to Toronto.[79] Furthermore, Drake's plans to remarry may also have played a part in his decision to begin an academic career.

The University moved quickly. Sirluck set up a committee to consider Drake for a professor's position. Letters of support were obtained from Marshall Clagett, Charles Gillispie, Derek de Solla Price, and Bernard Cohen—all of them senior historians of science. Drake received a letter of offer in early February and soon accepted a full professorship with tenure commencing July 1 1967. Gillispie wrote to Drake in January 1967, following delivery of one of the public lectures at Toronto:

> … after two visits to Toronto I have formed a very good impression of the tone and intellectual vigor of the university. John seems to have created a very hospitable climate for history of science, and your being there would certainly establish the subject in a most important and gratifying way."[80]

Within the history of science community, recruiting Drake would have been considered quite a coup for Toronto. At the same time as Drake accepted, Abrams secured the second appointment. Once again, it came about through the public lectures. Bernard Cohen had given the third talk in the series, on November 1, 1966. He recommended a Harvard doctoral student to Abrams, Jonathan Hodge, who specialized in the history of biology. Hodge came to Toronto for an interview in January and subsequently accepted an assistant professorship, with a starting date of July 1st. Typical for this period of university expansion, Hodge had not yet finished his dissertation. In addition to Drake and Hodge, the Faculty of Pharmacy attracted Ernst Stieb to return to Toronto from Wisconsin as a professor of the history of pharmacy. A good beginning had been made in assembling a core group of professionals.

While these individuals were being hired, Abrams' committee prepared a short proposal recommending a graduate institute in the history of science for submission to the Council of the School of Graduate Studies. It stated that the institute's purpose was to bring together scholars interested in the subject and to support a research program.[81] Until the proposed institute could offer its own degree programs, it would give courses and seminars to graduate students registered in existing departments. And, it would provide limited undergraduate instruction as necessary.

The Council met on March 17, 1967 and established a committee to consider the proposal.[82] The committee members felt that they had been placed in a difficult position given that faculty had just been hired with the intention of eventual appointment to the institute. Nevertheless, they studied the proposal during three meetings in April. They were in "unanimous agreement that there is a real need for study and research in an important area between the humanities, sciences, and the professions which is presently being neglected."[83] They also agreed that a separate unit was needed, and estimated that it would require $100,000 in its first year. The committee was also responsible for giving the institute, as it acknowledged, the "cumbersome" title of Institute for the History and Philosophy of Science and Technology. The committee wished to be clear that the research of the institute would be "on the philosophical as well as the historical aspects" of science and of technology.

The committee reported back to the Council on April 26th. After a full discussion, the Council resolved that the establishment of the Institute for the History and Philosophy of Science and Technology be recommended to the Senate.[84] The latter gave the item first reading, without any discussion, on May 29th, and agreed with creation of the Institute at its meeting on October 13th.[85] The Board of Governors approved the Senate's decision on October 26th.[86] One of the main goals of Abrams' committee had been realized. The Institute was now officially established. Yet another committee was struck to recommend a director. Not surprisingly, it unanimously nominated Abrams, who was appointed director of the Institute in March 1968 and approved on June 27th by the Board of Governors for a five-year term.[87]

When Drake and Hodge moved to Toronto in the summer of 1967, the Institute's establishment was still underway. They were both appointed to the History department and joined Abrams and his secretary, Lorna Price, at 621 Spadina Avenue, where Abrams had been given office space after his cross-appointment to History the year before. The additional staff permitted an increase in the number of history-of-science courses, all offered under the auspices of the History department. Four graduate courses were given, attracting 25 students. Abrams gave one on the history of the physical sciences and another on medieval astronomy (cross-listed with the Centre for Medieval Studies), Hodge a course on the history of the biological sciences, and Drake one on the Scientific Revolution. The undergraduate offerings were also expanded. There were now two Religious Knowledge courses: a first-year offering on the history of the physical sciences (150 students) and a second-year one on the biological sciences (80 students). There was also a new course taught by Abrams in the Faculty of Applied Science and Engineering, a third-year elective on the history of technology and engineering (125 students).[88] It would prove to be so popular with engineering students that it would cause tensions within the Institute around the appropriate balance between undergraduate and graduate teaching.

The developing program at Toronto did not go unnoticed by the broader history-of-science community. Derek de Solla Price included Abrams' committee in his published guide to graduate programs in the history of science, prepared in the spring of 1967.[89] It listed Abrams, Drake, Hodge, Stieb, and Swinton as faculty with May as an associate, noting that a degree program was anticipated in 1968-69. Coincidentally, both the History of Science Society and the Society for the History of Technology met in Toronto in December 1967, due to the meeting there of the American Historical Association. Abrams was in charge of local arrangements for both groups.[90] He was asked by the Society for the History of Technology to organize a session on work done in Canada in that field. The result was two speakers: J. J. Brown on technical museums in Canada, and Duncan F. Cameron on the importance of the history of technology to the contemporary museum visitor.[91] Mel Kranzberg, a professor of history and secretary of the Society, wrote to the University to acknowledge Abrams' assistance. He noted that

> … my colleagues and I were tremendously impressed by the announcement of your new Institute for the History and Philosophy of Science and Technology. The scope of this

> project and the scholarly resources which are mustered together promise to make it one of the great centres of knowledge and study of these extremely significant elements in our contemporary culture. I am certain that this new Institute will add lustre to your already great university.[92]

Kranzberg's letter serves as one more instance of the general support that the Toronto effort to establish a program received from the American history of science community.

By the close of 1967, much progress had been made. Specialists in the history of science had been recruited, course offerings expanded, a successful public lecture series extended, and a separate graduate institute created. Abrams' committee began to focus on its next steps, which were primarily about the structure and programs of the Institute.[93] It proposed that faculty whose principal interest was in the work of the Institute should be core members, whereas those who had related, but not primary interest, would be affiliates. The committee also identified a need for two new staff specializing in the history of technology, biology, chemistry, or geology. The most important challenge now was to design and obtain approval for graduate degree programs. With the formation of the Institute, however, all these tasks would be assumed by that organization. The Committee on History and Philosophy of Science was not formally disbanded until August 1968, but it appears to have had its last meeting in December 1967.

The IHPST

The establishment of the Institute within the School of Graduate Studies meant that its budget, space requirements, and other issues would be dealt with there rather than through discussions with the President. In 1968, the Institute had, for the first time, an entry in the School's Calendar. Some 15 faculty were listed. Besides Abrams, Drake, and Hodge from the History department, there were Pat Paterson and Ernst Stieb from Pharmacy, Kenneth May (Mathematics), William Swinton (Geology and Zoology), Francis Priestley (English), Ursula Franklin (Metallurgy), James Weisheipl (Medieval Studies), and five individuals from Philosophy—Thomas Goudge, J. Willison Crichton, Armand Maurer, James Wheatley, and Fred Wilson.[94] These faculty would comprise the first members and affiliates of the Institute, and would begin to meet to discuss the Institute's business.[95]

Abrams had asked for two new appointments for 1968-69, but received permission for one. Trevor Levere, a student of Crombie's at Oxford working on a dissertation in the history of chemistry, accepted the offer. When he arrived in Toronto, he joined Abrams, Drake, Hodge, and two secretaries at a new location. The Institute had moved to four leased rooms on the second floor of 191 College Street.[96]

The Calendar also listed 16 courses: four offered through History (the same ones given by Abrams, Drake and Hodge the previous year), one through Mathematics, three through Pharmacy, and eight through Philosophy. Abrams had hoped to have some new graduate courses (for example, in the history of geology), but found that could only be done if the relevant department was willing to sponsor it (in this case, Geology). This hurdle would remain until the Institute's own graduate degree programs could be approved. At the undergraduate level one new course was begun.[97] It was an honours History course, "Science in Western Intellectual History," for third- or fourth-year students team-taught by Abrams, Drake, and Hodge.

The lack of approved degree programs also meant that students could not be enrolled in the Institute. As was the case with graduate courses, students had to be registered in other departments. However, the Calendar for 1968-69 stated that in "anticipation of the formal implementation" of MA and PhD programs, prospective degree candidates could be accepted as special students. Three students took up that opportunity. Richard Jarrell enrolled in the History Department taking only history of science courses. He had moved to Toronto to avoid being drafted by the American military, having already completed a year of graduate work in the history of science at Indiana University. The other two, both graduates of Toronto, enrolled as special students. Ron B. Thomson had just finished a BA in History. Elizabeth Quance registered part-time as she was working at the Ontario Science Centre, having obtained a BSc in physiology and biochemistry in 1963.

Abrams had begun work on a submission for the appraisal process for the Institute's proposed programs, consulting with Sirluck and others in the School of Graduate Studies in the summer of 1968. At one point, the plan had been to set up a master's program first, followed a year later by a doctoral program. But the School thought there were sufficient resources in the University to go forward with both at the same time. The Council of the School approved the submission in November. It was then forwarded to the Ontario Council on Graduate Studies for review. This process was fairly new, having been instituted at the beginning of 1967 as part of an effort by Ontario universities to show the Ontario government, during that period of rapid expansion, that they could govern themselves.[98] Three external consultants were selected by the end of December. Their task was to advise the appraisals committee on whether the Institute's programs were consistent with acceptable standards in the discipline. The first to visit the campus, in early March 1969, was Edward Grant from Indiana University. His report had just been submitted when a dispute arose that threatened to delay the review process.

The Philosophy Department had met and prepared a letter stating that it found the Institute's proposed PhD program unacceptable.[99] It wanted its presence in the program increased or "philosophy" taken out of the Institute's name. Since the start of Woodside's committee philosophy had been paired with history. The grouping of history of science and philosophy of science was not unusual at that time in programs at other universities—nor without its difficulties.[100] All the new appointments at Toronto had been in the history of science and been associated, for the most part, with the History department.

Figure 3. John Abrams. Photo taken at the Burndy Library, probably in 1974. Source: Jacqueline (Abrams) Elton.

Perhaps because Philosophy was a large, well-established department, it was believed that no additional appointments were needed there. The Toronto committees had never explicitly laid out how the relationship between history and philosophy would be manifested in the Institute's graduate programs. Abrams, and likely most of the other core faculty, thought it should be limited to the history of the philosophy of science. Philosophy did not agree, however, and wanted to include some contemporary philosophy of science courses, with sole responsibility for them.

A quick round of meetings was held, with Sirluck putting pressure on the parties out of concern that the issue would delay the beginning of the Institute's programs. By April 3rd the matter had been resolved. A commitment to interdisciplinarity appears to have been the deciding factor. All graduate students in the Institute would be required to take at least a half course in contemporary philosophy of science.[101] Members of the philosophy department would teach these courses. The word "philosophy" would be deleted from the titles of courses offered by Institute core members—for example, HPS 1011 changed from "History and Philosophy of Science: Physical Sciences" to "History of the Physical Sciences." Kenneth May played a key role in the negotiations. In the process, a constitution was drafted for the Institute specifying its membership, committees, and governance.[102] May wanted to put the Institute "on a sound basis so we can proceed with our business without raids by outsiders."[103]

With the issue resolved, the other two consultants—Bernard Cohen of Harvard and Glenn Sonnedecker of Wisconsin—visited the campus. Together with Grant, they gave their full support for the program.[104] Grant wrote "I can see no good reason to delay the start of what will become a major program in North America." They did have some concerns and advice. For example, Sonnedecker was worried about the "uneasy alliance" between the Institute and Philosophy, Grant thought there was some weakness in period coverage, and Cohen believed the Institute should pay attention to the "special features of Canadian scientific development." All three were very impressed by the range and depth brought to the Institute by its affiliates.

The Ontario Council on Graduate Studies endorsed the proposed graduate programs on June 26. The PhD was approved for the 16 areas that had been put forward, apparently reflecting faculty interests.[105] These were a curious mix of very general, such as science in intellectual history, philosophy of biology, and history of mathematics, and quite specific—Newtonianism, history of operational research, and science in the 16th century. The bundle of areas would cause problems later on when the Institute wished to move into areas not covered in their submission, such as the history of medicine. On October 9, 1969, the University Senate established the MA and PhD degrees in history and philosophy of science and technology, and their courses of study.[106]

The Institute's graduate programs were designed to give its students both a broad and deep knowledge of the history of science, and had been formulated after discussions with leading historians of science. Abrams thought that they closely resembled graduate programs at University College London.[107] The MA program normally took two years and required seven graduate courses and competence in one language other than English. Students had to take at least a half course in contemporary philosophy of science, two courses chosen from the history of the physical sciences, biological sciences or technology, and one advanced course requiring a major research paper. There was an option in the second year to replace several courses with a thesis. The PhD program required the completion of an Institute MA or equivalent, all three courses in the history of the physical sciences, biological sciences and technology, qualifying exams (both a general one and a specific one in two separate fields), and a dissertation.[108]

To help deliver the programs, some new core faculty were added to the Institute for 1969-70. Bruce Sinclair, an historian of technology at Kansas State University, was recruited as an associate professor (on Kranzberg's recommendation). Mary P. Winsor, a doctoral student in the history of biology at Yale, came as a replacement for Hodge who left for UC Berkeley. And James MacLachlan, working on a doctoral dissertation at Harvard, joined the Institute on a half-time basis, the other half being at the University's college in Mississauga. To accommodate them, the University rented the remaining space on the second floor of 191 College. The Institute's expenditures for that year totaled $81,835.[109]

The now fully established Institute attracted 15 graduate students (in addition to the three from the previous year) into its new programs in 1969-70. For the next decade, the annual total enrollment would number in the thirties. The 1969-70 cohort provided the first of the Institute's PhDs. Nachum Rabinovitch obtained a doctorate in 1971 with a thesis on "Probability and Statistical Inference in Ancient and Medieval Jewish Literature," as did Peter Bowler later that year with "The Impact of Theories of Generation upon the Concept of a Biological Species in the Last Half of the Eighteenth Century." Ron B. Thomson, in 1970, earned the first MA granted to a student enrolled in the Institute (Richard Jarrell had completed his MA in 1969 in the History department). After that several MAs would be granted annually. Fifty years later, well over a hundred Institute students have earned PhDs and many more MAs.

Six years had been required to take the Institute for the History and Philosophy of Science and Technology from idea to implementation. Even with the support of senior officials and a favourable environment of university expansion, many institutional hurdles needed to be overcome. It took the judgment and perseverance of two presidential committees, the dedicated efforts of John Abrams, and the work of several other committees to create the Institute. While a pioneer in Canada, the Institute was itself inspired by the handful of universities that had led the way in transforming the history of science during the prior decade. The University had grafted the emerging newly institutionalized discipline onto its own longstanding interest in the history of science. Encouraged and assisted by the external scholarly community, Toronto created a graduate program that aimed at participating fully in the new discipline. Its goal was to join in with the efforts of those universities in advancing research and in guiding the development of professional historians of science.

While the six-year gestation period was lengthy, it did result in a robust organization. University policies and priorities would continue to evolve. Several of the issues the Institute had faced during its formation—such as its relationship with Philosophy, the appropriate balance between undergraduate and graduate teaching, tight financial resources, and its location in the School of Graduate Studies—would resurface in the following years. The frontiers of the history of science would also shift. The Institute's programs, which at the time it was formed reflected the discipline's focus on the Scientific Revolution and emphasis on intellectual history, would be questioned. Yet the Institute that had been established in the 1960s proved to be resilient enough to deal with all these challenges.

Philip Enros studied at the IHPST in the 1970s, completing a PhD in 1979. Now retired, he spent most of his career working in science policy in the Government of Canada. Philip is the author of Environment for Science: A History of Policy for Science in Environment Canada *(2013). He continues to research various aspects of the history of Canadian science policy.*

Endnotes

1 Memo to the President, October 3 1963, UTA A77-0020/18. In the following endnotes, UTA stands for University of Toronto Archives and LAC for Library and Archives Canada. I am indebted to the staff of these archives for their help in finding and accessing material for this article.

2 The Canadian society is now called the Canadian Society for the History and Philosophy of Science.

3 No reasons were given for this decision in Woodside's report (op. cit., endnote 1).

4 Memo to Woodside, October 11 1963, UTA A71-0011/84

5 University of Toronto, *President's Report 1953-54* (Toronto: University of Toronto Press, 1954)

6 Report of the Special Committee on the Humanities (1954), UTA A83-0036/19. After Innis's death in 1952, Woodside became the committee's chair.

7 The book was *Leonardo da Vinci, The Anatomist (1452-1519)*, written by McMurrich at George Sarton's suggestion. Sarton had given three lectures at the University of Toronto in January 1918 before a large audience. One was on daVinci, the others on the need for the history of science and, of course, his signature theme of the new humanism. See the student newspaper, *The Varsity*, January 18 and 21, 1918.

8 Frederick Brasch, "List of Foundation Members of the History of Science Society," *Isis* 7, 3 (1925): 371-393

9 David Orenstein, "Jazz Age Toronto," paper presented at the meeting of the Canadian Science and Technology Historical Association, November 2015

10 Arnold Thackray, "The Pre-History of an Academic Discipline: The Study of the History of Science in the United States, 1891-1941," *Minerva* 18, 3 (1980): 448-473. See also Marshall Clagett, "Review of George Sarton's Horus – A Guide to the History of Science," *Isis* 44, 1-2 (1953): 91-93

11 Martin Friedland, *The University of Toronto: A History* (Toronto: University of Toronto Press, 2002)

12 University of Toronto, *President's Report 1969-70* (Toronto: University of Toronto Press, 1970)

13 There is no overview of the history of the history of science. I have relied especially on: Elena Aronova, "Studies of Science before "Science Studies": Cold War and the Politics of Science in the U.S., U.K., and U.S.S.R., 1950s-1970s" (PhD dissertation, UC San Diego, 2012); C.C. Gillispie, "A Professional Life in the History of Science," chapter 2 in *A Master of Science History: Essays in Honor of Charles Coulston Gillispie*, ed. J.Z. Buchwald (Dordrecht: Springer, 2012); Marie Boas Hall, "Recollections of a History of Science Guinea Pig," *Isis* 90, 52 (1999): S68-S83; Thomas S. Kuhn, "Professionalization Recollected in Tranquility," *Isis* 75, 1 (1984): 29-32; Anna-K. Mayer, "Setting Up a Discipline, II: British History of Science and 'the end of ideology', 1931-1948," *Studies in History and Philosophy of Science* 35 (2004): 41-72; and, Nathan Reingold, "History of Science Today, 1. Uniformity as Hidden Diversity: History of Science in the United States, 1920-1940," *British Journal for the History of Science* 19, 3 (1986): 243-262

14 Duane H.D. Roller, "The Teaching of the History of Science in the United States" (July 1 1965), copy in LAC, Abrams papers, box 40

15 Memo from Hughes, November 22 1963, UTA A77-0020/18

16 Minutes of the First Meeting, November 7 1963, UTA A77-0020/18

17 Bruce Sinclair, "John W. Abrams (1913-1981)," *Technology and Culture* 23, 3 (1982): 527-530. For more on Innis's and McLuhan's thinking about technology, consult R. Douglas Francis, *The Technological Imperative in Canada: An Intellectual History* (Vancouver: UBC Press, 2009).

18 Letter from Cohen, January 10 1964, UTA A77-0020/18

19 Letter from Woodside, January 13 1964, UTA A77-0020/18

20 Victor L. Hilts, "History of Science at the University of Wisconsin," *Isis* 75, 1 (1984): 63-94

21 Michael Hoskin, "History of Science Gathers Strength," *New Scientist* no. 376 (January 30 1964): 274

22 The institutionalization of the history of science in US universities followed many paths, some as separate departments, some within history departments, and still others as interdepartmental committees. Richard H. Shryock, "The History of Science in American Universities," *Proceedings of the American Philosophical Society* 105, 5 (October 1961): 512; and, I. Bernard Cohen's contribution in Part 8, "The History of Science as an Academic Discipline," in *Scientific Change*, eds. A.C. Crombie and M.A. Hoskin (London: Heinemann, 1963)

23 Memo from Abrams, January 7 1964, UTA A77-0020/18

24 Minutes of the Second Meeting, March 19 1964, UTA A77-0020/18

25 Report to the President, May 11 1964, UTA A77-0020/18

26 Cohen, op. cit., endnote 22

27 Op. cit., endnote 25

28 Ibid.

29 Memo for the President, October 16 1964, UTA A77-0020/18

30 Woodside to Hanson, December 7 1964, UTA A77-0020/18

31 Letter from Goudge, October 19 1964, UTA A77-0020/18

32 Matthew D. Lund, *N.R. Hanson: Observation, Discovery, and Scientific Change* (Amherst, NY: Humanity Books, 2010)

33 Hanson to Woodside, December 16 1964, UTA A77-0020/18

34 Flying was a passion for Hanson. It would claim his life two years later in April of 1967.

35 Goudge's personal journal, UTA B1996-0009/1

36 Letter from Hanson, January 28 1965, UTA A77-0020/18

37 N.R. Hanson, "A Report to the University of Toronto on History and Philosophy of Science as a Subject for University Research and Teaching," UTA A77-0020/18

38 Minutes, February 25 1965, UTA A75-0021/19

39 Op cit., endnote 35

40 Woodside to Toulmin, March 4 1965, UTA A77-0020/18.

41 Toulmin to Woodside, March 24 1965, UTA A77-0020/18.

42 Minutes, April 20 1965, UTA A77-0020/18

43 Crombie to Woodside, June 8 1965, UTA A77-0020/18

44 Buchdahl to Woodside, July 12 1965, UTA A77-0020/18

45 Minutes, November 1 1965, UTA A77-0018/20

46 Bissell to Woodside, November 24 1965, UTA A77-0020/18

47 Swinton to Woodside, December 8 1965, A77-0020/18

48 Minutes, December 6 1965, UTA A77-0020/18

49 Bissell's diary, December 13 1965, UTA B88-0091; and, memo from Bissell, February 2 1966, UTA A80-0029/1

50 He left the Defence Research Board at the end of 1962 or very early in 1963 with the intention of joining the University of Toronto in July. For the first half of 1963 he worked as a consultant with Price Waterhouse & Co.

51 Jonathan Turner, "The Defence Research Board of Canada, 1947 to 1977" (PhD dissertation, University of Toronto, 2012)

52 Speech at Abrams' Memorial Service, November 5 1981, UTA B2011-0018/12

53 Memo from Porter, April 15 1963, UTA A85-0009/12

54 Op. cit., endnote 51

55 Notebooks, LAC Abrams papers, box 4; University of London, University College, Calendars for 1949-50 and 1950-51

56 Woodside to Toulmin, March 4 1965, UTA A77-0020/18

57 Interim report, March 21 1966, UTA A1985-0009/12; and, Bissell to Careless, March 31 1966, UTA A80-0029/2

58 Careless to Bissell, April 7 1966, UTA A80-0029/2; and, SGS Committee on the history of science and technology, April 13 1967, UTA A85-0009/10. Careless served as a trustee of the Ontario Science Centre from 1963 to 1973.

59 Bissell to Woodside, May 20 1966, UTA A77-0020/20; see also Bissell's diary, April 15 & 22 and May 18 1966, UTA B88-0091

60 Bissell to Woodside, ibid.

61 Circular letter from the Committee, no date, UTA A75-0005/10

62 Lists of faculty responses, LAC Abrams papers, box 43

63 Survey of Departments in Faculty of Arts and Science, LAC Abrams papers, box 62

64 Esplin to Abrams, LAC Abrams papers, box 43

65 Drake's collection was comprised of approximately 2,348 volumes, then estimated to be worth a little over $88,000. The Library's offer was conditional on it having first chance to buy any material Drake wished to sell. Abrams to Drake, January 18 1967, and Esplin to Drake, June 28 1967, Thomas Fisher Rare Book Library, Drake Collection, box 89

66 The Varsity Fund was a pool of private donations to the University. Memo to Abrams, July 12 1966, UTA A80-0029/2

67 Bissell to Abrams, April 28 1967, UTA A80-0029/2

68 Minutes of the meeting, June 22 1966, UTA A2000-0005/6

69 "Report of the Committee on the History and Philosophy of Science," October 12 1966, LAC Abrams papers, box 43

70 Course outline, LAC Abrams papers, box 70

71 Op. cit., endnote 69

72 Report of the Committee, October 12 1966, LAC Abrams papers, box 43

73 Ten centres or institutes had been created between 1960 and 1965. "Laskin Report", *Graduate Studies in the University of Toronto: Report of the President's Committee on the School of Graduate Studies, 1964-1965* (Toronto: University of Toronto Press, 1965). See also chapter 34, Friedland, op. cit., endnote 11, and Ernest Sirluck, *First Generation: An Autobiography* (Toronto: University of Toronto Press, 1996).

74 Sirluck to Drake, April 7 1969, UTA A1985-0009/12

75 Bissell's diary, December 16 1966, UTA B88-0091

76 Abrams to Bissell, September 26 1966, LAC Abrams papers, box 43

77 Abrams to Bissell, November 10 1966, Thomas Fisher Rare Book Library, Drake Collection, box 89

78 Drake to Sirluck, March 28 1969, UTA A1985-0009/12

79 S. Drake, "A Memorial Tribute to Kenneth O. May," *Historia Mathematica* 5 (1978): 3-12

80 Gillispie to Drake, January 30 1967, Thomas Fisher Rare Book Library, Drake Collection, box 89

81 Report of the Committee, n.d., UTA A1984-0028/10

82 Council meeting, March 17 1967, UTA A1985-0009/10

83 Report of the [SGS] Committee, 1967, UTA A1984-0028/10

84 Council meeting, April 26 1967, UTA A1984-0028/10

85 Minutes of the Senate, May 29 1967, UTA A79-0037/4; Senate statute number 2995, October 13 1967, UTA A1984-0028/10

86 Minutes of the Board of Governors, October 26 1967, UTA A1978-0019/1

87 Sirluck to Sword, January 29 1968, UTA A75-0021/96

88 Report of the Committee, [Dec. 6 1967], UTA A75-0005/27

89 Derek de Solla Price, "A Guide to Graduate Study and Research in the History of Science and Medicine," *Isis* 58, 3 (1967): 385-395. It included 29 institutions (all in the US, except for Toronto) totaling 144 full-time faculty and 324 graduate students.

90 He had also helped with local arrangements for the History of Science Society meeting in Montreal in 1964.

91 SHOT, December 1967, LAC Abrams papers, box 21. See also "The Toronto Meeting December 27-29, 1967," *Technology and Culture* 6, 2 (1968): 327-345

92 Kranzberg to Sword, January 8 & 26 1968, UTA A75-0021/96

93 Op. cit., endnote 88

94 School of Graduate Studies, *Calendar* for 1968-1969

95 The first meeting was on April 28 1968, UTA A1985-0009/12

96 Abrams to Sirluck, November 19 1968, UTA A85-0009/10. The house was owned by the Royal Canadian Institute, a resilient scientific organization founded in 1849 in Toronto as the Canadian Institute.

97 The Religious Knowledge courses were still offered. They would be replaced in 1969-70 by regular undergraduate courses in the history of science and technology when the "New Programme" of undergraduate studies in Arts & Science was implemented. For more on the reforms of the undergraduate curriculum, see Emily Greenleaf, "The Toronto Scheme: The Undergraduate Curriculum in the Faculty of Arts and Science at the University of Toronto, 1945-2000" (PhD dissertation, University of Toronto, 2010)

98 Friedland and Sirluck, op. cit., endnotes 11 and 73

99 Letter from John G. Slater, March 12 1969, UTA A1985-0009/12

100 See Lund, op.cit., endnote 32; and, Thomas Nickles, "Philosophy of Science and History of Science," *Osiris* 10 (1995): 139-163

101 For more details see a transcript of the meeting of March 25 1969, LAC Abrams papers, box 43

102 Draft Constitution (n.d.), LAC Abrams papers, box 62. The Institute's constitution set up a Council as its governing body, largely consisting of core staff and affiliates. Woodside would chair the Council for its first few years.

103 May to Abrams, March 30 1969, LAC Abrams papers, box 43

104 Notes from consultants, UTA A85-0009/11

105 Ontario Council on Graduate Studies, UTA A85-0009/10

106 Senate statute 3038, UTA A1984-0028/11

107 Abrams' Report for the 5-Year Review, 1972, UTA A85-0033/12

108 School of Graduate Studies, *Calendar* for 1970-71

109 Abrams to Bissell, November 9 1970, UTA A1977-0020/80

Technology Development at the Bedford Institute of Oceanography, 1962-1986

Michael Murphy

Abstract: *This paper explores the relationship between technology and discovery in oceanography, examining examples of instrumentation development at the Bedford Institute of Oceanography (BIO). Between 1962 and 1986, BIO researchers and technicians initiated a wave of rapid technological development, while also adopting technology developed elsewhere. These developments were a bridge into the digital age as BIO staff incorporated computer hardware and software into instrument development. This paper summarizes these developments, their impact on the work of the Institute, and factors that influenced this work, and how they changed over time BIO emerged as a world-class oceanographic institution.*

Résumé : *Cet article explore la relation entre technologie et découverte en océanographie, en examinant des exemples de développement instrumental à l'Institut océanographique de Bedford (IOB). Entre 1962 et 1986, les chercheurs et les techniciens de l'IOB ont initié une vague de développements technologiques rapides, tout en adoptant des technologies développées ailleurs. Le développement de ces instruments a constitué une entrée dans l'ère numérique, puisque nombre d'entre eux incorporaient du matériel et des programmes informatiques. Cet article résume ces développements, leurs impacts sur les travaux de l'Institut, les facteurs ayant influencé ces travaux, ainsi que la manière dont ils ont évolué à travers une période où l'IOB a émergé comme une institution océanographique de renommée mondiale.*

Keywords: oceanography, Bedford Institute of Oceanography, technology development, instrumentation

Introduction

> "It appears, therefore, that the most promising mode of advancing our knowledge…is to examine the laws which can be collected from observation, taking so great a number of observations, that the effects of all accidental causes may disappear..."[1]

William Whewell, the influential English philosopher and scientist, articulated the role of observation in the scientific process: indeed, that observation provided the base for scientific knowledge. We discover the laws of nature through observation and the collection of precise, reliable, and traceable measurements, at a scale and cost that fit the circumstances. In essence we need tools—instruments, equipment, and processes—to make measurements and to collect data. All branches of science are dependent on technology and instruments to some degree, but few more so than oceanography as it faces challenges from having to operate in the adverse conditions of marine environments.[2] As Helen Rozwadowski and David van Keuren have observed,

Michael Murphy, "Technology Development at the Bedford Institute of Oceanography, 1962-1986" *Scientia Canadensis* 39, 1 (2016-17): 74-92.

"what oceanographers have learned about the ocean has been based almost exclusively on what various technologies, or machines, have taught them."[3] Instruments such as the thermometer, the barometer, and the plankton net, among others, have driven oceanography. And as instruments have developed alongside advances in areas such as microelectronics and computing, oceanographers have been able to acquire more data, more precisely, and at a lower cost, allowing them to further develop and test oceanographic theory.

This paper will explore this relationship between technology and discovery in the field of oceanography, by examining examples of instrumentation development at the Bedford Institute of Oceanography (BIO) between 1962 and 1986. Established in October 25, 1962 with the mandate to be Canada's centre for oceanographic research and technical surveys for the Atlantic and Arctic Oceans, BIO's first twenty-five years were marked by a period of rapid technological development.[4] These advances were of two types: in-house developments and the adoption (and adaptation) of technologies developed elsewhere. Both reflected the transition to digital technologies as microelectronics and computing transformed oceanographic observation and theorizing. Focusing on in-house developments, this paper considers a number of features of instrumentation development at BIO: first, the developments themselves; second, their impact on the work of the Institute; and finally, the factors that encouraged or discouraged these developments. The examples have been chosen to demonstrate the range of work at BIO, particularly the integration of various oceanographic and technological disciplines, and highlight the critical transition from mechanical instruments to ones driven by microelectronics and computer technology, and finally, the evolution of trends in oceanographic research from 1962 to 1986. While oceanographers probed the mysteries of the oceans using these new technologies, historians can, through examining their development, analyse their influence on how institutions were organized, their chosen of areas of study, and what roles various groups played. The history of BIO shows how conscious choices established an atmosphere that encouraged technological innovation and how that changed through time as the Institute evolved into "one of the largest and most influential oceanographic laboratories in the world."[5]

Establishment of the Bedford Institute of Oceanography

> "The Bedford Institute was conceived as Canada's Atlantic and Arctic center for shipborne surveys and for marine research in the physical sciences. It was set up to meet national requirements in support of fisheries, navigation and maritime defence, and to provide assistance in the delineation of natural resources and in weather forecasting."[6]

Canada's efforts in oceanography after the Second World War are best described as diffuse, with numerous government agencies following separate agendas. The establishment of the Joint Committee on Oceanography (JCO) in 1946 attempted to coordinate research programs by bringing together federal departments with an interest in oceanographic research. Research had expanded during the war years, as the Canadian Navy realized its need to understand the physical properties of the ocean to improve sonar submarine detection. This focus on military research continued with the advent of the Cold War, expanding from strictly military concerns to sovereignty issues, especially in the Arctic. American interest in the high Arctic was driven by the threat from the Soviet Union: the polar region could be used as a staging area for nuclear attack from submarines and was also the flight path for bombers armed with nuclear weapons. This necessarily drew in Canada, which participated in the construction of the Distant Early Warning (DEW) line of radar installations across the Arctic and in the building of joint weather stations. Canada ventured into oceanographic work in the Arctic in response to American projects, such as the work in 1948 collecting temperature and salinity profiles by the USCG ships Edisto and Eastwind. Royal Canadian Navy (RCN) vessels began making sporadic trips into both the eastern and western Arctic and took oceanographic observations as part of their mission, although sovereignty was in all likelihood the prime reason.[7]

By the late 1950s, Dr. W.E. van Steenburgh had joined the Department of Mines and Technical Surveys (DMTS) as the Director-General of Science Services and had begun steering that department towards a greater involvement in oceanography, picking Halifax, with its large naval presence and the existing Defence Research Board (DRB) laboratory, as the site of east-coast activities. It seemed a logical choice with a newly established oceanography program at Dalhousie University under negotiation by 1958 and the Fisheries Research Board of Canada (FRB) proposing to move the Atlantic Oceanographic Group (AOG) from St. Andrews to Halifax in the same year. By December 1959, van Steenburgh, now the chair of the reorganized Canadian Committee on Oceanography (CCO), was in a position to announce the establishment of BIO and the construction of a scientific vessel, the CSS Hudson, to support its work.[8]

Staff moved into unfinished buildings at BIO in the summer of 1962 and began the task of implementing van Steenburgh's vision. Ninety-five staff representing three federal agencies—AOG, Canadian Hydrographic Services (CHS), and Marine Services Branch (MSB), both part of DMTS—were on site by the official opening on October 25, 1962. In 1963, the marine geology unit of the Geological Survey of Canada (GSC) joined BIO, a response to the leasing of offshore areas for petroleum exploration. In its early years, the Institute was clear that its activities directly served the needs of those involved in the fisheries, navigation, and maritime defence, making efforts in its annual report to outline the tangible results that BIO provided to what it termed its "customers." Not surprisingly, the Institute devoted more space to maritime defence than to fisheries and navigation in the 1963 report.[9] At the time of BIO's establishment, the Cold War was more hot than cold, with the building of the Berlin Wall in 1961, the Cuban missile crisis of 1962, the escalating conflict in Vietnam, and the assassination of President Kennedy in November, 1963.[10]

Envisioned as a bold experiment, BIO brought together, in one physical location, scientists whose work ranged across oceanography, hydrography, geophysics, chemistry, geology, and biology. The facility also housed technicians and support staff, provided vessels and docking facilities, and a high level of electronic and mechanical engineering design and support. BIO extolled itself as "the only example of its kind in North America," a statement with a touch of hyperbole.[11] While combining the capacity to conduct technical surveys for navigational charting and tide charts in an institute with oceanographic research was novel, certainly other institutes combined many disciplines in integrated facilities. The Scripps Institution of Oceanography (SIO) and Woods Hole Oceanographic Institution (WHOI) had similar organizational structures to BIO: a campus with a number of quasi-independent labs or organizations; common, shared facilities such as ships and wharves; and support staff for data processing and instrument development.[12] In its earliest days, BIO considered this dual role of research and applied science as appropriate, each depending on the other for support and synergy in the transfer of ideas and techniques. Especially important and noted explicitly from its beginnings was the desire for BIO to develop its engineering capacity, specifically for instrument development. By 1963, design and development work had already commenced in this area.[13]

Technology Development at BIO

> "The development of highly accurate and dependable instruments for Oceanography is one of the major problems facing man in his endeavors to understand and effectively utilize the wet continents."[14]

The first twenty years of BIO's existence marked a transition period for technology in general as instrument makers began incorporating microelectronics and computers. In the early 1960s, the tools used for physical oceanography (**Figure 1**) would not have been unfamiliar to members of the Challenger expedition of the 1870s.[15] But the revolution in solid state and microelectronics was underway and, coupled with the advent of microcomputers, would transform the collection and analysis of data in ways that the early pioneers of oceanography could not have imagined. By 1986, the world had changed: more analysis was done *in situ*: remote sensing and satellite usage was expanding; costs for computers and microelectronics were dropping quickly; and data-transmission methods through satellites and computer networks were becoming standard practice. No longer did oceanographers seek to collect detailed, highly accurate observations at a small number of stations, a method limited by the availability of ship time. Rather, oceanographers with new instruments began gathering masses of data over wide areas using relatively inexpensive methods, and analyzed them using new computer tools to derive insights.[16]

Other factors drove changes in a similar direction. Inflation, the scourge of fixed incomes, ran rampant through the 1970s with fuel costs skyrocketing as a result of OPEC's oil embargo after the Yom Kippur War in 1973.[17] The

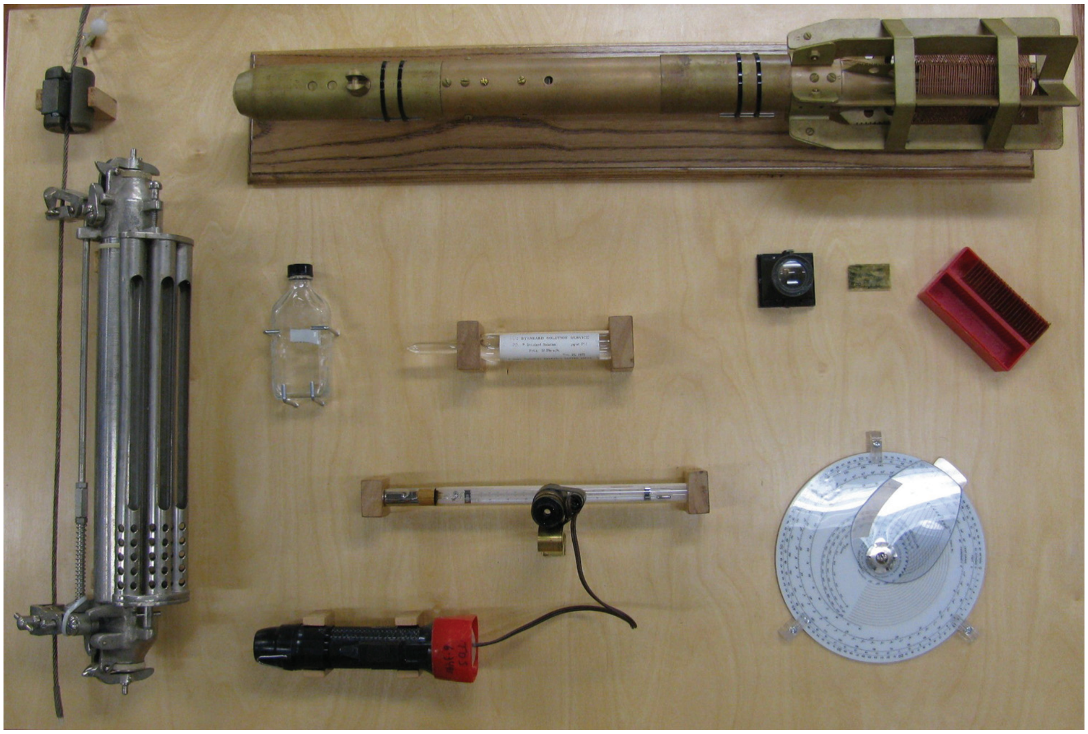


Figure 1. *Tools of the trade for physical oceanography in the early 1960s. From the top: bathythermograph (BT) for measuring water temperature at various depths; slide holder and glass magnifier for reading slides from the BT; special slide rule for converting thermometer readings to temperature and depth; illuminated magnifier for reading reversing thermometers; just above is a reversing thermometer; above that is a standard sample of sea water used to compare recovered samples; to its left is a sterile water bottle for storing seawater samples for later testing; far left is a Knudsen water bottle for collecting seawater samples. Credit: BIO Oceans Association, Physical Oceanography - Twentieth Century Tools of the Trade, http://www.bio-oa.ca/phys_oc/index.html downloaded Feb. 25, 2014.*

Iranian Revolution in 1979 and the subsequent Iran-Iraq war also drove up oil prices, which reached $35/barrel—ten times the early 1970s price. These events also drove up the costs of ship time and conducting on-board research.[18] This period also saw significant changes in government policy regarding research and development in Canada, guided by the work of the Senate Special Committee on Science Policy chaired by Maurice Lamontagne. Beginning with its first three reports issued from 1970 to 1973 and continuing to its last report late in the 1970s, the Committee exerted great influence on science in Canada and on the development of technology at BIO in particular.[19] The government accepted several of the Committee's recommendations, including the establishment of the Natural Sciences and Engineering Research Council (NSERC) as the primary granting agency for Canadian scientific research; the requirement for more industry involvement in research and design through targets and technology-transfer programs; and the implementation of new funding processes, particularly what became known as the unsolicited proposal process. BIO's response to these initiatives was part co-operation, part soft resistance.[20] When the situation suited, BIO cooperated, such as when an instrument or platform developed by BIO staff could be transferred to industry for production and sale. But BIO was less accommodating when it came to its research programme and the government's requirement that 50% per cent of BIO activity be conducted by the private sector. BIO outlined numerous challenges to meeting this requirement, citing the small size of Canada's research and instrumentation industries, its inability to meet quality standards, and the difficulties in dealing with administrative hurdles associated with the contracting process. It even attempted to sidestep this requirement, and protect its research programme, by including maintenance and servicing of equipment in its calculation of private-sector activity. By 1974, however, this resistance to contracting-out for services softened after a review of all research activities was undertaken to determine suitable candidates for private-sector delivery. This resulted, by 1976, in the identification of such partners as Huntec (70), Guildline Instruments, and Hermes Electronics.[21] BIO management was not above using this new emphasis on partnership with the private sector, for example, when proposing a building expansion to relieve overcrowding. The pitch for additional capital funding anticipated significant benefits for the private-sector partners resulting from such an expansion without mentioning, of course, how it might benefit the staff of the institute.[22]

In its beginnings, the philosophy of BIO was clear: research was dependent on the utilization of the newest equipment and, while the production of that equipment could be left to commercial interests, the design and development of those tools should be done by BIO staff in conjunction with the researchers at BIO. That philosophy led to the establishment in 1964 of the Instrument Design Group headed by Dr. R.L.G. (Reg) Gilbert to work on developing new electrical and mechanical equipment, and improving the operation of existing equipment.[23] During its growing pains, BIO searched for the right organizational structure to reflect these changes: in 1965, the recently formed Instrument Design Group was subsumed into the Engineering Services Group and in 1966 the Metrology Division was split off from Engineering Services. The division was headed by Dr. Gilbert until 1970, when he left BIO for a position in Ottawa with the Department of Fisheries and Forestry. He was succeeded by Dr. Clive Mason and later by Dr. David McKeown in 1976.[24] The Metrology Division would become the driving force behind the research and development of oceanographic instrumentation at BIO for more than twenty years, continuing to exist with minor changes until the 1994-5 merger of the Department of Fisheries and Oceans (DFO) with the Canadian Coast Guard (CCG) brought about significant change to BIO's organizational structure.[25]

The following examples of technological development are illustrative of the shift to microelectronics, computer applications, industry participation, and increased operating costs at BIO. These projects are representative of the hundreds of projects carried out at BIO between 1962 and 1986, and convey the breadth of work that crossed oceanographic and technological disciplines, and illustrate how oceanographic research has evolved into a multidisciplinary endeavour during this twenty-five-year period in BIO's history.

Hydrostatic Rock-Core Drill

In 1965, John Brooke and Reg Gilbert of the Metrology Division led the development of a hydrostatic rock-core drill with the goal of creating a tool capable of collecting rock cores from depths between 800 and 2000 meters. This was part of BIO's efforts to investigate the new theory of plate tectonics and the incidence of sea-floor spreading by examining shallow areas of the Mid-Atlantic Ridge. Existing drills were limited by the lack of an independent power source and required power cables from the surface. The hydrostatic drill used the water pressure at depth as its means of power, with the flow of water into an empty reservoir providing sufficient power to drive a small drill system. But challenges remained particularly with downloading, the need to apply downward pressure for the drill to penetrate the rock. While the usual solution was to fix mass at the top of the drill, this decreased its stability. Instead, Brooke and Gilbert devised an automatic load-sensing download mechanism that sensed the power consumption of the hydraulic motor and, through the pressure along the hydraulic circuit coupled with a hydraulic cylinder, applied the appropriate amount of downward pressure on the drill bit. By 1969—the year Brooke and Gilbert patented it—the drill was producing one-inch diameter cores up to 15 inches long from the Ridge area in water over 800 metres deep. Unfortunately, the depth range of the drill limited its work to the relatively shallow peaks of crests found in the Median Valley of the Ridge and work began on an improved version capable of drilling in waters 4000 metres deep. Although controlling and monitoring the drill was difficult, it was used to obtain samples for various research programs at much cheaper cost than alternative means such as specialized drill ships.[26]

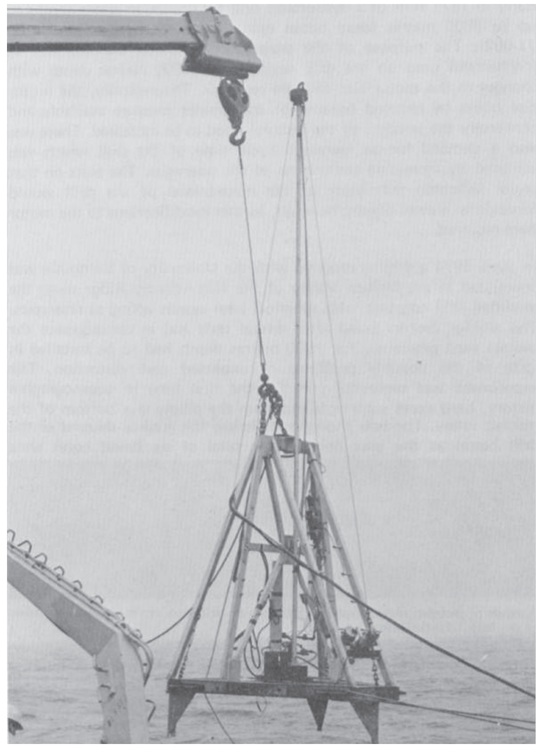


Figure 2. Shallow-water electric rock-core drill with 20 foot barrel. BIO, Biennial Review 1971/72, 150.

The success of the hydrostatic drill stimulated further development work on drills capable of working in shallower water. The shallow-water drill (**Figure 2**) could not rely on water pressure to drive the drill, so the designers added a small three-phase pump motor to the drill. This connection also provided the opportunity to constantly monitor and control the drill. Initially designed for work on the continental shelf in waters up to 400 meters deep, a version was later modified for use in waters ten times deeper, equivalent to the depth location of the mid-ocean ridges. Capable of drilling up to nine meters into the seafloor, the electric rock-core drill was used extensively to collect core samples from hundreds of stations from the Bay of Fundy up to the high Arctic region. These cores still represent the only source of information on the geological bedrock of many sections of Hudson Strait and the Baffin Island Shelf, an area with potential for hydrocarbon development. Like the hydrostatic drill, the electric rock-core drill saved money as it was less expensive to operate than a specialized drill ship.[27]

Hydro-acoustic Assessment of Fish Stocks

During the 1970s, more fish stocks came under quota-management systems that used stock assessments and abundance estimates to determine catch levels. As regulatory regimes became more segregated with stocks subdivided into smaller management units, the demand for stock information increased and drove scientists to look for more accurate tools for estimating fish abundance. The traditional method in the 1960s was the trawl survey, which provided a basis to determine the catch-per-unit of effort and thus an estimate of abundance. In 1966, the Marine Ecology Laboratory (MEL) began experimenting with echo sounders and the properties of acoustic signals produced when passing through an assembly of fish. By 1974, Dick Dowd and Ross Shotton of MEL had developed the Computerized Echo Counting System (CECS, **Figure 3**), which was capable of sorting the returning acoustic signals from a transducer into size categories that could be then used to calculate the number of fish per 1000 cubic metres of water, providing a real-time measure of fish density. Initially developed for demersal species, Dowd and Shotton soon expanded this work to include herring and other pelagic species. The basic components of the system were an echo sounder, a transducer, and a computer, but the real work was performed by their computer programs that crunched the numbers on stock-abundance estimates.[28]

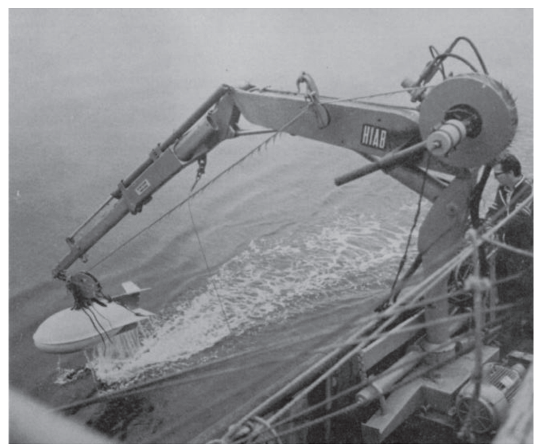


Figure 3*. A hydraulic crane is used to lower and raise the CECS towed body, which contains the echo sounder's transducer, as part of the acoustic fish-counting program. BIO, Biennial Review 1973/74, 242.*

But users of CESC faced challenges that put into question their reliability for stock-assessment work. Echo-sounder systems exhibited high variability in return signals, a problem caused by different sizes of fish and their relative position to the sound beam. Fish closer to the center of the beam, for example, returned a stronger echo than those at the edges. As well, different vessels surveying the same stock gathered different results showing high degrees of variability in the returns. To resolve these issues, Dowd and Shotten continued work on the concept into the 1980s with the development of a new system called ECOLOG that used two transducers to obtain better estimates of fish size and stock abundance. By 1983, the system had been built and tested with encouraging results, but it needed further development before it was accepted.[29]

Seabed Mapping

Understanding the topography and composition of the seabed floor is critical to the exploration of the oceans. The increased interest in marine geology after World War II led to a drive to collect samples of materials on the subsurface as well as the seabed. The development of seabed mapping programs at BIO—beginning in 1974 with Huntec Ltd. and continuing through Project Seabed I and Project Seabed II which ended in 1985—to address these needs brings a focus to many of the themes discussed here, including the use of new technologies, collaboration between different groups at BIO, and the use of public-private partnerships. The genesis of seabed mapping occurred in the late 1960s with Lewis King and other researchers from the Marine Geology Section who realized that the echo sounders on the BIO fleet provided more information than water depths at their sample sites. The echo sounders recorded the results on rolls of paper and King realized that there was a correlation between the type of sediment on the seabed and the image on the paper roll; for example, the echoes penetrated mud bottoms, returning a different pattern than echoes from bedrock or till where the echoes do not penetrate. This discovery led to the use of echo sounders to map and characterize large areas of the seabed using echograms and seabed-sediment analyses.[30]

By the 1970s, geologists used a variety of tools based on King's discovery with echo sounders using high-frequency sound waves and seismic profilers using low frequencies being the most popular. But neither system worked well in all conditions, either because of the type of sediment layers on the sea floor or due to wave and wind conditions on the surface. Given the level of interest in exploration for offshore oil in the early 1970s, a system capable of providing clearer profiles of the surficial sediment stratigraphy was needed. Marine geologists would then be able to "see" beneath soft, muddy clay sediments that had previously obscured hard sediments such as till or sand and allow them to find specific features such as stacked tills which indicate areas of glacial movements. To address these needs, Huntec met with the Metrology Division and Atlantic Geoscience Centre to develop a proposal for review under the new unsolicited proposal process established in 1972 to stimulate research and development and encourage commercialization. Huntec proposed in 1974 to develop a deeply-towed seismic system (DTS) capable of achieving high levels of resolution of the seabed and deeper penetration into the sediment even when towed at relatively high speeds.[31]

Testing of the new DTS system in the summer of 1974 led to numerous improvements and the results were considered to be outstanding, leading to

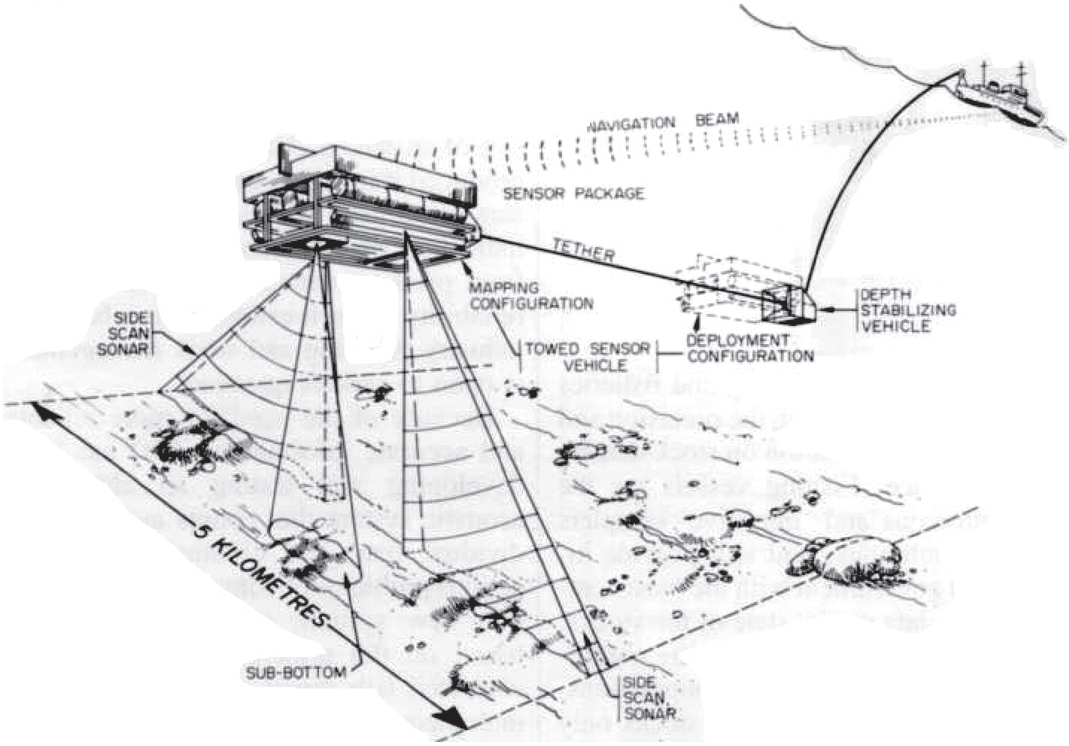


Figure 4. *A schematic depicting the principle of operation of the two-stage Seabed II integrated mapping system. BIO, BIO Review '83, 41*

recommendations to include the system in BIO's toolkit and to prepare a long-term program of system development. To this end, Huntec entered into a five-year partnership in 1975 with BIO and Memorial University called Seabed I to further develop the tool and begin mapping the seabed floor. Through the five years of the program, numerous improvements were made to the system and by 1980 Huntec was successfully marketing operational units to international clients.[32]

Seabed II (1981-1985, **Figure 4**) built on the efforts of the first project and extended the range of the submersible so it could work in much deeper waters and cover larger areas. Equipped with improved technology, it could work below depths of 2000 metres and its side-scan sonar covered 2.5 km on either side of the submersible. Although successfully tested in 1983 and 1984, the project was terminated in 1985 due to reductions in government spending. By incorporating some of the new technology developed for the Seabed II into the older Huntec DTS, BIO continued its program of geological mapping in the offshore territories and collected data along lines stretching more than 250,000 kms to date.[33]

Temperature Probes: Digibridge, OCTUPROBE (Oceanic Turbulence PROBE) and EPSONDE

This period saw a rapid evolution in the capability of measuring ocean temperatures, from the reversing thermometers of the 1960s to probes capable of transmitting extremely precise data instantaneously to the surface. This ability to measure temperature variations on very small scales (representing small-scale turbulence in the ocean) was an innovation that significantly altered the conceptions of physical oceanography at that time.[34] One of the earliest examples of an integrated digital-electronic instrument developed at BIO was the Digibridge. Developed in 1970 by a team led by Andrew Bennett of the Metrology Division, the Digibridge recorded a precise time-series of ocean temperatures. The device, which could operate continuously for up to 20 days, featured a recorder that measured the resistance of three glass-bead thermistors every five minutes, thus providing a temperature reading with an accuracy approaching 0.003°C. The Digibridge was secured on a mooring with a pop-up frame, and was activated by an acoustic command from the surface.[35]

As the sensitivity and precision of instruments improved, oceanographers discovered variations in temperature profiles throughout the water column that were not earlier suspected. The Digibridge was limited in studying these variations as it was fixed on a secure mooring, which led to improved instruments such as the OCTUPROBE (Oceanic Turbulence Probe. **Figure 5**), a device designed by Neil Oakey of the Instrumentation Group of the Ocean Circulation Division to measure variations in temperature, salinity, and turbulent velocity in the water column. The OCTUPROBE was allowed to free-fall through the water column with data being recorded using an internal tape drive. When the desired depth was reached, the probe was retrieved using an attached line, and the process was repeated until the tape drive was filled. Oakey and his team continued to make design and technical changes based on improving computer and electronic capabilities for measuring, storing, and transmitting data and, by 1982, the OCTUPROBE evolved into the EPSONDE. While the EPSONDE used similar sensors as the earlier OCTUPROBE, it was capable of transmitting data digitally directly to the surface through the tether line, making the internal tape recorder obsolete.[36]

Navigational Accuracy—BIONAV

Accurate positioning at sea has long challenged mariners and scientists, at the same time that our definition of accuracy has evolved with increasingly precise technology such as GPS. By the 1970s, BIO ships utilized a number of different navigation systems because ship cruises performed a variety of tasks during each voyage, including retrieving buoys, running survey lines, locating drill sites, or maintaining position over several hours. Each of these tasks was under the direction of a different group, who usually used a different navigation system suited to the task at hand. Each system had strengths and weaknesses, working well in certain applications and under certain conditions but not in others. After surveying users in 1975 to determine their needs, programmers Stephen Grant and David Wells began to develop a software package that could integrate the various systems then in use, such as Transit satellite navigation, Loran-A and Loran-C, Decca, speed logs, and gyrocompasses. The result was

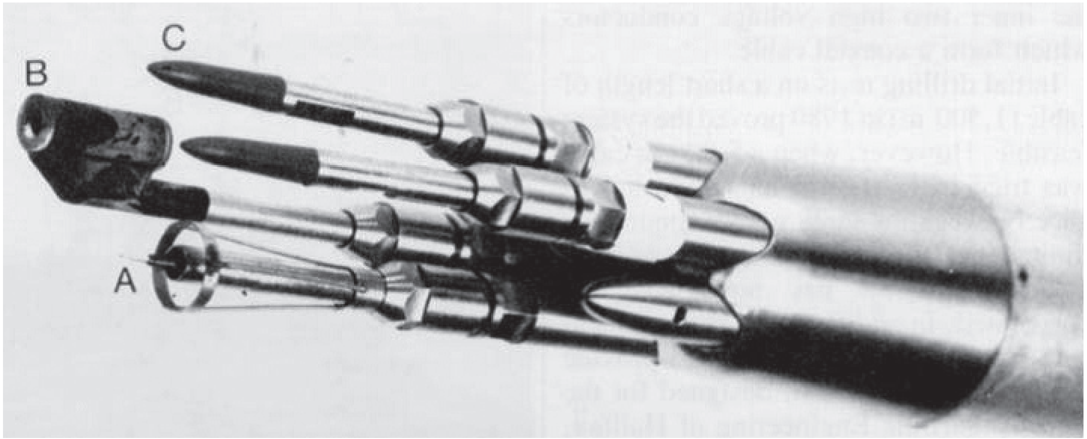


Figure 5. OCTUPROBE, showing the internal structure of the 2 metre probe with three sensors: A is a thinfilm sensor to measure temperature microstructure; B is the conductivity sensor; C are two lift probes to measure two perpendicular components of velocity microstructure or turbulence. BIO, BIO Review '83, 47.

the BIONAV system, developed in 1978 to maximize the strengths of individual navigational systems, plot survey-data in real time, guide the ship to an exact position, and reduce operating costs by using ship time more efficiently. Written in-house in Fortran IV by Grant and Wells, BIONAV consisted of 150 individual computer programs, library routines, and procedures totalling over 30,000 lines of code.[37]

The free distribution of the system to other institutions and private companies promoted its extensive use throughout Canadian marine waters. Users could modify BIONAV for different hardware and the system became remarkably successful, allowing scientists and hydrographers to navigate more accurately. It was only replaced with the advent of the Global Positioning System (GPS) in the late 1990s.[38]

Biological Sampling—BIONESS

The uneven spatial distribution, or patchiness, of plankton has challenged oceanographers who have attempted to estimate populations of these miniscule organisms, the foundation of oceanic food and energy chains. Opening-closing nets, developed in the late nineteenth century, were the main tool available to scientists until Alister Hardy introduced his Continuous Plankton Recorder (CPR) in the 1930s. Designed to be towed behind ships of opportunity, it was roughly one meter in length, with spools of silk mesh situated to capture plankton as the seawater flowed through the CPR. After the Second World War II, researchers improved on this design and other mechanical instruments and by the 1960s began developing electronic and acoustic-control systems.[39] The technology revolution in the 1970s finally enabled researchers to move beyond simple opening-closing net systems to gain a fuller understanding of the patchiness of plankton.[40]

This was evident at BIO, where close cooperation between engineers and researchers led to new methods for determining planktonic spatial patterns using advances in control systems and technology that could measure salinity, temperature, and other variables. Doug Sameoto of the Marine Ecology Laboratory developed the Bedford Institute of Oceanography Net and Environment Sensing System (BIONESS) consisting of a system of ten nets capable of being opened or closed allowing the researcher to take samples at various depths, providing a vertical distribution of plankton in the water column. As well, additional smaller mesh nets could be inserted into the mouth of the other ten nets, allowing a total of twenty separate samples to be collected in each tow. Alex Herman, an engineer in the Metrology Division, added computer technology to the system with a microprocessor capable of controlling the unit underwater. With sensors to provide physical oceanographic data such as temperature, salinity, and depth connected to the controller, the nets could be opened or closed based on predetermined information; for example, at a certain depth or temperature, a specific net would open or close. The control system also collected data on water speed and volume, chlorophyll *a* fluorescence, and light. The adaptation of these controls to pumping systems to correct for the motion of the ship allowed biological sensing and sampling with a discrimination of one metre in 100 metres of depth. Another example of the technology transfer program, this system went into commercial development and units are still available for purchase.[41] The use of microcomputers to control systems and the development of sophisticated sensors capable of connecting to those control systems provided researchers with the tools needed to acquire an accurate picture of both vertical and horizontal patterns of plankton distribution.[42]

Physical and Biological Data Capture—Batfish (towed CTD and plankton counter)

The development of the Batfish (**Figure 6**), a towed vehicle capable of moving vertically through the water column carrying multiple sensors, brought together many of the themes evident in the other examples. It evolved from its initial design as an automatic bathythermograph capable of collecting temperatures as it oscillated between pre-set depths of 50’ and 250’, into a sophisticated platform for collecting physical and biological data throughout the water column as it was towed and controlled from a ship at normal cruising speeds. A young, recently hired engineer, J.G. Dessureault, led the work from 1966 for many years and based his Master’s thesis on its development.[43] The evolution from its conception to its state in 1986 captures many of the developments discussed previously: the rapid expansion of the use of microelectronics and digital equipment; the transfer of technology from the public to the private sector; the increased use and power of computing technology; and the interaction between various groups at BIO resulting in a co-operative approach to solving problems.[44]

By 1975, the Batfish had been developed into a vehicle with a bottom-avoidance system, able to collect data on temperature and salinity variations in the top 400 metres on a continual basis as the vehicle moved horizontally

Figure 6. Batfish on CSS Hudson during a 1980 Gulf of St Lawrence cruise. Photo: Andrew Bennett.

and vertically through the water. This ability revealed complexities in the wave field that could not be observed with conventional vertical casts of conductivity, temperature and depth (CTD). Importantly, that year marked the shift into biological sensing in addition to the CTD work. In 1974, the Batfish had been used to collect CTD information and then was fitted with a fluorometer to get a two-dimensional picture of chlorophyll concentrations. This work was advanced in 1975 as the Metrology Division adapted fluorometers for use on the Batfish in conjunction with CTD sensors and work commenced on developing a zooplankton counter that could be integrated into the data-collection array on the vehicle.[45]

Improvements were continually made to address difficulties encountered with the counter, such as its need for continual cleaning, leading to short towing periods of less than three hours and its inability to measure animals longer than 3mm. With advances in optical technology, particularly in the field of low-power light-emitting diodes, BIO, through the work of Dr. Alex Herman, developed an optical plankton counter that could be fitted onto the Batfish. Patented as the Laser Optical Particle Counter, a newer version is still available for sale through ODIM Brooke Ocean.[46] A light beam was used to determine the size of animals that broke the beam, getting an estimate of the zooplankton; and the same beam could provide an estimate of phytoplankton biomass by measuring the light attenuance of the water. Freed from the need for a net, tows were no longer limited in duration. By 1986, the Batfish was a more complete data-collection platform with some sensors developed solely by BIO, others in conjunction with industry partners, all of it available commercially through various technology-transfer arrangements.[47]

Conclusion

The various technologies developed in the early years of BIO serve as examples of how data gathering and analysis have been revolutionized by the technological advances of that period. A complete survey of the vast number of projects carried out by BIO in its first twenty-five years was beyond the scope of this work, but even the examination of a limited number of examples can be instrumental in highlighting critical factors evident in that time.

The decision in the very early years of BIO to build the capacity to design and develop instruments and technology served it well over the period, evident in the examples presented and the many others detailed in the annual reports of BIO. The co-location of many disciplines on the BIO campus created a cross-fertilization of ideas and concepts. The consultations that led to the development of BIONAV and the evolution of Batfish into an instrument for biological oceanography doubtless happened because these diverse groups all worked in the same location. The role of the Metrology Division in its various forms was critical; the group maintained links with all the various users and served as a form of clearing house for ideas that could be transferred from one field to another.

Along with the transfer of ideas was the acceptance of new technology and processes that propelled development in this period. An openness to experiment and to challenge existing orthodoxy prevailed. But the experience of BIO was not unique; this spirit was evident in the universities, the culture, and throughout society in the 1960s and 1970s. This openness was evident at BIO in the invention and rapid adoption of new technology, as well as the enthusiastic adaptation of these new tools for uses in other fields or modification for another use, exemplified by the hydrostatic rock drill.

The questions in biological oceanography largely remain the same as in the early 1960s. What controls the production cycle and what governs the biological cycle? What are the chemical reactions between sediments and ocean water, and the influences of the biological communities on these reactions? What has changed is the technology used to answer these questions.[48] Regardless of any changes in the focus of research, it is evident that this period was transformative, as oceanographers progressed from collecting data while aboard ships using bottles, nets, thermometers and slide rules to utilizing vast arrays of remote sensors and satellite images all analyzed by powerful computers at their fingertips. The advances made in this period were due to the ability to collect and analyze large sets of data.

The challenge today becomes not the collection of data but the management and quality assurance of it, that is, the need for practitioners to understand the technical aspects of the data-collection process and have the ability to relate that to the questions at hand.[49] While the methods get increasingly sophisticated and the technology allows the oceanographer, in theory, to collect data without ever being near the source—through the use of arrays of sensors, remotely operated vehicles, acoustics, or modelling—there is a danger of missing a connection. There is also a danger of getting lost in this mass of data. Would philosopher William Whewell still think the most promising way to advance knowledge is to collect a mass of observations if he knew that the power to collect data could not just remove all accidental causes, but perhaps obscure possible causes?

Michael Murphy is a Research Associate with the Gorsebrook Research Institute, St. Mary's University. After a long career with Fisheries and Oceans Canada at various places across Canada, including a number of years at the Bedford Institute of Oceanography, he completed a MA (Hist) at Dalhousie University. His research interests currently center on the development of the Maritime provinces after the Second World War.

Endnotes

1 William Whewell, *On the Empirical Laws of the Tides in the Port of London; With Some Reflexions on the Theory,* Phil. Trans. R. Soc. Lond. 1834 124, doi: 10.1098/rstl.1834.0004, published 1 January 1834, 18. I need to thank a number of people for their contributions to this project. Dr. Eric Mills was most helpful in the early stages of this paper and his comments guided me throughout. Dr. Shirley Tilliston provided detailed comments after my presentation at a Stokes Seminar at Dalhousie University. The anonymous reviewers and editors provided thoughtful comments that improved the paper immensely. I would like to add a thank you to the BIO Oceans Association for their efforts in preserving the history of the Bedford Institute of Oceanography, especially the equipment. A number of members have been active in documenting and preserving the various pieces of equipment used or developed at BIO. As well, the management of BIO has been helpful in providing space for the storage and display of the artifacts. A special "thank you" needs to be given to Dr. David McKeown who has led the project and provided me with guidance on areas of research as well as some helpful tools to search the BIO Annual Reports.

2 Margaret Deacon, *Scientists and the Sea—650-1900 a study of marine science* (London, New York: Academic Press, 1971), 167. While Deacon outlines the link between technology and instrumentation throughout this work, it is most appropriate to refer to a section from the chapter dealing with the investigations of that great instrument maker, Robert Hooke.

3 Benson, Rozwadowski, van Keuren, "Introduction," xiv.

4 Bedford Institute of Oceanography, *Second Annual Report 1963*, BIO 63-6, December 1963, 1-2.

5 Eric L. Mills, "Canadian Marine Sciences from before Titanic to the Establishment of the Bedford Institute of Oceanography in 1962," in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography,* ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille (Dartmouth, N.S.: BIO-Oceans Association, 2014) 3.

6 BIO, *Annual Report 1963*, 2.

7 Mills, "Canadian Marine Sciences from before Titanic to the Establishment of the BIO," 3-11. Mills provides a substantial overview of marine science in Canada tracing its development from the late 1800s up to the creation of BIO in 1962. He outlines developments in charting, tidal studies, and various disciplines of oceanography. Considerable detail on the organizational struggles in the federal bureaucracy, culminating in the decision of W.E. van Steenburgh to establish BIO is provided. Also useful is Jennifer M. Hubbard, *A Science on the Scales: The Rise of Canadian Fisheries Biology, 1898-1939* (Toronto: University of Toronto Press, 2006). Particularly pertinent is Chapter 8 (p. 192-224) outlining the struggle of the St. Andrew's Biological Station and the rise of Halifax as the predominant center for oceanographic studies on the Atlantic coast of Canada.

8 Mills, "Canadian Marine Sciences from before Titanic to the Establishment of BIO," 10.

9 BIO, *Annual Report 1963*, 2-3.

10 Simone Turchetti, "Sword, Shield and Buoys: A History of the NATO Sub-Committee on Oceanographic Research, 1959–1973," *Centaurus* Vol. 54 (2012): 205–231. Turchetti provides a comprehensive examination of NATO's involvement in oceanographic research in this period, especially efforts connected to anti-submarine warfare.

11 BIO, *Annual Report 1962*, 1-2.

12 See for example Scripps Institution of Oceanography, *Annual Report for the Year Ending June 30, 1967*. Downloaded from http://scilib.ucsd.edu/sio/annual/Annual_report_1967.pdf (April 12, 2014). It outlines the work of the Special Development Group charged with developing new instruments for oceanographic research (see p. 11, 21, 28-31, and 33 for examples). Also, Woods Hole Oceanographic Institution had a Department of Applied Oceanography that was charged with a similar mandate – to develop and test instruments. See for example Woods Hole Oceanographic Institution, *Annual Report 1966,* (p. 21-23) for some description of their activity. Downloaded from http://www.whoi.edu/fileserver.do?id=20506&pt=10&p=16574 (April 10, 2014).

13 BIO, *Annual Report 1963*, 2-6.

14 Gilbert Jaffe, "The Systems Approach to Oceanographic Instrumentation – An Introductory Address," in *Systems Approach to Oceanographic Instrumentation*, ed. Fred Alt (Pittsburgh: Instrument Society of America, 1967), 1.

15 The *Challenger* expedition left Portsmouth, England in December 1872 on a three and a half year voyage. Led by Wyville Thomson, it travelled more than 130,000 kms around the world and its findings laid the basis for the science of oceanography. The expedition was charged to investigate the physical, chemical, and biological properties of the oceans. Deacon, *Scientists and the Sea,* 331-365, provides an excellent overview of the expedition and its importance.

16 D.J. Baker Jr., "New Devices and Concepts for Ocean Measurements," in *Oceanography, the Present and Future*, ed. Peter G. Brewer (New York: Springer-Verlag, 1983), 363-376.

17 OPEC – Organization of Petroleum Exporting Countries.

18 WRTG Economics, http://www.wtrg.com/prices.htm, accessed Apr. 5, 2014.

19 Maurice Lamontagne (chair), *A Science Policy for Canada, Report of the Senate Special Committee on Science Policy*, 4 volumes. Downloaded from http://www.albertasenator.ca/?mainloc=savvy51 accessed Apr. 5, 2014. The web site of Sen. Elaine McCoy contains links to the Lamontagne report. Also of interest is G. Brent Clowater, "Canadian Science Policy and the Retreat from Transformative Politics: The Final Years of the Science Council of Canada, 1985-1992," *Scientia Canadensis: Canadian Journal of the History of Science, Technology and Medicine / Scientia Canadensis : revue canadienne d'histoire des sciences, des techniques et de la médecine* Vol. 35, n° 1-2, 2012, p. 107-134. While the article deals specifically with the Science Council of Canada, it provides a comprehensive overview of science policy from 1945 through to 1992, and addresses the Lamontagne Report on p.114.

20 R. L. G. Gilbert and C. S. Mason, "The Bedford Institute of Oceanography and Industry - Experience and Progress in the Past Decade," in Bedford Institute of Oceanography, *Biennial Review 1971/72*, 58-66.

21 BIO, *Biennial Review 1975/76*, 47.

22 BIO, *Biennial Review 1973/74*, 1.

23 BIO, *Third Annual Report 1964*, BIO 64-18, December 1964, 34-35.

24 All three received their doctorates from Cambridge University (Cantab) considered at the time to be a hotbed of geophysical research.

25 BIO, *Fifth Annual Report 1*966, BIO 66-10, December 1966, 54-59.

26 Brian MacLean, Graham L. Williams, and George A. Fowler, "Bedrock Studies of the Baffin

Island Shelf and Hudson Strait: A Technological and Scientific Adventure," in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography*, ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille, (Dartmouth, N.S.: BIO-Oceans Association, 2014), 331-332. Also BIO, *Annual Report 1966*, 59-61 and BIO, *Biennial Review 1969/70*, 126-127.

27 MacLean, Williams, and Fowler, "Bedrock Studies of the Baffin Island Shelf and Hudson Strait," 332-333. Also BIO, *Annual Report 1966*, 59-61; BIO, *Biennial Review 1969/70*, 126-127; BIO, *Biennial Review 1975/76*, 52. Leading the development of the electric drill were W.C. Cooke, G.A, Fowler, and W.J. Whiteway. Later innovations were done in partnership with Dalhousie University – P. Ryall and J.Ade-Hall.

28 BIO, *Biennial Review 1973/74*, 139-140 and 241-251.

29 BIO, *BIO Review '83*, 42-43.

30 Gordon B.J. Fader et al., " Seadbed Sediment Mapping at the Bedford Institute of Oceanography: From Single Beam to Multibeam,' in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography*, ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille, (Dartmouth, N.S.: BIO-Oceans Association, 2014), 191.

31 David L. McKeown, Peter G. Simpkin, Gordon B.J. Fader, D. Russell Parrott, and David C. Mosher, "The Huntec Deep Tow Seismic System: A Revolution in High Resolution Profiling," in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography*, ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille, (Dartmouth, N.S.: BIO-Oceans Association, 2014), 337-340.

32 Ibid., 338 and BIO, *Biennial Review 1977/78,* 169-173.

33 Ibid., 340 and BIO, *BIO Review '83*, 41.

34 BIO, *BIO Review '83*, 47.

35 BIO, *Biennial Review 1969/70*, 124.

36 BIO, *BIO Review '83*, 46-47, Peter C. Smith et al., "Coastal Ocean Circulation Studies," in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography,* ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille, (Dartmouth, N.S.: BIO-Oceans Association, 2014),151-153.

37 Stephen T. Grant and David E. Wells, "The Bedford Institute of Oceanography Integrated Navigation System (BIONAV)," in *Voyage of Discovery: Fifty Years of Marine Research at Canada's Bedford Institute of Oceanography,* ed. D.N. Nettleship, D.C. Gordon, C.F.M. Lewis, & M.P. Latremouille, (Dartmouth, N.S.: BIO-Oceans Association, 2014), 353-356; BIO, *Biennial Review 1975/76*, 42-43 ; and BIO, *BIO Review '81*, 59-60.

38 Grant and Wells, "The Bedford Institute of Oceanography Integrated Navigation System (BIONAV)," 356, and BIO, *BIO Review '81*, 59-60.

39 Peter H. Wiebe and Mark C. Benfield, "From the Hensen net toward four-dimensional biological Oceanography," *Progress in Oceanography* 56 (2003): 7–136. Wiebe and Benfield provide an exhaustive view of the developments in plankton collecting systems from the 1880s to the present. See pages 38-41 for details on Hardy's CPR.

40 A. Herman and T. Platt, "Meso-scale Spatial Distribution of Plankton" in *Oceanography: The Past*, ed. Mary Sears and Daniel Merriman (New York: Springer-Verlag, 1980), 204-222.

41 BIO, *BIO Review '83*, 55-56; Bedford Institute of Oceanography, *BIO Review '86*, 4-8.

42 BIO, *BIO Review '86*, 4-8.

43 Jean-Guy Dessureault, *The Lateral and Directional Stability of Batfish, an Underwater Towed Body withWings*, (Halifax: Nova Scotia Technical College, 1977). Thesis as a requirement for a M.Eng. Copy at Dal Sexton Library.

44 Bedford Institute of Oceanography, *Biennial Review 1967/68*, 69. A complete description of the engineering development behind the Batfish is presented in J. G. Dessureault, " 'Batfish' – A

Depth Controllable Towed Body for Collecting Oceanographic Data," *Ocean Engineering* 3 (1976): 99-111; see also Tim Foulkes, "Technology in Marine Science at the St. Andrews Biological Station, 1908-2007", in Jennifer Hubbard, David J. Wildish, and Robert L. Stephenson, eds. *A Century of Maritime Science: The St. Andrews Biological Station* (Toronto: University of Toronto Press, 2016), 156-178, for a similar discussion on these developments.

45 BIO, *Biennial Review 1975/76*, 47-50 and BIO, *Biennial Review 1973/74*, 109-111.

46 ODIM Brooke Ocean, Laser Optical Particle Counter (LOPC™)—Next-Generation Particle Measurement Instrumentation. http://www.brooke-ocean.com/lopc.html (accessed April 15, 2014).

47 BIO, *BIO Review '86*, 4-8.

48 Eric Mills, *Biological Oceanography: An Early History 1870-1960* (Toronto: University of Toronto Press, 2012), xxvi. His discussion refers specifically to the biological questions and the use of new technology.

49 John Cullen, "Foreword" in Eric Mills, *Biological Oceanography: An Early History 1870-1960* (Toronto: University of Toronto Press, 2012), ix-xvii.

Book Reviews / Comptes rendus

Jessica Van Horssen. ***A Town Called Asbestos: Environmental Contamination, Health and Resilience in a Resource Community.*** 228p. Vancouver: UBC Press, 2019. $32.95 (paperback) ISBN: 978-0-77482842-0

I am surrounded by asbestos. Behind the four walls of my office lies at least some of this deadly substance; breathing in even a small amount can cause deadly lung diseases such as asbestosis and mesothelioma (an aggressive form of cancer) to develop years later. While safely inert behind plaster (I hope), I dare not put a nail, or even a thumb tack into the wall. I am not paranoid: asbestos remains the biggest cause of workplace death in Canada, killing anywhere between 300 and 600 people annually, and some predictions suggest teachers and professors who work in older asbestos-filled buildings will be prominent among the next generation of victims. The Canadian government plans a long overdue ban on the use of the substance by 2018, but the almost casual industrial use of substance known for decades to be dangerous raises questions about who knew what when, and why was this allowed to happen. Jessica Van Horssen's stunning new book, *A Town Called Asbestos*, provides several answers to these questions, a chilling reflection on the lengths to which the asbestos industry went to deny the mounting evidence of danger associated with the substance.

The book's focus is the massive open pit Jeffrey Mine and the mining town of Asbestos, Quebec, a mining development that, along with the Thetford Mines near Quebec City, positioned Canada as global leader in asbestos production as early as the 1880s. The early chapters describe the growth of the mine and the co-development of the town, the latter always giving way to the insatiable demands of pit expansion as production increased in response to technological developments and market demands. As urbanization proceeded rapidly in North America during the early twentieth century, the owner of the Jeffrey Mine, construction materials giant Johns-Manville, was set to reap whirlwind profits as demand for the new miracle substance asbestos was sought after to make fire resistant wall plaster and insulation for the interior of walls and for electric wiring. In the book's early chapters Van Horssen's analysis of the relationship between technology, labour, and cascading changes to the landscape and the town are as evocative as any in recent works of environmental history.

The heart of *A Town Called Asbestos* is, however, the later chapters depicting the pattern of denial, suppression and deceit Johns-Manville employed as evidence of the dangers associated with asbestos production and use mounted beginning in the 1920s. The story is shocking, with Johns-Manville's handling of the issue providing a significant antecedent to the anti-public health campaigns of the tobacco industry and other "merchants of doubt" after World War Two. As with other hazardous trades, a primary strategy was to exert control over the health monitoring and scientific study of the issue, steering workers to company doctors, funding the establishment of a Department of Industrial Hygiene at McGill (with expectations of a return on investment), and the suppression of scientific studies detrimental to the industry's interests. Van Horssen's book is at its absolute best when she describes Johns-Manville's deplorable (and illegal) practice of secretly shipping the lungs of deceased workers across the Canada-U.S. border to the Saranac Lake Laboratories between 1944 and 1958, and then hiding the clear evidence of 70 cases of lung cancer. While environmental historians have justly celebrated the work of pioneering industrial hygiene crusaders such as Alice Hamilton, Van Horssen provides a stark reminder that the practitioners of many "dangerous trades" were almost able to completely impede rational approaches to workplace health and safety issues when they proved too great a threat to business.

The latter point alone represents a substantial contribution to the environmental history literature, but Van Horssen also manages to challenge prevailing interpretations of one of the most significant post-war moments in Quebec history: the 1949 strike at the Jeffrey Mine. According to the conventional wisdom, the heated and sometimes violent strike represented an early assertion of Quebec nationalism, a struggle by francophone Quebeckers to wrest control of the economy from the Anglo corporate elite, resentment magnified by the fact that Johns-Manville was American-owned. Add in the fact that three prominent activists against the oppressive anti-labour policies of Marice Deplessis' government, the *Le Devoir* journalist Gerard Pelletier, union leader Jean Marchand, and the writer and intellectual Pierre Trudeau, became the core of Quebec's new assertive presence in the federal government when appointed as the "three wise men" to Lester Pearson's cabinet in 1965, and you have seemingly irrefutable proof that the strike was, as Trudeau famously declared, "the violent announcement that a new era had begun." Van Horssen argues convincingly that interpreting the strike as a harbinger of the Quiet Revolution masks the reasons that workers went on strike in the first place, including pay, holidays, union recognition, and especially improved dust control measures to reduce the risk of asbestos-related diseases. The publication of a report by journalist Burton LeDoux in *Le Devoir* on the eve of the strike largely confirmed what workers had suspected: the company had been lying to them and suppressing evidence about the health risks of asbestos in the mines. While there may be some hints of a broader symbolic nationalism attached to the 1949 strike, Van Horssen reclaims the meaning of the strike for the workers who fought a front line battle to protect the health of their own bodies.

The decisive defeat of the strike allowed Johns Manville and their allies in the provincial and federal governments to deny the deleterious health effects of asbestos, particularly the chrysotile variant produced in Canada. Workers remained aware of the danger, and did fight for the maintenance of an ever-diminishing buffer zone between the pit and the community in the years after the strike.

But Van Horssen argues that after increasing pressure from international asbestos bans in the early 1980s, and after Johns-Manville sold the mine to a group of former executives, workers and residents of Asbestos tended to adopt the idea that the mineral was safe. Indeed, from 1983 to the final closure of the mine in 2011, government, industry and organized labour unanimously supported the false argument that chysotile asbestos was safe for export to emerging Third World markets so long as it was handled safely. I do quibble somewhat with Van Horssen's suggestion that workers adopted the idea asbestos could be safe as a rational choice meant to protect their jobs. She might have delved a little bit more into the broader "job blackmail" strategy that corporations adopted in the early 1980s and explored the role that structural power (of markets, or corporations, of growing neo-liberal ideals in the 1980s) played in transforming workers' attitudes to asbestos. However, this is slight criticism of what is otherwise one of the finest works of Canadian environmental history to come out in recent years. Painstakingly researched with a compelling writing style, *A Town Called Asbestos* fulfills the promise of recent U.S. environmental histories that integrated histories of labour, public health, and environmental change into a single narrative. It is essential reading for anyone interested in labour, industrial or environmental history, or any person who wants to know why a deadly substance may persist behind the walls where they live and work.

John Sandlos, Memorial University

François Jarrige. *Technocritiques. Du refus des machines à la contestation des technosciences*. Paris: Éditions de la découverte, 2014. 420 p. 28.00$. ISBN 978-2-7071-7823-7

L'auteur se penche ici sur les technocritiques, un néologisme emprunté au philosophe Jean-Pierre Dupuy pour qualifier les discours et les pratiques qui mettent en cause le développement technologique. Pourquoi ce thème? Selon Jarrige, le phénomène technique est ambivalent (281) et le refus du changement ne renvoie pas forcément à la technophobie ou à l'obscurantisme. En effet, « La résistance n'est [...] qu'une des dimensions du processus complexe de négociation sociotechnique à travers lequel toute société définit son rapport aux artefacts matériels » (18). Or, le projet technique qui se trouvait au fondement de la modernité « est désormais entré en crise avec la reconnaissance des limites physiques du globe et de la finitude du temps » (14). Étant donné que: « L'histoire technologique, comme l'histoire politique, est toujours écrite par les vainqueurs » (79), il vaut donc la peine de « donner la parole aux vaincus de l'histoire » (9) afin de dégager les nombreux enjeux soulevés par les techniques. Dans ce but, travaillant sur la longue durée et adoptant une perspective multiséculaire, Jarrige remonte aux origines de l'ère industrielle pour suivre le fil des technocritiques jusqu'à nos jours. C'est cette histoire qui fait l'objet de l'ouvrage, divisé en trois grandes sections de quatre chapitres chacune.

Intitulée « L'invention de l'industrialisme », la première section se penche sur les mouvements de protestation apparus à l'époque où l'Angleterre devient l'atelier du monde, notamment le mouvement luddite. On assiste alors à la naissance de la figure du prolétaire, phénomène où l'Angleterre fait office de précurseur par rapport aux autres pays européens. Jarrige rappelle les contestations populaires du machinisme naissant, souvent réprimées férocement par les autorités. Et, il le montre clairement, qu'il s'agisse des ouvriers du textile, des typographes ou des paysans (chapitre 2), les protestations contre la mécanisation du travail ne relèvent pas forcément de l'immobilisme psychologique ou d'une attitude archaïsante, mais traduisent plutôt une recherche de voies alternatives de production. Après tout, les exigences nouvelles du capitalisme industriel engendrent de graves problèmes de santé, tandis que le machinisme pose des risques inédits pour les milieux naturels (chapitre 3). C'est pourquoi une bonne partie du mouvement romantique, bientôt rejoint par certains promoteurs du socialisme, leur emboîte le pas. C'est ainsi que se fait jour le « premier âge de la critique » (71) et que la société occidentale, faisant du machinisme un enjeu social, devient, pour ainsi dire, technoréflexive. Bien que le terme n'existe pas encore (il sera créé par Haeckel en 1866 seulement), c'est dans ce contexte que naît le souci écologique, au moment même où s'impose « la conception industrialiste, rationalisatrice et productiviste de la technologie » (108).

La deuxième partie de l'ouvrage, « L'âge des machines » (une expression de Carlyle), court du milieu du XIXe siècle à la fin de la Deuxième Guerre mondiale. Portée par un vaste mouvement d'acculturation, « la technique devient alors le destin du monde et des sociétés » (123), et ce grand récit disqualifie progressivement les divers réquisitoires. Cette légitimation renforce le culte de la machine, tout en héroïsant l'ingénieur et en consacrant l'inventeur et ses brevets (chapitre 5). C'est ainsi que « le train colonise les imaginaires » (131) et que la vulgarisation scientifique devient une pédagogie de l'industrialisation. Ces discours atteignent leur apogée à la fin du siècle, une période marquée par l'impérialisme occidental et la mainmise européenne sur la planète (chapitre 7). En fait, il faudra attendre les affres de la Grande Guerre et la crise des années 1930 pour qu'un sérieux doute s'installe: c'est ce qu'on a appelé la « querelle de la machine » (chapitre 8). L'extension rapide du parc automobile coïncide en effet avec une première « crise de civilisation », nombre d'européens voyant désormais l'Amérique comme le « symbole du gigantisme et de la démesure technologique » (212). C'est alors que fleurit, avec les Zamiatine, Capek, Rolland, Huxley et Orwell, le genre dystopique mettant en cause le messianisme technologique. Cependant, ces critiques seront temporairement balayées par les impératifs liés à la Deuxième Guerre mondiale: lutte contre le fascisme et le nazisme, puis reconstruction des pays dévastés et définition d'un nouvel ordre mondial.

C'est sur les « Trente Glorieuses », la période de forte croissance des pays occidentaux, que s'ouvre la dernière partie de l'ouvrage, « Modernisations et catastrophes ». La transformation accélérée de l'après-guerre témoigne d'un progrès à marches forcées : maîtrise du nucléaire civil, naissance de l'ordinateur, révolution agricole, automatisation du travail, aéronautique commerciale, conquête spatiale, la liste est presque sans fin, car une mystique du développement épouse alors l'injonction du progrès. Une fois de plus, cette dynamique donne naissance à une contrepartie réflexive, appuyée principalement sur les sciences humaines, qui, pourtant, devaient en principe favoriser l'acceptabilité sociale du progrès. Ainsi, à la technophilie d'un Fourastié répondront les appels à la prudence d'un Ellul ou d'un Mumford. Ce malaise devant le triomphalisme technique sera d'ailleurs amplifié par le désenchantement philosophique de Heidegger, répercuté aux États-Unis par Hannah Arendt et Günter Anders (chapitre 9).

C'est dans la mouvance de cette troisième et dernière vague critique qu'il faut situer la montée rapide du mouvement écologique ainsi qu'un autre tournant décisif: l'année 1968. Se développent alors, concurremment à la société de consommation, la contre-culture alimentée par des philosophes comme Marcuse, mais aussi la critique du complexe militaro-industriel, une expression forgée par le président Eisenhower. Comme l'a montré Gilbert Hottois, la technique se mue alors en technoscience (chapitre 10). Mais ces mouvements seront mis à mal par « la «contre-révolution» néolibérale des années 1980 » (284), pendant laquelle le micro-ordinateur et Internet atteignent le grand public. Une nouvelle utopie prend alors forme, celle du capitalisme immatériel, la fameuse société du savoir (291). Cependant, un contre-discours va aussitôt émerger, ciblant trois dangers précis : les conséquences de l'informatisation sur l'organisation du travail, le risque d'une surveillance généralisée de la société civile et, enfin, le caractère délicat de l'utilisation des NTIC, entre autres à l'école (chapitre 11). Les nouveaux luddites prennent alors la forme de *hackers* ou de destructeurs de champs d'OGM. Aujourd'hui, l'anthropocène, la « nouvelle ère géologique inaugurée il y a deux siècles par la révolution thermo-industrielle » (16), est en cours, et nous sommes conscients du caractère fini des ressources planétaires. Aussi la société postindustrielle est-elle devenue la première société du risque durable. Et pas plus que les biotechnologies, les nanotechnologies ne peuvent apaiser entièrement les angoisses générées par les techniques de pointe. L'auteur termine en examinant les théories de la décroissance et en plaidant pour une démystification de la technique ainsi que pour une politique des choix technologiques (chapitre 12).

Cet ouvrage mobilise une immense documentation, tant en histoire qu'en sociologie ou en analyse des technologies (ce qu'on appelle en anglais le *technology assessment*), documentation que l'auteur maîtrise parfaitement. En somme, il s'agit d'une synthèse aussi remarquable qu'érudite. Aussi faut-il saluer ce tour de force, rien moins qu'une relecture de l'histoire globale des trois derniers siècles, vue sous l'angle des techniques et de leurs mises en cause sociales, politiques ou culturelles. La technique n'est jamais neutre, dit Jarrige. Comme elle façonne nos existences et médiatise notre rapport au monde et à la société, les technocritiques peuvent servir à la démocratiser (346). C'est pourquoi il faut en définitive voir, dans ces discours récurrents, une invitation à améliorer notre condition et à y dégager de nouveaux espaces de liberté.

Jean-Claude Simard, Cégep de Rimouski

Jean-Pierre Proulx (avec la collaboration de Christian Dessureault et Paul Aubin). ***La genèse de l'école publique et de la démocratie scolaire au Québec. Les écoles de syndics. 1814-1838.*** Jean-Pierre Proulx (avec la collaboration de Christian Dessureault et Paul Aubin). Québec: Presses de l'Université Laval, 2014. 497 p. 49.00$. ISBN 978-2-7637-2388-4

La saga des luttes parlementaires autour de l'implantation du premier système public d'écoles élémentaires au Québec, entre 1814 et 1836, s'inscrit au cœur de l'affrontement politique entre le mouvement patriote et l'oligarchie coloniale au cours des années précédant les Rébellions de 1837-38. On en connaît les grandes lignes : rejets répétés par le Conseil Législatif et/ou par les autorités coloniales des nombreux projets de loi adoptés par la Chambre d'Assemblée entre 1814 et 1823; adoption en 1829, à la faveur d'une période d'accalmie politique, de la loi des Écoles de Syndics et mise en place subséquente d'un vaste réseau public d'écoles élémentaires; enfin, en bout de piste, retournement du Conseil Législatif qui refuse en 1836 de renouveler la législation, entrainant ainsi la fermeture de la majorité des quelques 1 200 écoles alors existantes.

Premier véritable spécialiste de l'histoire de l'éducation au Québec, Louis-Philippe Audet, avait déjà reconstitué au début des années 1950 le récit détaillé des événements dans son volumineux *Système Scolaire de la Province du Québec*, un remarquable travail de pionnier. Par la suite, aucun autre historien ne se penchera à nouveau sur l'ensemble de la période 1814-1836 pendant près de soixante ans. Puis, soudainement, nous arrivent en rafale deux études d'envergure sur la question, celle de Bruce Curtis, *Ruling by Schooling Quebec*, en 2012 et celle de Jean-Pierre Proulx en 2014. Pour prendre la mesure de la contribution originale, fort importante, de l'ouvrage de Proulx, il faut forcément le situer en regard de celui d'Audet et, encore plus, de celui de Curtis. Nettement plus ambitieux que *La genèse de l'école publique* de Proulx, l'ouvrage de Curtis couvre en effet une vaste période qui va des années 1780 jusqu'au projet de loi rétablissant les écoles élémentaires publiques en 1841 sous l'Union, tout en débordant par ailleurs largement de la question des écoles élémentaires publiques. Pour sa part, Proulx s'en tient aux écoles élémentaires publiques et la séquence événementielle sur la législation scolaire qui constitue la première partie de son ouvrage ne déborde pas des années 1814-1836.

Cela dit, le compte-rendu de Proulx sur certains événements clés au cours de cette dernière période est souvent plus précis et plus exact que celui de Curtis. « Lost in the Assembly » nous informe ainsi Curtis, concernant le sort présumément réservé à l'important projet de loi de 1814, le premier de la série. Et pourtant, tel que le rapporte fidèlement Proulx, l'Assemblée a bel et bien adopté ce projet et c'est plutôt le Conseil Législatif qui l'a rejeté de facto en en renvoyant l'examen aux calendes grecques! Quant au projet de renouvellement de la loi scolaire adopté par l'Assemblée en 1836, Curtis affirme à plusieurs reprises que le Conseil l'a retourné à l'Assemblée avec amendements, mais que celle-ci, faute de quorum, ne les a pas pris en considération. Proulx, au contraire, rend compte des événements tels qu'ils se sont réellement déroulés: le Conseil Législatif a bien formulé nombre d'objections au projet de l'Assemblée, mais n'a jamais renvoyé de projet amendé à l'Assemblée, rejetant plutôt carrément le projet en décidant de ne pas procéder ultérieurement sur la question. Voilà deux erreurs factuelles significatives, qui affectent l'interprétation des événements, erreurs que Proulx a pour sa part su éviter en s'appuyant sur une lecture attentive des *Journaux* de l'Assemblée et du Conseil Législatif. Le compte rendu que fait Proulx de ces événements majeurs est également plus complet. Ainsi, il a retracé, dans une annexe à l'édition originale londonienne de 1839 du Rapport Durham, le texte des principales dispositions des deux projets clés de l'Assemblée rejetés par le Conseil Législatif en 1814 et en 1836.

La seconde partie de *La genèse de l'école publique*, consacrée à la mise en œuvre de la législation sur les écoles de syndics, est la plus substantielle de l'ouvrage. Proulx s'y démarque encore des analyses de Curtis. On rappellera que Curtis, s'il reconnaît les intentions généralement éclairées des législateurs patriotes, dresse en bout de piste un constat particulièrement sévère sur la mise en œuvre de la législation entre 1829 et 1836: syndics analphabètes, donc incapables d'exercer la fonction de direction des écoles que leur confiait la loi, instituteurs foncièrement incompétents, manuels scolaires se réduisant essentiellement (en milieux francophones) aux catéchismes et autres livres pieux, députés exerçant un pouvoir démesuré sur le système en général et sur les instituteurs en particulier, abus et fraudes multiples de la part des syndics, instituteurs et députés, absence totale de toute gestion centralisée du système par le gouvernement. Proulx, pour sa part, bien qu'il partage en partie le constat de Curtis sur une mise en œuvre généralement chaotique de la législation, porte toutefois un jugement nettement plus nuancé sur plusieurs aspects du fonctionnement du système, tout en notant avec insistance que la disparition d'une proportion importante des rapports administratifs d'époque doit inciter le chercheur à éviter toute conclusion péremptoire.

Ainsi, en jumelant les informations provenant de plusieurs sources, Proulx, en collaboration avec Christian Dessureault, dresse un portrait des statuts socioprofessionnels des syndics élus entre 1829 et 1832 dans la grande région de Montréal, une enquête qui révèle que le quart d'entre eux étaient des notables, curés, notaires, médecins, marchands ou seigneurs (chapitres 6, 7 et 11). Il apparaît donc qu'une proportion minoritaire certes mais importante des syndics n'était de toute évidence pas illettrée au cours de cette première période. Cela dit, Proulx admet que par la suite, avec la loi de 1832: « on peut raisonnablement penser que la décentralisation des élections dans les arrondissements et donc dans les rangs a augmenté le taux d'analphabétisme » (355). Par ailleurs, en s'appuyant sur une recension effectuée par son collaborateur Paul Aubin, Proulx constate un « véritable décollage de la production du manuel québécois », soit une centaine de publications destinées aux écoles élémentaires entre 1829 et 1836, dont la moitié constitue des nouveaux titres (317-328). Et si les titres à caractère religieux arrivent en tête, on retrouve aussi bon nombre de manuels dans d'autres domaines (lecture, écriture, grammaire, arithmétique, histoire et géographie). Ce qui amène Proulx à mettre en doute l'analyse de Curtis sur la pauvreté du stock de manuels utilisé dans les écoles francophones (333).

Pour Curtis, la loi des écoles de syndics, en laissant le contrôle d'une part à des syndics élus analphabètes et d'autre part aux députés, n'a fait en pratique que conforter l'hégémonie des notables (notamment des curés) sur l'école élémentaire. C'est seulement par la création d'un organisme central de contrôle, telle que proposée par le Conseil Législatif en 1836, que cette situation aurait pu être évitée. Dans son chapitre de conclusion, Proulx conteste - beaucoup trop succinctement toutefois - cette interprétation. Il soutient d'abord qu'il n'y a pas vraiment à s'étonner que l'école des syndics n'ait pas renversé totalement la « domination de l'establishment »: « Forcément! En six ans, soit la durée de vie des écoles de syndics, la situation n'a pu changer radicalement. Le changement ne pouvait survenir qu'à long terme. » (455). Quant à la création d'un organisme central de contrôle des écoles, si elle représentait, affirme-t-il, une « proposition parfaitement rationnelle […] c'était en même temps pour le Parti patriote prendre un risque impossible » (444). En effet, « il aurait fallu accepter que l'on confie cette autorité à l'exécutif, ce dont il ne pouvait être question à la Chambre d'assemblée » (453). Tout comme il était tout autant inacceptable pour le pouvoir colonial de laisser ce contrôle aux mains de l'Assemblée. Ainsi, pour Proulx, la question du contrôle des écoles s'insérait forcément dans « celle plus large de la reconfiguration des pouvoirs entre la Chambre et le gouvernement » (443).

Robert Pilon, Université du Québec à Montréal

Richard A. Jarrell. ***Educating the Neglected Majority: The Struggle for Agricultural and Technical Education in Nineteenth-Century Ontario.*** 418pp. Montreal & Kingston: McGill-Queens University Press, 2016. $37.95 (paperback). ISBN: 9-78-0-7735-4738-4

It is a testament to the late Richard Jarrell's intellectual and academic breadth that he began his academic odyssey with a Ph.D. thesis on the Early Modern astronomer Michel Maestlin and ended with this fine-grained study of Canadian technical and agricultural education, seen through to posthumous publication by his widow Martha Jarrell. To say that this work is long-awaited and badly needed would be an understatement. We have been responding to and relying upon Robert Stamp's unpublished dissertation for going on half a century now. I would expect that this book, by the late long-time editor of this journal, will essentially restart the historiography on Canadian technical education.

The book is organized into pre- and post-Confederation periods, with the latter more clearly divided further into Ontario and Quebec and stopping short of the Royal Commission on Technical Education. While linguistic and confessional matters were not unimportant, the biggest factor influencing the different Ontario and Quebec cases seems to have been different rates and patterns of literacy. The careful delineation of the striking dynamic, almost dialectic, between formal and informal efforts in the areas of agricultural and technical education is a real strength of this book. The efforts of private groups to disseminate new ideas and best practice in agricultural knowledge slowly drew in the State after 1840. While not the book's principal purpose, these stories help us better to understand the development of the colonial and provincial States, including the quasi-federalism of Province of Canada with its two Boards of Agriculture. Jarrell pushes back the involvement of the State through educational institutions and in partnership with private bodies supporting science and technology in economic development – even if not always successfully and always difficult to measure. Indeed if anything I think Jarrell is a bit "glass half empty" in his assessment of the earliest efforts.

By Confederation government support for agriculture was more advanced than for industry including technical support and education. But in fact, and this is another crucial strength of this book, the two (along with art education) were closely linked. Agriculture and industry were converging, from the mechanization of agriculture and the important implement industry to the industrialization of food processing, most notably with dairy farming and factory cheese making. It was the Agricultural Act of 1857 which gave rise to Boards of Arts and Manufactures in Upper and Lower Canada while Mechanics Institutes reported to the Department and later Commissioner of Agriculture. After Confederation the new Ontario quickly abolished the Boards of Agriculture and of Arts & Manufactures in favour of a single Bureau of Agriculture and Arts

The Canadian case was not the same as either the UK or the US though drawing on both. Ideas circulated widely through the Anglo Atlantic world as they did among francophone regions. Although the Morrill Act was not a model, Canadians watched the emerging Land Grant Colleges with interest. The influences were not all one way; the Ontario College of Agriculture at Guelph became a North American leader, discussed and admired in the United States.

I have a few, if not objections, then at least concerns. Jarrell dismisses apprenticeship as declining but then makes several references to apprentices throughout this book, suggesting that reports of its death might be exaggerated. It would also be useful to know in this context about First Nations schooling. Similarly, girls and women make fleeting appearances in this book though they are hard to find using the index and gender is not fully engaged as an issue. Indeed Jarrell argues that in both provinces the feminization of the teaching profession was an obstacle to the teaching of agriculture in rural (or for that matter urban) schools. But, as we do see if we pay close enough attention through this book, women were both sources and audiences for agricultural and technical education, mechanics institutes classes were open to women and women were certainly involved with art education. I would also put more stress on the significance of domestic science, under various names and guises, as a type of technical training for girls and women.

While at times this book reads like a frustrating tale of false starts and unrealized hopes this not my takeaway. Rather I think Jarrell is telling us that the campaign for technical education that bore fruit in early twentieth century had very deep roots, roots entwined in the fabric of nineteenth century Canadian history.

James Hull, University of British Columbia

Yves Gingras. ***Les dérives de l'évaluation de la recherche. Du bon usage de la bibliométrie.*** Paris : Raisons d'Agir, 2014. 122 pp. 14,95$. ISBN 978-2-91210-77-56

Yves Gingras, historien et sociologue des sciences, propose dans cet essai une réflexion critique sur l'évaluation du monde de la recherche et de l'enseignement supérieur. L'auteur retrace dans un premier temps les origines historiques de la bibliométrie afin, dans un deuxième temps, de remettre en question les usages actuels des indicateurs utilisés pour l'évaluation des activités scientifiques.

D'entrée de jeu, Gingras dénonce la volonté actuelle de tout évaluer à l'aide d'indicateurs qui sont considérés comme des façons « objectives » d'évaluer et de classer les institutions et chercheurs. Cette vision gestionnaire de la recherche donne une place de choix à la bibliométrie – cette méthode s'appuyant sur les publications scientifiques et leurs citations comme indicateurs de la production scientifique et de ses usagers. L'utilisation massive d'indicateurs ayant une visée évaluative est aujourd'hui décriée par de nombreux chercheurs en raison des effets pervers qu'elle entraîne. Pour en comprendre les dérives actuelles, Gingras remonte aux origines de la bibliométrie, de ses balbutiements au début du XX^{e} siècle, à son utilisation par les bibliothécaires pour la gestion des collections de périodiques scientifiques. La croissance exponentielle du nombre d'articles scientifiques publiés après la seconde Guerre mondiale mène à la création du Science Citation Index (SCI) par Eugene Garfield en 1963. Dès les années 1960, les historiens et sociologues des sciences, menés par Derek de Solla Price, s'emparent du potentiel d'un tel index pour étudier les propriétés des publications scientifiques et analyser à grande échelle les dynamiques du changement scientifique.

La diffusion du SCI a contribué à modifier les pratiques de citation des chercheurs qui prennent alors conscience de l'acte de citer et entraîne une systématisation de la forme de ces citations. Selon Gingras, l'effet pervers le plus important associé à la diffusion du SCI concerne les revues scientifiques, le facteur d'impact d'une revue étant devenu un outil promotionnel pour ces dernières. Qui plus est, cet indicateur lié à la revue est considéré à tort comme une mesure de la qualité des articles individuels, alors que la distribution des citations aux articles publiés dans une même revue suit plutôt une courbe de type Pareto où environ 20% des articles reçoivent 80% des citations. La publication d'un article dans une revue à haut facteur d'impact n'est donc pas gage de citations. Gingras souligne alors que « [t]out comme la pression pour publier toujours davantage engendre une croissance des fraudes, l'importance exagérée accordée aux facteurs d'impact pousse les rédacteurs des revues vers des comportements déviants » (68).

Un tournant important dans l'organisation des sciences survient au cours de la seconde moitié des années 1960 : la bibliométrie devient un outil au service des politiques scientifiques et sera employé à partir des années 1980 pour évaluer les groupes et institutions de recherche. Jusqu'au début des années 2000, les gestionnaires se gardent bien d'appliquer les mesures bibliométriques à un niveau individuel. Toutefois, l'accès aux données bibliométriques, facilitée par Internet, entraîne l'apparition d'indicateurs fantaisistes construits sans aucune rigueur méthodologique tel que le fameux indice h qui « est défini comme étant égal au nombre d'articles n qu'un chercheur a publiés et qui ont obtenus au moins n citations chacun depuis leur publication» (63). Cet indice se voulait une mesure servant à quantifier la production scientifique d'un chercheur à l'aide d'un seul chiffre. Cependant, il s'agit plutôt d'un composite arbitraire du nombre de publications (quantité) et du nombre de citations (qualité) qui classe de manière incohérente des chercheurs dont le nombre de citations augmente de façon proportionnelle. L'indice h ne peut donc être considéré comme un indicateur approprié de la qualité des publications d'un auteur ou de leur impact scientifique. Malgré ces défauts évidents, l'usage de l'indice h s'est généralisé dans de nombreux domaines scientifiques au cours des dernières années.

Au-delà de son usage évaluatif, la bibliométrie demeure incontournable pour l'étude des dynamiques de la science. À cet effet, Gingras fait un bref survol de ces dynamiques. Les études bibliométriques démontrent notamment que le développement scientifique d'un pays est étroitement lié à son développement économique. Les données bibliométriques révèlent également une importante tendance vers la collectivisation de la recherche avec l'augmentation du nombre moyen d'auteurs par article. Il est aussi possible de suivre l'émergence de nouveaux domaines de recherche à partir, entre autres, des mots-clés contenus dans les titres et les articles. Enfin, la bibliométrie permet de mesurer de façon empirique les transformations des pratiques de recherche au cours du XX^e^ siècle et de mettre en évidence les différences qui existent entre les champs disciplinaires, tant sur le plan des pratiques de publication que de citation.

Il convient cependant de rappeler que l'évaluation est à la base même du processus scientifique, le problème est donc moins l'évaluation en elle-même que sa multiplication qui se situe aujourd'hui à tous les niveaux – des publications, aux projets de recherche en passant par les chercheurs, les départements et centres de recherche ainsi que les universités. Les dérives de l'évaluation tiennent donc à l'utilisation d'indicateurs mal construits et aux mauvais usages du facteur d'impact des revues. Les classements d'universités constituent l'apogée de ces dérives. Gingras démontre alors que ces classements se composent d'indicateurs de nature si différente amalgamés à l'aide de facteur de pondérations arbitraires qu'il en résulte invariablement un classement qui ne représente strictement rien, si ce n'est un outil marketing. L'auteur propose finalement trois propriétés essentielles que tout bon indicateur devrait posséder : i) être en adéquation avec l'objet mesuré ii) être homogène dans sa composition et iii) varier en conformité avec l'inertie de l'objet mesuré, de trop grandes variations étant souvent révélatrice d'une distorsion ou une imprécision de la mesure.

Dans cet essai nuancé, qui a le mérite d'être précis et très bien documenté tout en restant lisible pour un lecteur non expert, Yves Gingras présente de façon synthétique les méthodes de recherches bibliométriques, leurs usages et mésusages. Gingras y démontre l'inconsistance de nombreux indicateurs et des classements qui se révèlent dans bien des cas sans valeur scientifique. L'auteur met cependant en évidence la pertinence des outils et méthodes bibliométriques et démontre la nécessité de se les réapproprier afin d'en faire une utilisation beaucoup plus large que la seule évaluation de la recherche, notamment pour analyser le développement des sciences selon une perspective tantôt historique et sociologique, tantôt économique et politique. Cet ouvrage nous invite à repenser les formes actuelles d'évaluation quantifiée et nous amène à conclure que l'évalation individuelle des chercheurs serait mieux servie par des méthodes purement qualitatives.

Adèle Paul-Hus, Université de Montréal

Daniel Macfarlane. ***Negotiating a River: Canada, the US and the Creation of the St. Lawrence Seaway.*** 356pp. Vancouver: UBC Press, 2014. $34.95 (paperback). ISBN: 978-0774-8264-33

Negotiating a River covers the long negotiations between the United States and Canada over the building of a joint waterway into the Great Lakes, and a related power project, with particular attention to the final years of negotiations; the design and building of the system; the operation of the completed Seaway; and environmental issues associated with the construction. All of these are framed within a critique of the engineering and scientific assumptions which underlay the project. It is a complex but well-executed mixture of diplomatic and political history along with technological and environmental history.

The first section of the book is devoted to the negotiations between the two countries that lasted almost half a century. Macfarlane does a fine job of condensing material that forms a major portion of earlier works on the Seaway. On the other hand, the author devotes considerably more space than these works to the years between 1945 and 1954. His thesis in so doing is that the Canadian government lost patience with the Americans and decided to go it alone. Various writers have debated whether the Canadian government really intended to build an all-Canadian system, or it was just bluffing in order to pressure the United States to join the project. Macfarlane develops a convincing argument to prove the former, though he then has to explain why Canada did not begin work, but instead waited almost two years until the American government decided to participate. This hesitation left portions of the Canadian public which wanted a seaway frustrated, as the government had engaged in an extensive campaign to prepare the populace for a Canadian one. Indeed, as Macfarlane points out, the image of an improved water route to the interior reinforced the nationalistic concept of an east-to-west corridor which would hold Canada safe from the allure of the United States.

The next section of the book deals with construction of the Seaway. This has been covered by numerous authors. This was, however, a massive engineering project, and no account completely duplicates any other. From acquiring the land on both sides of the border necessary to create a sufficient depth of water, to planning for new communities, to engineering decisions, and the setting of tolls (an American necessity), the project was complex and involved numerous difficult, often contentious, decisions. The author does an excellent job of highlighting all of these in his narrative.

This section ends with a short discussion of the operations of the Seaway since its opening and an analysis of the negative effects of the construction. Sadly, the belief of communities stretching across the Great Lakes that a seaway would bring increased prosperity proved not to be true, as the canals were built only to handle existing shipping. Even the belief of American planners that tolls would pay off the huge cost of the project proved illusionary.

The author then returns to a theme that he initially raised in his introduction. Ultimately he frames the whole story of the Seaway in this theme, which he terms 'High Modernism.' This is a theory that states engage in social and ecological engineering by taking a simplistic approach that favours the use of "technocratic scientific expertise, excluding local and vernacular knowledge, to order both nature and society." (p. 17) In the case of the Seaway, the author sees this as using the scientific and technological resources of the two nations not only to dominate nature and reorganize portions of society but also to prove the superiority of the western democracies over the Soviet Union.

In concluding his chapter on construction, Macfarlane comments that "[n]evertheless, one can interpret the St. Lawrence project as a socially and ecologically imperialist undertaking that followed the dictates of industry, big business and modern capitalism." (p. 178) In order to do this most efficiently, governments forced citizens to move to centralized locations, close to efficient transportation routes, designed with new concepts of how a town should be organized. The theme is continued in the next chapter as the author criticizes the hubris involved in determining the 'natural' level of water in the St. Lawrence and Lake Ontario and maintaining it at a constant level, while allowing power generation (a task which proved very difficult). He attributes this to the engineers' training and beliefs, which emphasized the cooperation of "industrial capital and the state to maximize the development of natural resources in the name of economic and social progress." (p. 183)

Essentially Macfarlane is saying that government mobilized science and technology to mold nature and society in the interests of a concept of national economic progress. Collateral damage, such as people displaced, increased pollution, shoreline damage, invasive species, damage to marine life, was judged not sufficient to warrant serious concern. He recognizes that economic spinoffs from the operations of the Seaway have been beneficial to both countries and especially to Canada, as has the power generation. However, the overall failure of the waterway, combined with the ecological and social damage done, leads him to conclude that "in hindsight the project should be considered a mistake." (p. 207)

Undoubtedly the author's analysis of the 'imperialist' reasons behind the project, and the negative consequences of it, invite controversy. On one aspect, Macfarlane's suggestion that the whole range of environmental damage was extensive, this reviewer finds the author's evidence less than convincing, while agreeing that the introduction of invasive species was a major negative result of construction. Overall, however, this work is a well-researched and generally well-argued examination of one of the greatest engineering projects of the twentieth century.

Ronald Stagg, Ryerson University

Roberta M. Styran and Robert R. Taylor. ***This Colossal Project: Building the Welland Ship Canal.*** 340 pp. Montreal: McGill-Queen's University Press, 2016. $44.95 (hardcover). ISBN: 978-0773-5479-02

Building on their previous book about the three nineteenth century iterations of the Welland Canals, in *This Colossal Project* former Brock University professors Roberta Styran and Robert Taylor address the fourth incarnation, the Welland Ship Canal. Accessibly written, amply illustrated, and extensively researched, the book chronicles the 1913-1932 building of this underappreciated Canadian technological achievement. The improved canal could accept much larger vessels and boasted much fewer – but much larger – locks, including the twinned flight locks that traverse the Niagara Escarpment.

The authors classify their effort as "on the ground" history, and they provide a rich and comprehensive account of the technical construction of the canal while also putting a human face on the project. The first two chapters investigate the challenges, ranging from the local to the international levels, that delayed the waterway's completion for many years. Ample attention is paid to the chief considerations that factored into choosing the new course of the canal, such as which sites were suitable for lock foundations. The next few chapters are case studies of specific elements of the project, such as creating the prism and the locks. The perspective of the lead engineers is emphasized, and a reoccurring theme is the constant need to adjust plans because of geology and other conditions.

I appreciated an entire chapter on water management, which covers the supply works for the canal as well as the revamping of other intertwined water bodies such as the Welland River, which was taken under the canal by a syphon culvert. The following chapter examines other types of infrastructure that had to cross the canal: e.g., bridges, tunnels, and wires. This was one of the first occasions in Canada where concrete was used on such a vast scale, and the authors' discussion of its deployment and its attendant ramifications for the workforce (e.g., stonemasons) was fascinating. Later chapters focus on various social and local aspects: labour conditions, worker accommodations, health and deaths (well over 100 workers died), and the impacts on canal communities.

The book takes great pains to catalogue every statistic and dimension, but repeatedly misses opportunities to engage key debates and theories in connected fields – as a result, it tends to be historiographically weak and methodologically unsophisticated. The most obvious omission is the complete lack of environmental history analysis and insight, which is surprising in a study on massive landscape alterations. Given the emphasis on technology, the book would have benefitted in particular from incorporating or showing familiarity with enviro-technical approaches utilized in other works on canals and hydraulic engineering: e.g., path dependencies, hybridity, high modernism, megaprojects, mobility/spatiality, cultural landscapes, etc.. Classic concepts such as "organic machine" and "technological sublime" are invoked, but only superficially. The authors don't recognize the ecological disruptions resulting from the canal's creation or operation, nor the myriad ways that environments and technologies exert historical agency. There is no mention of invasive species, such as the sea lamprey, which were able to move to the upper lakes through the Welland Ship Canal since it further removed the natural hydrological separation provided by Niagara Falls.

The authors do a good job of uncovering the personal and professional lives of the project's lead engineers, and demonstrate that this was the first Welland project where most were Canadian, had been schooled in Canada, and had experience on other canals in Canada and abroad. But this fine-grained detail isn't used to identify overarching engineering or governmental mindsets and practices. The ship canal is frequently labeled as "modern" and "ultra modern", but these terms are bandied about in problematic ways (particularly considering the extensive use of mule- and steam-power). One is left with many questions about the engineering profession: e.g., what was unique about Canadian canal engineering techniques? Unfortunately, *This Colossal Project* directly endorses the flawed "engineer as hero" construct undermined by so much history of technology literature. This leads to exaggerations such as the unfounded claim that the Welland Ship Canal may be the most impressive Canadian technological achievement of the twentieth century. In fact, like the St. Lawrence Seaway which absorbed it, government planners probably would not have built the Welland Ship Canal if they had known its actual financial, environmental, and human costs.

Technology and science scholars may well find this book conceptually unsatisfying, as it is more a technical history than a technological history, though canal and hydraulic engineering historians could profitably use the book for comparative purposes. *This Colossal Project* will be of greatest interest to locals with a personal or family connection to the Welland Canal, Niagara peninsula historians, and the popular audience interested in heritage canals and ships.

Daniel Macfarlane, Western Michigan University

Raf De Bont. ***Stations in the Field: A History of Place-Based Animal Research, 1870-1930.*** 208 pp. Chicago: University of Chicago Press, 2014. $40.00 USD (paperback). ISBN: 978-0226-1420-67

A recent and exciting development in the history of science is the "spatial" turn, a move to locate the *place* of science. Longstanding is the belief that true science produces place*less* knowledge, but a number of new studies have shown that the place of science does indeed affect the *what* of science. The location in which science is done can affect the results produced, and the recent work that engages with this idea shows how the locality of science can be slowly erased in order to achieve more universal conclusions. Perhaps the most well-known among these is David Livingstone's *Putting Science in its Place* (University of Chicago Press, 2003), although this area of research certainly dates back through a longer lineage, notably to *Laboratory Life* (Princeton University Press, 1979) by Bruno Latour and Steve Woolgar. It is within this new volume that Raf De Bont's *Stations in the Field* is situated, part of a growing monopoly of titles on the subject published by the University of Chicago Press.

The first thing a reader might notice about De Bont's book is that it is not about America. De Bont is a professor at Maastricht University in the Netherlands, and *Stations in the Field* pulls its material from late 19th century French, German, and Belgian history. This struck me as refreshing, adding a European perspective to more common histories of science in the U.S. and UK. It adds a nice complement to Deborah Coen's *The Earthquake Observers* (University of Chicago Press, 2013), which itself draws from European sources, although not exclusively.

De Bont's book traces a history of biological field stations and what might be called "proto-ecologists". He focuses on a number of individuals who worked at the formative and somewhat ambiguous intersections of biology, physiology, and zoology. These scientists attempted to construct a conceptual space in which research in the field, as opposed to in the laboratory, provided authoritative data. The focus of these experiments was the interaction between animals and environment, and these proto-ecologists emphasized that what they did was in fact experimentation, and not simply observation. This was an important distinction for any scientist looking to distance himself from the practice of natural history, which was predominantly understood as nothing more than an accumulation, rather than analysis, of observations and materials. In short, these proto-ecologists were attempting, at the turn of the century, to professionalize.

The key to this endeavor was the establishment of biological field stations. These stations were ideally permanent structures set down *in* nature, based on the assumption that nature is best studied from within. De Bont traces the development of field stations as part of a broader "station movement", which he argues was a counterpart to the "laboratory movement" (11). In a time when the lab was considered to be the pinnacle of epistemic authority, researchers at field stations went against the grain by claiming that they could in fact produce universal knowledge through their work. More significantly, it was *because* they did research at these field stations, in "real" nature, that their knowledge had a universal quality. The biological field station was a practical site of study, but was more importantly a symbol of professionalizing ambitions. As a result, De Bont argues, the "station movement played a crucial role in transforming biological work in the field" (52), laying the foundation for modern-day ecology.

De Bont's book is exhaustively researched, and makes a convincing argument for the importance of biological field stations to the early development of ecology and field research. While it firmly and satisfyingly sits within the literature on the spatial turn, it does not significantly extend this theoretical framework. Nevertheless, the book has several key strengths. It clearly demonstrates the blurred boundaries between pure science and education/amusement (e.g. public aquariums used for research), between professional and amateur science (e.g. gentleman scientists or other enthusiastic amateurs who set up their own field stations), and between public and private funding sources (e.g. university vs. private donors). De Bont also clearly articulates how national politics affected the structure and goals of field research in the late 19th century, notably in the cases of France and Germany. Whereas France saw the establishment of field stations as a means of catching up after their defeat in the Franco-Prussian War and so officially sanctioned them, the German academy tended to be rigidly hierarchical and uninterested in field studies, forcing amateur scientists to turn instead to private sources of funding.

Stations in the Field offers a detailed and comparative case study of the effects of place on the content and way of doing biological science in Europe during the late 19th and early 20th centuries. It is argued well, substantially referenced, and in terms of new theory in the history of science, timely.

Matthew Hayes, Trent University

Nikolas Rose et Joelle M. Abi-Rached. ***Neuro: The New Brain Sciences and the Management of the Mind.*** Princeton : Princeton University Press, 2013. 335 p. 28.70$ ISBN 978-0-691-14961-5

La recherche sur le cerveau fascine une part sans cesse croissante de la communauté scientifique. Dans l'espace public, les capacités « extraordinaires » du cerveau constituent le socle d'innombrables ouvrages grand public et de plus en plus de politiques publiques. C'est à partir de ce constat que Joelle M. Abi-Rached et Nikolas Rose proposent d'adopter une posture socio-historique critique à l'égard de l'influence grandissante des théories, des techniques et des conceptions neuroscientifiques sur la compréhension contemporaine de l'individu. Le premier chapitre décrit comment les fondements épistémologiques des neurosciences se sont, dans les années 1960, ancrés dans le paradigme neuro-moléculaire pour faire du cerveau un organe structuré et régi par des processus biologiques. Ce paradigme aurait offert la possibilité de comprendre le cerveau en adoptant l'approche profondément réductionniste et matérialiste qui a permis aux neurosciences, alors en pleine émergence, de se constituer en discipline en rassemblant toutes les spécialités s'intéressant de près ou de loin au système nerveux, autour d'un objet unique, le cerveau.

Dans les quatre premiers chapitres, Les auteurs défendent l'hypothèse qu'un certain nombre de transformations conceptuelles, technologiques, économiques et biopolitiques ont permis aux neurosciences de prendre une place centrale dans les discours scientifiques, politiques et économiques. La prévalence du paradigme neurobiologique au sein des neurosciences doit ainsi selon eux être compris à la lumière du développement concomitant de la neuropharmacologie et de la génétique, de l'élaboration du concept de neuroplasticité, de l'évolution des techniques d'imagerie médicale, et de l'utilisation d'animaux de laboratoire dans l'élaboration de modèles applicables à l'être humain. Malgré leurs limites respectives, ces nombreuses influences théoriques, matérielles et conceptuelles ont permis aux neurosciences d'acquérir, à partir des années 1990, une légitimité scientifique suffisante pour étendre le champ de leur expertise aux dimensions sociales de l'être humain, en développant une approche permettant de lier l'activité et la structure cérébrale aux comportements et processus sociaux. Le chapitre 5 décrit de quelle manière ces neurosciences dites « sociales » placent les mécanismes de la sociabilité humaine dans le code génétique et à fortiori dans le cerveau de l'être humain, sous la forme d'un ensemble de connexions neuronales façonnées par l'évolution. En apposant un vernis de scientificité et d'objectivité sur des connaissances antérieures des sciences sociales, les neurosciences offriraient aux décideurs politiques des arguments supposément plus scientifiques pour gouverner. Dans le chapitre 6, Abi-Rached et Rose inscrivent ces nouvelles formes de régulation dans le cadre de biopolitiques plus larges qui visent à répondre à une demande publique pour plus de sécurité. C'est dans ce contexte qu'il faut comprendre la logique préventive de ce que les auteurs nomment le « screen and intervene », soit l'orientation dans une majorité de pays occidentaux des politiques publiques vers un objectif d'identification, sur la base d'une classification objective de symptômes prodromaux, des sujets à risque de nuire, dans un futur plus ou moins proche, au bien commun.

Le chapitre 7 explique comment la conception neuroscientifique des dimensions inconscientes des processus neuronaux qui gouvernent les décisions et les actions humaines s'inscrit dans le prolongement de la conception du choix, de la responsabilité et de la conscience de soi propre aux sociétés libérales avancées. Les arguments neuroscientifiques conduiraient les décideurs politiques à prôner la responsabilisation des individus dans une aire de « réflexivité neurologique », en présentant l'individu comme un entrepreneur de soi responsable de gérer sa biologie pour le bien commun. À la différence de nombreux travaux sociologiques sur les neurosciences, Abi-Rached et Rose estiment que les tenants de cette redéfinition de l'individu ne cherchent pas à imposer une conception « neurocentrée » de l'être humain, mais bien à proposer une approche complémentaire à celles existant déjà. Malgré la place grandissante que prennent les neurosciences, la conception d'une individualité profondément ancrée dans la neurobiologie servirait en somme plus à orienter les décisions politiques et les stratégies marketing d'une économie du « neuro » en plein essor, qu'à redéfinir profondément la manière dont les individus eux-mêmes se conçoivent. Pour les auteurs, il faut se garder d'apposer une étiquette sur ce phénomène malgré son apparente légitimation de la conception néolibérale de l'individu responsable. Bien qu'il y ait une affinité incontestable entre la conception neuroscientifique d'un individu au cerveau flexible, capable de s'ajuster aux contingences sociopolitiques d'un monde en changement constant et la conception contemporaine de l'individu, cette forme de socioréductionnisme ne saurait selon les auteurs rendre compte de la complexité et de la spécificité du contexte sociopolitique propre à chaque domaine où se négocie l'importation de ces savoirs et de ces techniques à la lumière des savoirs et pratiques préexistantes. C'est donc en envisageant le discours neuroscientifique comme tentant de s'imposer en tant qu'autorité légitime pour rendre compte de l'individualité qu'il faut comprendre l'essor du discours neuroscientifique dans les sociétés occidentales contemporaines.

Cet ouvrage constitue une excellente introduction à l'histoire et aux enjeux sociologiques entourant les neurosciences. Son gros point faible est cependant de ne pas aborder le rôle joué par la rivalité entre les chercheurs en intelligence artificielle et les neuroscientifiques dans l'institutionnalisation des neurosciences et dans le développement des neurosciences sociales à partir des années 1990. La position critique des auteurs est en revanche doublement intéressante car elle permet de porter un regard sans concession sur les enjeux éthiques, sociaux, politiques et économiques qui entourent le développement des neurosciences, et invite les chercheurs à mener des recherches empiriques sur les dimensions concrètes et complexes propres à chaque domaine où les neurosciences sont utilisées. Les auteurs semblent à cet égard plutôt optimistes et envisagent volontiers la réconciliation des neurosciences avec les sciences sociales. Cette position est cependant quelque peu problématique. À l'heure actuelle, les rapprochements multidisciplinaires qui s'opèrent entre les chercheurs en neurosciences, en nanotechnologies et en génie génétique d'une part, et en sciences humaines et sociales d'autre part, consistent plus en une tentative de légitimation sociale de l'avancement parfois controversé de la recherche biomédicale en s'arrogeant les services d'anthropologues, de psychologues et de sociologues. Cet appel à la multidisciplinarité omet également que l'engouement pour les neurosciences dans le milieu scientifique est à la fois vecteur d'une large reconnaissance symbolique et de fonds de recherche conséquents. Il serait donc naïf de croire que les chercheurs, dont l'activité repose en grande partie sur les financements qu'ils reçoivent, accueilleraient volontiers au sein de leur équipe des professionnels susceptibles de les priver de leur capacité d'agir.

William Wannyn, Université de Montréal

Margaret Porter (texte édité, augmenté et analysé par Lucia Ferretti). ***Histoire de l'Hôpital Sainte-Anne de Baie-Saint-Paul. Dans Charlevoix, tout se berce.*** Québec: Éditions du Septentrion, 2014. 312 pp. 27,95$. ISBN 978-2-8944-8795-2,

---

Publié près de 35 ans après sa rédaction par Margaret Porter, sœur de la congrégation des Petites Franciscaines de Marie de 1916 à 1980, cet ouvrage est paru aux éditions du Septentrion en 2014. Sœur Porter a œuvré sa vie entière à l'éducation des enfants avec incapacités intellectuelles et physiques et à partir de 1964, comme directrice de l'École de réadaptation de l'Hôpital Sainte-Anne de Baie-Saint-Paul. Elle nous invite ainsi à réfléchir sur l'univers de la déficience intellectuelle depuis la mise en place de cette institution en 1889 et plus particulièrement à partir des souvenirs personnels des dernières années de sa vie. Grâce à la plume lyrique de Porter, nous pouvons ainsi suivre l'histoire de cet hospice/hôpital dédié aux imbéciles et idiots de la province de Québec sur près de 100 ans. Au fil des pages nous trouvons trois sections chronologiques en plus de 75 photographies qui nous permettent de prendre le pouls en image de cette institution. Notons aussi que les propos de Porter sont annotés par l'historienne Lucia Ferretti qui en écrit aussi le dernier chapitre.

Le récit de Porter est divisé en trois parties. À l'aide des Annales des Petites Franciscaines de Marie, la première partie décrit les années de fondations et la mise sur pied de l'institution (chapitres 1 à 11). Elle raconte la vie difficile des premières années/décennies et les efforts des premiers dirigeants, le curé Ambroise Fafard et quelques années plus tard, sœur Anne. Sœur Porter décrit ainsi, de manière chronologique et avec une mise en récit qui nous rappelle les historiettes, cette institution dédiée à accueillir les déficients intellectuels et physiques. Sa position est claire : l'hôpital Ste-Anne est à la fois un « asile, dans sa nature originelle, [qui] comporte sécurité et porte même assurance d'indemnité; école suggère la souple contrainte qui s'impose aux frêles tiges pour les empêcher de grandir en herbes folles. Il s'agit donc d'un asile-école faisant corps avec un hôpital dont le propre est d'être secourable à toute souffrance comme à toute solitude » (108). Et c'est sur ces bases qu'elle entend nous rappeler les buts louables, bien que critiqués par la suite, de cette institution d'enfermement.

La deuxième partie relate les périodes de crises (économiques et politiques) de l'institution en prenant pour sources primaires les annales de la Maison Saint-Joseph (1927-1936) et les archives de l'École Marie-Bibeau (CMPP) dans les années 1960 (chapitres 12 à 16). Ces années, soit de 1930 à 1965, réfèrent au plus haut taux d'internement de la province. À titre d'exemple, plus de 20 000 personnes se retrouvent internées dans les institutions psychiatriques, au sens large du terme, dans les années 1940-50 au Québec. Cette situation de surpopulation, de mise à l'écart alimentera une curiosité exagérée envers des êtres jugés trop différents, notamment envers les personnes institutionnalisées avec des incapacités physiques. Qui n'a jamais entendu parler de l'hippocampéléphantocamélos de Rostand? Figure quasi mythologique, le célèbre homme à la tête de cheval fait figure d'attraction touristique même s'il n'existe que dans l'imaginaire des gens. Sœur Porter le précise : il n'y en a jamais eu à Ste-Anne mais, oui, bien sûr, l'un des patients présentait des difformités physiques et souffrait d'hémiplégie (161). Alors qu'à l'extérieur des murs de l'institution se propagent des histoires effrayantes et morbides, les hospitalisés ont plutôt tendance à tout sublimer, à créer des fables aussi douces que rassurantes, pour reprendre ses mots. Ainsi, elle raconte cette histoire à propos d'un petit enfant très malade au sujet duquel deux grands bonshommes se partagent des projets consolants : « Il est trop beau, [dirent-ils], quand il mourra, on le fera sécher pour remplacer le petit Jésus dans la crèche ». (163).

Enfin, la dernière partie écrite par sœur Porter mélange à la fois les archives de l'institution et ses souvenirs personnels en tant que membre de l'École de l'Hôpital à cette époque (chapitres 17 à 20). Il est connu que depuis les années 1960, des changements majeurs en matière de soins en santé mentale et en déficience intellectuelle ont eu lieu au Québec. Sœur Porter témoigne de ce chambardement, c'est le mot. Cette partie, plus poignante, décrit sa propre expérience des dernières années et questionne, avec justesse, ces réformes non pas dans ce qu'elles souhaitaient réaliser mais bien dans ce qu'elles pouvaient réaliser. En effet, peut-on changer les mentalités en si peu de temps et avec si peu de moyens? L'émotion est palpable au fil de la lecture de cette partie. Il s'agit aussi de la partie de l'ouvrage la plus annotée par Ferretti, qui elle, termine le livre avec un dernier chapitre intitulé « Pour une conversion du regard », dans lequel elle trace à grandes lignes l'histoire de la gestion et des soins envers les déficients intellectuels au Québec.

Cet ouvrage est le récit d'une institution québécoise spécifique, celle de Sainte-Anne de Baie-Saint-Paul. En se servant des annales de l'institution et étant elle-même membre de l'ordre confessionnel, l'auteure nous invite à lire les mots laissés par ceux et celles qui ont participé à la mise en place de cette institution et aux soins des personnes qui y furent institutionnalisées depuis la fin du 19e siècle. L'une des grandes forces de cet ouvrage est la sensibilité du propos de l'auteure. Je prends ici un extrait dans lequel elle questionne le concept de normalité. « Nous tendons à dénigrer ceux qui ne peuvent parvenir aux normes que nous avons fabriquées nous-mêmes. […] Ceux qui vivent selon NOS normes, nous les acceptons. Ceux qui n'y parviennent pas, nous les rejetons. Nous les appelons inférieurs et nous les rendons tels ». (218). Toute sa vie durant, sœur Porter aura vécu au sein d'un monde stigmatisé, celui des personnes vivant avec des incapacités physiques et intellectuelles. Cette position, celle du dedans, lui permet, au-delà de son récit élogieux, de critiquer la peur et l'appréhension envers les personnes internées à l'hôpital Ste-Anne de Baie-St-Paul, envers ceux que nous appelions il n'y a pas si longtemps les idiots et les imbéciles.

Isabelle Perreault, Université d'Ottawa

Dan Malleck. ***When Good Drugs Go Bad: Opium, Medicine, and the Origins of Canada's Drug Laws.*** 249 pp. Vancouver: UBC Press, 2015. $34.95 (paperback). ISBN: 978-0774-8292-05

When Good Drugs Go Bad is an intricately nuanced historical case study of opium in Canada at the dawn of the 20th century. It is a welcome contribution to the knowledge base emerging on the contested status of substance use within the history of medicine and socio-legal studies. Canada's first drug laws ushered in an era characterized by increasingly restrictive prohibition legislation.

Overemphasis on racist motivations in the past has frequently, notes Malleck, led to oversimplification of the social context and complexity of factors that resulted in the passing of the early legislation. His study does not span more recent decades of continuing commitment to the use of law to punish substance users. Nor does his focus stray towards the impact of these laws. Instead the emphasis is squarely on the law creation process, to further understanding of converging social forces at the time of the 1908 Opium Act.

Malleck sets the stage for this insightful exploration by capturing the societal ambivalence surrounding a drug that was both vilified and romanticized in western culture. The more threatening view of opium gained momentum and grew louder, fueling calls for regulation in a society fixated on a view of nationhood that was largely predicated on the social virtues of self-control and productivity. The movement to ban some drugs is conceptualized as being part of the effort to establish a Canadian identity, to shape the moral character and conduct of its citizens.

Drug law creation, from this standpoint, is connected to a larger project of rendering natural, or taken-for-granted, particular norms of social order and behaviour. Foucault's classic work on biopolitics and governance informs the aim of this book to examine forms of governance that have shaped ideas of proper personal behaviour, including norms of proper and improper use of drugs. Malleck's work surpasses most past studies in its level of attention to detailing an array of views and interests, including medical professionals and government officials, other influential stakeholders, and members of the public.

The role of interest groups and claims making is highlighted throughout to explore the process of creation of drug policy by asserting certain meanings, definitions, and discourses. Malleck takes a long view, documenting the discursive shift observed from sin to sickness models of addiction with the expanding jurisdiction of medical authority, and the rising influence of social reform movements, among other influential social forces of the day. Each chapter stands alone, while overlapping other chapters, to provide a multi-layered, more nuanced view of history.

It is well documented that throughout the 19th century, Canadians enjoyed unregulated access to opiated medicines and tonics. The extent of the indulgence is less clear. While Malleck demonstrates that books of remedies from folklore often mention opium, rarely does it feature as a prominent ingredient. The use of opium as medicine by medical professionals shows like appreciation of its value mixed with caution. Chronic intoxication, or habituation, appears to have been less of a concern for many doctors than acute toxicity, or the danger due to overdose.

The advent of the hypodermic syringe mid-19th century and the development of morphine were technological advances that furthered the legitimacy of medical professionals, granting them greater control and authority over definitions of the proper use of opiates. The momentum for increasing regulation was augmented by training and licensing requirements aimed at druggists, who had been entrusted to restrict the use of poisons, which over time expanded to include other "dangerous drugs."

The intensification of professional disputes between pharmacists, physicians (and retailers) to shape policy is but one facet of a fascinating confluence of factors. Debates about the meaning of mental illness and addiction—and disagreements between experts over diagnostic boundaries—appear to be as intricately connected to this process as the racial conflict that ignobly resulted in the targeting and labeling of the Chinese opium smoker as a threat to national values in the early 20th century. The resulting moral panics over opium, cocaine, and later marijuana are associated with a larger social project of inclusion and exclusion. Drug use is only one category of behaviour that is subject to increasing surveillance and regulation through predominant discourses of morality and health.

Readers well versed in the literature on moral regulation and the social problems process will find much that is familiar in Malleck's framing of the origins of Canada's first drug law. His analysis does not extend to posing innovative theoretical connections for advancing the two literatures. Nor is he concerned about engaging with internecine debates between constructionists or moral regulation scholars. These shortcomings (for some readers) are unlikely to diminish the lasting contribution of *When Good Drugs Go Bad* for those seeking further insight on the intricacies of history that have shaped drug policy in Canada today.

Andrew D. Hathaway, University of Guelph

Jason Sean Ridler. ***Maestro of Science: Omond McKillop Solandt and Government Science in War and Hostile Peace, 1939–1956***. 246 pp. Toronto: University of Toronto Press, 2015. $55.00 (hardcover). ISBN: 978-1442-6474-73

Dr. Omond Solandt became one of Canada's most influential voices on military and science affairs during the nuclear age. He established a name in operational research in Britain during the Second World War and translated his wartime experience into postwar success as a prominent official in the Canadian defence establishment. *Maestro of Science* has a two-fold objective. Author Jason Ridler attempts to situate Solandt's contributions to government science within a growing international literature on the history of twentieth-century state science in Canada and Britain while also using Solandt's career to map significant developments in the science and defence policies of both countries during and immediately following the Second World War. In answering a wide variety of questions concerning the legacy of Solandt, Ridler traverses topics that include medical history, military science and technology, industrial engineering, and national security policy in both Canada and Britain.

While the bulk of the analysis examines Solandt's science career during and after the war, the first two chapters delve into the early developmental years of Solandt's life and offer important insights for considering his rise to prominence in the Canadian science and defence establishment. *Maestro of Science* provides a wealth of insight into other prominent defence officials as well. By following the professional career of Solandt, Ridler's analysis touches on important and influential Canadian personalities such as Minister of National Defence Brooke Claxton, Chairman of the Chiefs of Staff Charles Foulkes, Canadian Cabinet minister C.D. Howe, and President of the National Research Council C.J. Mackenzie. Ridler also describes interactions between Solandt and Sir Henry Tizard, Chief Scientific Adviser in Britain, to emphasize the development of cordial and important cross Atlantic science relations between the two governments.

Much of the book chronicles Solandt's legacy with regard to the Defence Research Board (DRB), Canada's first federal organization for military science in peacetime. As founding Chairman of the DRB, Solandt oversaw the development of the organization into an important branch of Canada's military and security establishment, and a respected component of scientific research among the nation's allies. The Liberal government of Louis St. Laurent so valued Solandt that, as Chairman he required prime ministerial permission to leave his post atop the DRB. After nearly a decade on the job, Solandt was "driven out" of government service in 1956 when, according to Ridler, "the palace for his most stunning intellectual achievements in government science had become a metaphorical prison" (p. 237).

Ridler relies extensively on original research to examine and contextualize Solandt's contributions to science and government. Archival research in Canada yielded insights from repositories such as Library and Archives Canada and the Department of National Defence's Directorate of History and Heritage in Ottawa, Ontario. Ridler also conducted research in Britain at the Imperial War Museum and the National Archives in London, England. Yet the bulk of his archival documentation derived specifically from the Omond McKillop Solandt fonds, which are held at the University of Toronto Archives. Along with an important collection of interview transcripts acquired through David Grenville, a former colleague and biographer of Solandt, Ridler uses these primary materials in combination with secondary source literature to weave an intricate narrative of Solandt during the nuclear age.

While Solandt certainly deserves recognition for his many accomplishments and contributions to the development of state science and national security policy in Canada, Ridler's overwhelming positive analysis leaves questions about the legacy of his subject unanswered. The author makes an important and astute statement about the limitations of biography in the introduction: "If uncritical, [biographies] become hagiography. If too critical, they become a witch hunt" (p. 8). It is with these two extremes in mind that Ridler attempts to navigate and explain Solandt's role and influence on science policy in Canada, but his assessment is inadvertently less-balanced than the introduction suggests. For example, in his discussion of Solandt's role in chemical and biological weapons testing in Chapter 12, Ridler makes only brief reference to public criticism for military research in Canada, opting instead to emphasize the cool and pragmatic leadership style of his subject in the midst of postwar concerns. Moreover, as Chairman of the DRB Solandt supported extensive human trials in military-related scientific research, yet the potential negative consequences of these important details extend beyond the scope of Ridler's analysis. Considering the relative youth and sparseness of historical scholarship on science policy and the Cold War Canadian state, perhaps it is too early to suggest, as Ridler proclaims in the conclusion, that: "Excelling was just part of his nature" (p. 241).

Solandt's effect on government science policy should not be ignored, but to date only a few academic publications—*Defence and Discovery* (Godefroy, 2011) and *Pathogens for War* (Avery, 2013), for instance—have probed the military and civil impact of state-sponsored defence science in Canada. A wealth of archival documentation remains unexamined and it is premature to draw definitive conclusions on the legacy of Solandt or the state policies championed during his career. Nevertheless, *Maestro of Science* makes a valuable contribution to historical scholarship on the development and implementation of state science in both Canada and Britain. The biography will serve as foundational reading for scholars interested in civil-military relations and the inner-workings of Canada's security establishment during the Second World War and early Cold War years.

Matthew S. Wiseman,
Wilfrid Laurier University

Ben Bradley, Jay Young, Colin M. Coates, editors. ***Moving Natures: Mobility and Environment in Canadian History.*** 338 pp. Calgary: University of Calgary Press, 2016. $34.95 (paperback) and Open Access (ebook.)ISBN 978-1-55238-862-4

Canada, we are often told, is really big. Its vast distances have informed everything from popular music to the once-dominant "staples" and "Laurentian" paradigms of economic development. *Moving Natures: Mobility and Environment in Canadian History*, edited by Ben Bradley, Jay Young, and Colin M. Coates is a welcome intervention in several fields that engage with Canada's size, including environmental history, mobility studies, science and technology studies, and Canadian social and cultural history. Here, dominant narratives of transportation networks as vaunted annihilators of Canadian distances are complicated and decentralized by prying open the black-boxes of mobility studies and environmental history with the crowbars of the other. The editors seek to add "materially grounded, place-specific studies" of historical interactions between "older, less exotic" networks and the environment to mobility studies, and the mechanisms by which visitors enjoy parks, wilderness areas, or "natural" leisure activities to environmental history. (10) The result is a well-rounded set of twelve interdisciplinary stories that address both the impact of mobility networks on the environment as well as changing perceptions of the environment when viewed from different transportation platforms.

Moving Natures is divided into two sections. The first and larger section engages generally with mobility and labour. Some of the essays here, such as Daniel Macfarlane's piece on the St. Lawrence Seaway and Jay Young's fascinating account of displacing dirt for the Toronto subways, are concerned with the environmental effects of transportation infrastructure. Others, such as Merle Massie's essay on freighting and tourism in northern Saskatchewan, deal with the impact of the seasons on Canadian mobility patterns. Seasonality is a major through-line of *Moving Natures*; the relationships between Canadians and their seasons have yet to be given the scholarly attention they deserve, and these essays suggest some potentials for the field. The second section is the more cohesive and deals with the framing of Canadian environment-based experiences through mobility. Although tourism appears as an analytic throughout this volume, it is spotlighted here, where the essays break down the methods by which Canadians have undertaken leisure voyages and centralize the lived experiences of travelers. They highlight how Canadian environments have been constructed through mobility, as Elsa Lam and Maude-Emmanuelle Lambert show in their pieces on rail and automotive tourism, suggesting that mobility patterns "helped to make certain environments into regionally or nationally iconic landscapes." (200) These themes are helped along by visuals such as promotional posters, brochures, maps, and postcards, which help tie the environmental consequences of mobility to historical perceptions of Canadian environments.

The essays in this volume deal with wide range of mobilities, from steamships to subways to the automobile, but are closely linked thematically as well as by their playing with the methodological and analytic ideas of scale and speed. The editors hint at this in their volume and section introductions, and it is one of the great strengths of this collection. The chapters zoom in and out, so to speak, from national megaprojects to the hyper-local, such as Thomas Peace, Jim Clifford and Judy Burns' micro-history of small-town Nova Scotia shipbuilding, and from the dizzying speed of trains to the leisurely pace of golf games. In so doing, they connect individual travel experiences to regional, national, and even global flows of people, goods, and ideas, as well as larger questions of modernity, urbanization, and place.

As with any edited volume, there are some holes. The editors rightly point out that the volume is lacking a pointed analysis of animal-drawn vehicles and aviation. They have also privileged relatively elite Euro-Canadian narratives, which neglects regions (the Arctic is conspicuously absent,) voices, and uses of transportation that could really stretch the boundaries of mobility studies. Some of this stems from the occasional accidental conflation of mobility with modern industrial transportation; even when "pre-modern" mobility networks appear, such as in Jessica Dunkin's excellent paper on canoe clubs, they seem decentralized. This is not the case in every essay— J. I. Little's chapter on steamboat tourism, for example, acknowledges that there are voices missing—but, when taken together, they present a somewhat hegemonic story of mobility. However, these missing pieces are small, and do not detract from the engaging and informative set of stories presented in the volume. As a proof-of-concept work showing new directions for Canadian environmental history-tinted studies of mobility (and vice versa,) this is an absolutely successful volume. Moving Natures presents an innovative approach to both mobility studies and environmental history, and there is plenty of room for these gaps to be filled by others. The field, like, Canada, certainly is big enough.

Blair Stein, University of Oklahoma