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

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Volume 17, numéro 1-2, 1993

Dominions Apart: Reflections on the Culture of Science and Technology in Canada and Australia 1850-1945

URI : https://id.erudit.org/iderudit/800364ar
DOI : https://doi.org/10.7202/800364ar

Aller au sommaire du numéro

Éditeur(s)

CSTHA/AHSTC

ISSN

0829-2507 (imprimé)
1918-7750 (numérique)

Citer cet article

Home, R. W. (1993). Defining the Boundaries of the Field: Early Stages of the Physics Discipline in Australia. *Scientia Canadensis*, *17*(1-2), 53–70. https://doi.org/10.7202/800364ar

Defining the Boundaries of the Field: Early Stages of the Physics Discipline in Australia

R.W. Home

'Physics' in its Aristotelian meaning—as the science of nature in general — has been an integral component of the university syllabus since the middle ages. Despite this, physics has been a comparative latecomer among the various branches of modern science in establishing its disciplinary and professional identity. The process by which it has done so has in recent years begun to attract attention from historically minded sociologists of science, including Yves Gingras who has written extensively on the formation of physics as a discipline in Canada.[1] By the time the new discipline emerged, however, the term 'physics' had acquired a much narrower meaning than it had previously had, and now referred to a restricted field of scientific inquiry. Intimately bound up with the question of how physics became established as a discipline, or as a profession, is the question of what subject-matter the term 'physics' actually embraced in different times and at different places. A purely sociological analysis of the growth of disciplinary or professional forms can thus not be expected to yield, on its own, an adequate understanding of events. It is also necessary to take into account the changing intellectual structure of the field.

What constitutes a particular scientific field such as physics is of course never going to be decided unilaterally, by practitioners in one country alone. Such a question will always be determined at an international level by, for example, the editorial and employment practices adopted in relation to the field in a number of leading countries. I shall be arguing in what follows, however, that peculiar circumstances of time and place may constrain developments locally in such a way as to influence not just the institutional structures that are created but also, to some extent, the way in which the field itself is conceived there. More specifically, I shall be suggesting that, whereas in the leading scientific nations of Europe physics became narrowly identified both institutionally and intellectually during the last years of the nineteenth century as a laboratory-based practice, elsewhere, particularly in the case of Australia which I know best but I suspect also in countries such as Canada, this did not happen to anything like the same extent. There, the boundaries of the field were more loosely defined, for reasons that we must investigate. The consequences could sometimes be of more than local significance.

1 See his book, *Physics and the Rise of Scientific Research in Canada* (Montreal/Kingston: McGill-Queen's University Press, 1991).

An indication of the differences involved may be gained from the proceedings of the first Australia-wide gatherings of scientists working in this field, the meetings of Section A, 'Astronomy, Mathematics, Physics and Mechanics,' at the early congresses of the Australasian Association for the Advancement of Science (AAAS).[2] As the name of the Section reveals, physics did not stand alone at these congresses but was joined with other, cognate sciences. Yet the title also makes clear that physics itself was recognized as, at least in principle, a subject with an identity of its own. Why, then, was it linked with others under the Section A umbrella? Part of the explanation lies in the small numbers of people involved in these sciences in Australia at this time: even when they were brought together on the program, it was not always easy to fill the time available, especially at congresses held in the smaller population centres. I shall however be arguing that the grouping together of these subjects also reflected genuine and still fluid connections between them: the boundaries of the physics discipline remained flexible and open.

The meetings of Section A gained much of their authority from the continuing involvement of the various colonial astronomical observatories and the standing of their directors, three of whom, R.L.J. Ellery from Melbourne, H.C. Russell from Sydney and Charles Todd from Adelaide, were the only practitioners in any of these fields in Australia during the Association's earliest years to enjoy the status of Fellows of the Royal Society of London. Papers were also contributed by members of university mathematics and physics departments, the more active university professors taking turns with the directors of the observatories at presiding over the Section. William Sutherland, a prolific and highly regarded independent researcher living in Melbourne at this period, presented papers regularly, and several papers were contributed by members of government survey departments. The sessions were open to members of the public, who were encouraged to register for the congresses, and papers were sometimes presented by non-specialists (though only very rarely were more than the titles of these included in the published proceedings). Thus these occasions were by no means designed as boundary-drawing exercises intended to mark off the sciences concerned as fields open only to professionals. They were, however, dominated by full-time and (Sutherland apart) professionally engaged scientists. The meetings were, in fact, the closest approximation Australia had in these years to meetings of a national learned society covering the fields in question.

The topics discussed include some that can be categorized as purely astronomical or purely mathematical. Among the former may be listed Ellery's presidential survey of the then state of astronomical knowledge at the inaugural meeting and

2 R.W. Home, 'The Physical Sciences: String, Sealing Wax and Self-Sufficiency,' in Roy MacLeod (ed.), *The Commonwealth of Science: ANZAAS and the Scientific Enterprise in Australasia, 1888-1988* (Melbourne: Oxford University Press, 1988), 147-65.

a paper by him at a later congress on the international project on the photographic charting of the heavens in which several of the Australian observatories had become involved;[3] and papers by Russell on instrumental improvements and on measurements of double stars.[4] Examples of the latter are a paper by the Melbourne mathematician J.H. Michell on algebraic curves, a paper on actuarial science, and two papers by different authors on quaternions.[5] 'Mechanics' figured in the title of the Section only for the first four congresses, and was never represented by a paper that could be classified unambiguously under this heading.

The 'physics' papers were much more heterogeneous. Laboratory-based precision measurement had become increasingly the hallmark of physics research in Europe and the United States during the preceding two or three decades,[6] but was first introduced into Australia in the mid-1880s. Initially, work of this kind featured only sparingly on the program at the AAAS meetings. At the inaugural meeting, the new professor of physics at the University of Sydney, Richard Threlfall, standard bearer for the view that such work ought to be the chief characteristic of the subject,[7] contributed two papers reporting some early achievements of the ambitious program of electrical research on which he had embarked as soon as he arrived in Sydney, as well as an account of the various special features of the new laboratory just erected for him by his University.[8] This was at the time the only physical laboratory worthy of the name in the country, but by the early 1890s T.R. Lyle at the University of Melbourne likewise had a functioning laboratory and from here, shortly afterwards, the first research students came to the AAAS meetings to present reports on their work.[9] By the first years of the new century, W.H. Bragg at the University of

3 Ellery, 'The Present Position of Astronomical Knowledge,' *AAAS Report*, 1 (1888), 26-38; 'On Some Difficulties arising in the Photographic Charting of the Heavens,' *idem.*, 4 (1892), 260.

4 Russell, 'Exhibition of a Model for Fine Distance Adjustments,' *Ibid.*, 106; 'A Proposed Method of Recording Variations in the Direction of the Vertical,' *idem.*; 'On Measurements of Double Stars,' *idem.*, 5 (1893), 302.

5 Michell, 'A Property of Algebraic Curves,' *Ibid., 4* (1892), 257; J.J. Stuckey, 'The Application of Mathematics to Actuarial Science,' *idem.*, 5 (1893), 280-6; A. McAulay, 'Quaternions as an Instrument of Physical Research,' *idem.*, 261; G. Fleuri, 'From Number to Quaternions,' Ibid., 5 (1893), 301.

6 Romualdas Sviedrys, 'The Rise of Physics Laboratories in Britain,' *Historical Studies in the Physical Sciences*, 7 (1976), 405-36; David Cahan, 'The Institutional Revolution in German Physics, 1865-1914,' *idem.*, 15 (1985), 1-65.

7 R.W. Home, 'First Physicist of Australia: Richard Threlfall at the University of Sydney, 1886-1898,' *Historical Records of Australian Science*, 6 (pt.3), (1986), 331-56.

8 Threlfall, 'On the Measurement of High Resistances, and on Galvanometers Suitable for the Purpose,' *AAAS Report*, 1 (1888), 109-10; 'On the Clark Cell as a Source of Small Standard Currents, and on a Galvanometer for the Prince Alfred Hospital,' *idem.*, 110-12; 'On the New Physical Laboratory at the University of Sydney,' *idem.*, 86-97.

9 W.H. Steele, 'The Conductivity of Solutions of Copper Sulphate,' *ibid.*, 4 (1892), 256-7; 'Thermo-Electric Diagrams for Some Pure Metals,' *idem.*, 5 (1893), 302-5.

Adelaide also had a reasonably satisfactory laboratory in which to work.[10] Here he began the remarkable research on ionizing radiations that was to lead in quick succession to his election in 1907 as a fellow of the Royal Society of London, his return to England two years later to the chair of physics at Leeds, and the 1915 Nobel prize for physics that he shared with his Adelaide-educated son, W.L. Bragg.

Laboratory investigations of this kind, however, in so far as they were pursued at all, were confined to the thinly populated physics departments of the universities; alternative institutional loci that emerged in other countries, such as the great national physical laboratories of Germany, Britain and the United States, or laboratories established by industrial corporations, did not appear in Australia until many years later. Even among the universities, until well into the twentieth century only the Universities of Sydney, Melbourne and Adelaide had the capacity to support even a modest research program. In the meantime, at the roughly biennial meetings of AAAS, most of the 'physics' papers presented to Section A tackled questions of a different kind. So, too, did the various specialist committees of investigation established by the Section, that to some degree maintained the spirit of intercolonial scientific co-operation between congresses. Most of the Section's energy was directed not to carefully confined laboratory research but to 'terrestrial physics,' as it was called by Pietro Baracchi, Ellery's successor in 1895 as director of the Melbourne Observatory[11]—that is to say, to larger-scale questions relating to the physics of the Earth and its surrounding oceans and atmosphere. While here, too, high precision in measurement was the leading characteristic of the work, for the most part the investigations reported or set in train depended upon observational rather than experimental methods. Subjects taken up included earthquakes, tides, the weather, and the shape and magnetic field of the Earth.

Prior to the formation of AAAS, the small numbers of physical scientists in the Australian colonies had had little contact with their fellows beyond the particular city in which they lived. The regular AAAS meetings, and the work of the committees of investigation in between, served to bring them together as a group, bound together by a common scientific interest. Contacts made at the meetings could subsequently be exploited through correspondence or individual visits to other colonies.[12] The point I wish to emphasize here is that the

10 The construction of these laboratories is discussed in R.W. Home, 'Learning from Buildings: Laboratory Design and the Nature of Physics,' in Renato G. Mazzolini (ed.), *Non-Verbal Communication in Science prior to 1900* (Florence: Olschki, 1993), 587-608.

11 Baracchi, 'Presidential Address, Section A,' *AAAS Report*, 7 (1898), 157-75.

12 I have elsewhere shown how contacts made at the AAAS meetings contributed in this way to W.H. Bragg's career: see R.W. Home, 'The Problem of Intellectual Isolation in Scientific Life: W.H. Bragg and the Australian Scientific Community, 1886-1909,' *Historical Records of Australian Science*, 6 (pt. 1), (1984), 19-30.

field that thereby found institutional expression was neither confined to nor dominated by the style of laboratory-based research that came to be established in the universities at this period. On the contrary, it also embraced, on at least an equal footing, the study of real natural systems operating on a large scale — the kind of study for which Susan Faye Cannon coined the label, 'Humboldtian science.'[13]

During the period with which we are concerned, one of the most characteristic of the Humboldtian sciences, meteorology, was undergoing spectacular development. The recording of meteorological data had long been seen as a matter of public importance. In newly settled Australia, as in Canada,[14] a widely felt need for a better understanding of local weather patterns generated substantial public support for such work, and for the observatories that co-ordinated it. Until the middle years of the nineteenth century, meteorological ambitions were confined to collecting and analysing data for individual locales. However, with the spread of telegraph networks, the prospect arose of tracking storms and issuing warnings to places lying in their path. During the 1860s, the even more exciting prospect emerged of using the telegraph system to collect meteorological data recorded simultaneously at specified times on standardized sets of instruments in a number of different locations. These data could then be plotted on a map as a synoptic chart, to show the weather pattern over an entire region; and by studying the changes in the chart from day to day, the meteorologist could follow changes in the condition of the atmosphere, more or less as they occurred. In Australia, this idea was taken up enthusiastically in the 1870s by the directors of the three major colonial observatories, Ellery, Russell and Todd. By the end of the decade, all three had established networks of meteorological observers throughout their respective colonies who sent them synchronized reports by telegraph each day. An agreement in 1877 to exchange data between the three observatories opened the way for the preparation of daily synoptic charts showing the weather pattern over the whole of southeastern Australia. Intercolonial conferences in 1879 and 1881 that were attended by James Hector from New Zealand as well as the three Australians, together with another conference in 1888 attended by representatives of all the Australasian colonies, consolidated and formalized these arrangements, which

13 Susan Faye Cannon, *Science in Culture: The Early Victorian Period* (New York: Science History Publications, 1978), chapter 3. See also Jack Morrell and Arnold Thackray, *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (Oxford: Clarendon Press, 1981); David N. Livingstone, *The Geographical Tradition: Episodes in the History of a Contested Enterprise* (Oxford: Blackwell, 1993); Malcolm Nicolson, 'Alexander von Humboldt, Humboldtian Science and the Origins of the Study of Vegetation,' *History of Science*, 25 (1987), 167-94; and R.W. Home, 'Humboldtian Science Revisited: A Australian Case Study,' *ibid.*, forthcoming, 1994.

14 Suzanne Zeller, *Inventing Canada: Early Victorian Science and the Idea of a Transcontinental Nation* (Toronto: University of Toronto Press, 1987), Part 2.

parallelled developments that took place in Europe and North America at about the same time.[15]

A way had thus at last been found, it seemed, for meteorologists to advance beyond mere data-gathering at single localities. Now, there opened before them Alexander von Humboldt's seemingly impossible dream of studying the atmosphere as a whole, as an integrated, dynamical system. The key was the electric telegraph, the utilization of which was, as Charles Todd later was aptly to put it, 'to the meteorologist what the telescope is to the astronomer, in extending his field over large areas of the earth's surface.'[16] Todd himself was quick to recognize the fundamental feature of the weather patterns over the southern part of the Australian continent, the movement of a succession of high- and low-pressure systems in an easterly direction across the continent.[17] By the late 1880s, he and his colleagues, like their fellow meteorologists in Europe and North America, felt confident enough to issue daily weather forecasts based on their recognition of recurring patterns recorded on their synoptic charts.

Terrestrial magnetism was another field of investigation that had had a long history in Australia. The early ship-borne explorers had routinely recorded magnetic data, and from 1840 to 1854 the elements of the Earth's magnetic field had been systematically recorded at the Rossbank Observatory in Hobart, one of a world-wide chain of observing stations set up as part of an international 'magnetic crusade' co-ordinated by Britain's Edward Sabine.[18] By comparing the Hobart data with those recorded at the similar observatory set up in Toronto, Sabine had made an astonishing discovery, a new periodicity in the variations in the Earth's field that was linked to the then very recently discovered eleven-year cycle in sunspot activity. The magnetic condition of the Earth was thus connected directly to the actual physical condition of the Sun: in Sabine's words, 'we find ourselves landed in a system of cosmical relations, in which both the sun and earth, and probably the whole planetary system, are implicated.' In addition, Sabine had shown that the so-called 'irregular variations' of large amount were actually periodic and connected with both the

15 R.W. Home and K.T. Livingston, 'Science and Technology in the Story of Australian Federation: The Case of Meteorology, 1876-1908,' *Australian Journal of Politics and History* (forthcoming, 1994).

16 Todd, 'Meteorological Work in Australia: A Review,' *AAAS Report*, 5 (1893), 246-70; 252.

17 Todd, *Adelaide Meteorological Report*, May 1879; reprinted as Appendix 2 to *Minutes of Proceedings of the Intercolonial Meteorological Conference held at Melbourne on the 21st, 22nd, 25th, 26th, and 27th of April 1881 (Victoria, Parliamentary Papers, 1880-81, no. 99).*

18 John Cawood, 'The Magnetic Crusade: Science and Politics in Early Victorian Britain,' *Isis*, 70 (1979), 493-518; Morrell and Thackray, *op. cit.* note 13, 512ff.; Ann Savours and Anita McConnell, 'The History of the Rossbank Observatory, Tasmania,' *Annals of Science*, 39 (1982), 527-64.

Sun's position in the ecliptic and the Earth's diurnal rotation. More generally, as a result of the magnetic crusade, the whole subject of terrestrial magnetism had in Sabine's view been brought to much better order.[19]

Unlike its counterpart in Toronto, the Rossbank Observatory did not survive for long, once responsibility was passed in April 1853 to the respective colonial governments. Within a few years of its closing, however, a new magnetic and meteorological observatory had been opened on Flagstaff Hill in Melbourne under the direction of the young German geophysicist Georg Neumayer. From 1858 until his return to Germany in mid-1864, Neumayer kept hourly records of the Earth's magnetic field and, in conjunction with this, carried out a magnetic survey of the entire colony. His work, like the magnetic crusade earlier on, was directly inspired by Humboldt's ideals. His main aim was to shed light on the 'great questions' which, in his view, remained unanswered, despite the achievements of the magnetic crusade, namely 'the locality of the magnetic force and the cause of the horary and annual variations of the needle.' From a more immediately practical point of view, he also hoped that his magnetic survey would lead to the discovery of new mineral deposits. Because, like most geophysicists in his day, Neumayer expected some of the changes in the Earth's magnetic field to be linked with changes in the weather, he kept systematic meteorological records and, in early 1859, took over responsibility for maintaining and extending the colony's small but growing chain of meteorological recording stations. As well, he systematically analysed, according to the methods pioneered by the American hydrographer Matthew Fontaine Maury, the logs of ships entering the port of Melbourne, in an effort to gain a better understanding of the winds and currents on the Australian sailing routes. In due course, he was able to publish practical recommendations in relation to the planning of routes for voyages to and from Australia.[20]

Neumayer was the first professionally trained physicist to work in Australia, and he brought with him new standards of precision and sophistication in

19 Sabine, 'On Periodical Laws Discoverable in the Mean Effects of the Larger Magnetic Disturbances,' *Philosophical Transactions of the Royal Society of London*, 141 (1851), 123-39 and 142 (1852), 103-29; idem, 'On What the Colonial Magnetic Observatories Have Accomplished,' *Proceedings of the Royal Society of London*, 8 (1856-7), 396-413; 'Report of the Joint Committee of the Royal Society and the British Association, for Procuring a Continuance of the Magnetic and Meteorological Observatories,' *British Association for the Advancement of Science, Report of the 28th Meeting, Leeds, 1858*, 295-305.

20 R.W. Home and Hans-Jochen Kretzer, 'The Flagstaff Observatory, Melbourne: New Documents relating to Its Foundation,' *Historical Records of Australian Science*, 8 (1991), 213-43; R.W. Home, 'Georg Neumayer and the Flagstaff Observatory, Melbourne,' in David Walker and Jürgen Tampke (eds), *From Berlin to the Burdekin: The German Contribution to the Development of Australian Science, Exploration and the Arts* (Sydney: New South Wales University Press, 1991), 40-53.

physical inquiry. Precision work is an art, one that Neumayer had learned at first hand from his teachers in Germany. His success in passing on the craft knowledge involved to assistants and colleagues in Melbourne led to an order-of-magnitude improvement in the quality of work done there. He himself, as a temporary visitor who then went home to sort and publish his results, would seem to epitomize the earliest, 'exploration' phase in the scientific history of a new colony.[21] Yet he was also instrumental in establishing physical research of international standard in Melbourne. Moreover, he saw to it that the program could continue after he left: prior to his return to Germany, he arranged with the colonial government that his instruments and research program should be transferred to the newly established Melbourne Observatory, together with some of the assistants he had trained to carry on the work.

At Neumayer's departure, Ellery as director of the Observatory took over responsibility for the meteorological observing network and continued to develop it, as we have seen. He also kept up the magnetic observations, and they remained a major feature of the Observatory's work into the period with which we are chiefly concerned in this paper — indeed, they continue to be recorded to this day, half a century after the closure of the Observatory itself, making them one of the longest runs of such data in existence anywhere. The data, once reduced, were published in the form of regular monthly reports until the early years of the twentieth century,[22] but without any serious attempt at analysis. Thereafter even the publication of data proceeded only spasmodically. In his presidential address to Section A in 1898, Pietro Baracchi bemoaned the failure of his observatory to analyse its data as 'very humiliating,' and called for a great expansion of national effort, to match the 'remarkable activity' in this field in many other parts of the world. Others, too, showed a renewed interest in the subject at this period. At the same 1898 congress, a committee was set up at the instigation of Section A to press the New Zealand government — successfully, as it turned out — to undertake a magnetic survey of that colony, while at the 1902 meeting, Alexander McAulay, professor of mathematics and physics at the University of Tasmania, and his colleague E.G. Hogg reported to the Section on a magnetic survey of their state that they had undertaken shortly before.[23]

As European settlers spread across the face of Australia, staking claims to ownership of the land, there was an urgent need to fix the boundaries of and

21 George Basalla, 'The Spread of Western Science,' *Science*, 156 (1967), 611-22.

22 *Monthly Record of Results of Observations in Meteorology, Terrestrial Magnetism, etc., etc., taken at the Melbourne Observatory...*, January 1872-December 1907 (the title of the publication varied slightly over the years.); Baracchi, *op. cit.* note 11, 168.

23 A. McAulay and E.G. Hogg, 'A Preliminary Magnetic Survey of Tasmania, 1901,' *AAAS Report*, 9 (1902), 81-94; also Hogg, 'The Magnetic Survey of Tasmania,' *Papers and Proceedings of the Royal Society of Tasmania*, (1900-01), 85-88.

between such claims. Survey departments were for this reason a prominent feature of colonial administration from the earliest days and, with their emphasis on precision measurement, formed an important institutional locus for work in the physical sciences. Given the nature of survey work, it invariably became linked with the local astronomical observatory, if one was established. In Victoria, for example, Ellery was head of the Trigonometrical Survey as well as Government Astronomer, while in New South Wales, even though the survey department built up a significant observatory facility of its own,[24] it still used the Sydney Observatory as its base point. In Queensland, where no government observatory was ever established, the survey department had to supply its own astronomically determined base points. Leading members of the various colonial survey departments attended AAAS meetings when these were held in their home cities, and at the 1898 Sydney congress, T.F. Furber of the New South Wales department presented an extended account to Section A of the work being done.[25]

The focus on precise determinations of angles and distances that characterized the work of the surveyors meant that they had much in common with late-nineteenth-century physicists in search of ever more precise measuring techniques, and from time to time the activities of the two groups overlapped directly. For example, when Richard Threlfall first arrived in Sydney, he set in train a spectacular investigation, in Sydney Harbour, of the speed of propagation of explosions through sea water.[26] As an essential preliminary, he engaged the services of the Government Surveyor, R.J.A. Roberts, to mark out the site and to provide the necessary distance determinations with the requisite accuracy. (J.A. Pollock, then an assistant at the Sydney Observatory, was recruited at the same time to calibrate Threlfall's clocks). In the early 1890s, university physicists returned the compliment by taking up work that directly underpinned the work of the surveyors. In Victoria, the local Royal Society in 1891 set up a working committee to promote the typically Humboldtian project of systematic determinations of the acceleration of gravity (and hence, ultimately, of the shape of the Earth) throughout the region. Its moving spirit was not, as might have been expected, someone from the Observatory or the Trigonometrical Survey, but a Cambridge-trained laboratory physicist, E.F.J. Love, lecturer in physics at the University of Melbourne. In due course, using the British standard lent by the Royal Society of London, Love established base points at the Melbourne and Sydney Observatories for the proposed

24 Graeme L. White, 'The Observatory at the Lands Department Building, Sydney,' *Proceedings of the Astronomical Society of Australia*, 5 (1984), 606-8.

25 T.F. Furber, 'The Trigonometrical Survey of New South Wales, with mention of Similar Surveys in the Other Australian Colonies,' *AAAS Report*, 7 (1898), 176-237.

26 R. Threlfall and J.F. Adair, 'On the Velocity of Transmission through Sea-Water of Disturbances of Large Amplitude caused by Explosions,' *Proceedings of the Royal Society of London*, 46 (1889), 496-541.

survey.[27] Meanwhile, Threlfall at the University of Sydney, assisted by J.A. Pollock whom he had recruited from the Observatory to join his department, developed a quartz-thread torsion gravity meter of an altogether new design, with which they proceeded independently to measure the acceleration at a wide range of eastern Australian localities.[28]

The second AAAS congress, held in Melbourne in January 1890, saw the formation, at the instigation of Section A, of a committee to promote another characteristically Humboldtian project, a survey of the tides around the Australian coast. The committee included both university and non-university people. The leading spirit was the Harbourmaster at Port Adelaide, Alexander Inglis, but R.W. Chapman, lecturer in physics and later professor of engineering at the University of Adelaide, also played an active role in the work, and he and Inglis in due course jointly produced a number of published reports.[29]

Finally in this catalogue of observationally based research represented in the physical science program of the early AAAS congresses, a committee on 'Seismological Phenomena in Australasia' was established on the recommendation of Section A at the first, 1888 congress, and remained active for many years. The subject was of particular interest to investigators from geologically active New Zealand, where a seismograph designed locally by James Hector had been in operation in Wellington since 1884.[30] The committee's energetic secretary was a New Zealand schoolmaster, George Hogben, who co-ordinated a New Zealand-wide network of observers from his post at Timaru. Ellery, Russell and Todd were, however, all members of the committee, the recording of earth tremors been seen as yet another responsibility of the observatories they directed. Both the Melbourne and Sydney Observatories were equipped with early-model seismographs, a Gray-Milne instrument at Melbourne and a Ewing instrument at Sydney. Meanwhile, in Launceston a local bank officer, Alfred Barrett Biggs, who was also a member of the committee, recorded earth tremors on an instrument of his own design. In the late 1890s, the British Association for the Advancement of Science launched a campaign to establish an imperial network of seismographic recording stations equipped with stan-

27 '[Report of the Gravity Survey Committee],' *Proceedings of the Royal Society of Victoria*, 5 (1892), 218-21 and 6 (1893), 213-20; E.F.J. Love, 'Observations with Kater's Invariable Pendulums made at Sydney during January and February, 1894,' *ibid.*, 7 (1894), 1-18; *idem*, 'On the Value of Gravity at the Sydney Observatory,' *Journal and Proceedings of the Royal Society of New South Wales*, 28 (1894), 62-4.

28 Threlfall and Pollock, 'On a Quartz Thread Gravity Balance,' *Philosophical Transactions of the Royal Society of London*, *A*, 193 (1900), 215-57.

29 *AAAS Report*, 5 (1893), 277-79; *ibid.*, 7 (1898), 241-44; *ibid.*, 9 (1902), 67-8; Inglis and Chapman, *Australian Tides* (Adelaide, 1903).

30 R.M. Young, J.H. Ansell and M.A. Hurst, 'New Zealand's First Seismograph: The Hector Seismograph, 1884-1902,' *Journal of the Royal Society of New Zealand*, 14 (1984), 159-73.

dardized horizontal seismometers newly designed by the leading British authority on the subject, John Milne. In the following few years, Milne instruments were duly installed at the observatories at Perth (1900), Melbourne (1902), Sydney (1906) and Adelaide (1909), as well as in New Zealand. The observatory link was natural since the objective was to study the transmission of disturbances by recording exact times and phases of earthquakes as they were felt in different places. The Milne instrument had its limitations, however, and when in 1909 the Jesuit priest Francis Pigot installed horizontal and vertical seismometers designed by the German, Emil Wiechert, at Riverview College, a secondary school in Sydney operated by his order, this at once became (and for many years remained) the principal seismological observatory in the country.[31]

The early years of AAAS saw the various colonial observatories at the high point of their development. Even the smallest of them, the Adelaide Observatory, was as large as the largest of the university physics departments., and in the range of their research activities, they were able to dominate the Section A agenda. As a result, while the physics that was institutionalized in Australia at this period shared with the physics institutions of the major industrial countries of the Northern Hemisphere an emphasis on precision measurement as its defining characteristic, Humboldtian-style 'terrestrial physics' retained a much stronger presence than it did in those countries. More accurately, while the new-style laboratory physics found a secure footing in Australia during these years, it did not grow so rapidly as to overwhelm the terrestrial physics groups by sheer weight of numbers. Its failure to do so reflected fundamental features of Australian cultural and economic life that the country shared with Canada and indeed all but a very few of the most advanced nations at the time, namely a less developed university sector and a comparatively weak manufacturing base.

The great economic depression that overtook the Australian colonies in the 1890s had a devastating effect on both the observatories and the universities. Staffs and salaries were cut and programs wound back. The observatories were, however, indisputably the biggest losers, for much of the staff lost were never replaced. Instead, some of the programs that had generated their greatest public support were removed from them. The introduction of standard time throughout Australia in 1895 meant that local observatories were no longer required to provide a local time service.[32] In the more populous colonies in the south-

31 E.F. Pigot, 'Note on the New Wiechert Seismometers at Riverview College, Sydney,' *Journal and Proceedings of the Royal Society of New South Wales*, 43 (1909), 388-93; Pigot and L.A. Cotton, 'Seismology in Australia,' *Proceedings of the First Pan-Pacific Scientific Conference, Hawaii, 1920*, Vol. 2, 409-10; Lewis Pyenson, *Cultural Imperialism and Exact Sciences: German Expansion Overseas, 1900-1930* (New York: Peter Lang, 1985), 79-80.

32 Graeme Davison, 'Punctuality and Progress: the Foundations of Australian Standard

east of the continent, the basic topographical surveys were more or less completed and no longer needed to employ the large staffs that they once had.[33] Worst of all, following the federation of the Australian colonies in 1900, the meteorological work of the observatories, on which so much of their public reputation had rested, was in 1908 transferred to a new federal agency, the Commonwealth Bureau of Meteorology.[34] The observatories went into a steep decline from which they never recovered, and the emerging Australian physics community lost its major institutional base.

Despite this, the balance between terrestrial and laboratory physics did not tilt noticeably towards the latter at this time. The universities were also hard hit by the depression, and afterwards the revival of their physics departments was hampered by the introduction of new schemes that resulted in a steady drift of the best students to Britain for their research training.[35] Bragg's brief flurry of activity in Adelaide aside, it was not until the 1920s that university-based laboratory physics began a new phase of expansion, and by then the terrestrial physics tradition had also gained a new lease of life.

By the 1920s, however, meteorology, a generation earlier the most glamorous and rapidly advancing branch of terrestrial physics, had effectively left the fold. The seeds of its doing so may be seen in the very developments that brought the field its initial successes. Simply to gather reliable raw data out of which useable synoptic charts might be constructed demanded an enormous investment in time and effort. In the 1880s and '90s, in Australia as in many other countries, government meteorologists—including the observatory directors Ellery, Russell and Todd — found themselves transformed into meteorological bureaucrats, responsible for maintaining and extending the networks of observing stations and strengthening routines for mapping the data received and preparing and issuing forecasts. Instead of promoting research into the underlying physical processes of the atmosphere, they focused increasingly on a much more mechanical search for recurring patterns on the charts that could be linked with particular weather patterns for the purpose of forecasting. Unfortunately, in Australia the various colonial observatories were not only the dominant institutions in the field of meteorology, they were the only ones. When they became preoccupied with forecasting—which they were under considerable pressure to do, since this was the purpose for which their meteorological work was funded by their respective governments in the first place—there was simply no-one else to take up the deeper research agenda that

Time,' *Australian Historical Studies*, October 1992, 169-91.

33 Baracchi, *op. cit.* note 11, 170.

34 Home and Livingston, *op. cit.* note 15.

35 R.W. Home, 'The Beginnings of an Australian Physics Community,' in Nathan Reingold and Marc Rothenberg (eds),' *Scientific Colonialism: A Cross-Cultural Comparison* (Washington, DC: Smithsonian Institution Press, 1987), 3-34.

continued to be pursued in some other parts of the world. Paradoxically, therefore, in Australia the very success of the new meteorology served to take much of the research impetus from the field. When in due course the whole program was taken over by the Commonwealth Bureau of Meteorology, the science found itself not only with an agenda that had become largely disconnected from questions of physics but institutionalized in a separate and self-contained agency. At this point, physics and meteorology effectively parted company in Australia. Only during the brief period in the 1920s when the Bureau maintained a Research Division were some of the traditional links restored. Significantly, even then it was only staff of the Research Division (and particularly its director, Edward Kidson) who established links with the physicists. The rest of the Bureau's staff remained apart.

Until the 1920s, the AAAS meetings remained effectively the only occasions that brought the nascent Australian physics community together;[36] and when the Association went into recess for the duration of the First World War, even these opportunities disappeared. The post-war period saw an additional institutional form emerge in which Australian physicists rode on the coat-tails of a new British organization, itself a product of the unsatisfactory experience of British physicists during the war, the London-based Institute of Physics.

In October 1923, A.D. Ross, professor of physics and mathematics at the University of Western Australia, began an energetic letter writing campaign with the object of improving 'the position of the physicist in Australia.'[37] He sought expressions of opinion on the desirability of forming a local section of the Institute of Physics in Australia, and information about the number of people qualified for membership of the Institute and the number of physicists employed by industry in each state. In line with the objectives of the founders of the Institute, Ross confined himself to professional issues, being concerned in particular with securing the status of the physicist in Australia at a time when secondary industry in the country seemed about to expand considerably. As he reported to T.H. Laby, the professor at Melbourne:

> All those who are specialising in Physics seem to be keen on some organisation which will be instrumental in emphasising the status of the profession, and the necessity of seeing that as the secondary industries develop physicists should be placed in them where they are likely to be helpful.

36 The 1914 Australian meeting of the British Association for the Advancement of Science appears not to have functioned in the same way to bring the Australian scientific community together. The meeting was a peripatetic one, with the large contingent of scientists from overseas convening in one state capital after another. Most local scientists seem to have stayed at home and waited for the meeting to come to them (*BAAS Report*, 84 [Australia, 1914], 686, 699).

37 The phrase comes from a letter dated 9 October 1923, copies of which Ross sent to the professors of physics in all the Australian universities; Australian Institute of Physics papers, Basser Library, Australian Academy of Science, Canberra.

Ross felt that by forming a branch of the Institute, the nation's physicists, despite their numerical weakness, could ensure that appropriate standards for recognition as a physicist were adopted in Australia, namely those set by the Institute itself in London. 'Such a Branch,' he felt, 'would carry considerable prestige when approaching the Commonwealth or State Governments or similar bodies on matters concerning physics and physicists.'[38]

Ross did not respond favourably to Laby's counter-proposal that an Australian Physical Society be formed that could arrange conferences and sponsor a journal, since this would be unable to impose qualifications standards for admission and would thus not enjoy the same standing in its dealings with governments; moreover, he deprecated the idea of launching yet another journal. Instead, with authorization from the Institute of Physics to act as 'Hon. Local Secretary for Australia,' he set about signing up as many members of the Institute as possible from among those in Australia who were qualified for admission. In addition, not seeing any possibility of bringing the group together at other times, he adopted the stratagem of calling meetings of the thus informally constituted local branch of the Institute — it was not given a formal constitution until 1939 — during AAAS congresses. It must have come as a considerable surprise to him when, commencing in 1928, the group began arranging its own conferences, in between the AAAS congresses. From the programs of these conferences and of the meetings of Section A at the AAAS congresses at this period, we learn that, in Australia at least, the physics discipline continued to embrace the field-observation program of terrestrial physics as well as the experimental physics of the university or industrial research laboratory — indeed, as remarked earlier, the terrestrial physics program gained a new lease of life at this period.

The first signs of new vigour in terrestrial physics were displayed at the 1921 AAAS congress, the Association's first meeting after the war. In addition to an unusually strong set of papers from the mathematicians, several of them associated with the world-wide upsurge of interest at this time in the theory of relativity, Section A featured two papers describing some of the work of an important new institution on the Australian physics scene, the Carnegie Institution of Washington. A decade earlier, as part of its self-imposed quest for greater understanding of the Earth's magnetic field, this private American research foundation had through its Department of Terrestrial Magnetism launched a general magnetic survey of Australia which included two major expeditions by camel through the interior of the continent by the senior officer of the Australian program, the New Zealander Edward Kidson, as well as a number of lesser journeys. Subsequently the Institution had erected a well equipped geomagnetic observatory at Watheroo, Western Australia. This commenced work in 1919 with Kidson taking over soon afterwards as observer-in-

38 Ross to Laby, 16 November 1923; Australian Institute of Physics papers, *loc. cit.*

charge. At the AAAS congress two years later, shortly before moving to the Bureau of Meteorology to become director of its short-lived Research Division, he reported on both the progress of the survey and the work of the observatory.[39]

The Watheroo Observatory was conceived of, by those responsible for both its establishment and its continued operation, as a wholly American institution, an outpost of the Department of Terrestrial Magnetism in the southeast Indian Ocean region. Despite this, the observatory soon took on something of a life of its own and gradually developed links with the Australian physics community.[40] In part, this was due to the support provided by A.D. Ross who, without any facilities for research at his fledging university in Perth, welcomed the prospect of having a major geophysical observatory near at hand, and sought actively to establish close connections with it. The staff at Watheroo also, however, contributed to the building of friendly relations. Kidson's presenting his reports at the AAAS meeting was an early instance of this. Another opportunity arose in 1926, when AAAS met in Western Australia for the first time. The observer-in-charge at Watheroo, the American H.F. Johnston, presented a paper on the observatory's work on atmospheric potential gradients, while J.E.I. Cairns, one of several young physics graduates of the University of Western Australia to work as an assistant at the observatory at this period, read two papers describing work he had been doing on the propagation of radio waves. Johnston likewise attended the following AAAS congress, held in Hobart in January 1928, and presented another paper on the potential-gradient work. On the latter occasion he was also able to visit the observatories in Melbourne and Adelaide and advise them on the magnetic recording work that by this time they were both doing.[41]

Cairns' research on radio had been encouraged by his superiors both for practical reasons, in the hope of improving the observatory's communications with headquarters in Washington, and because of its obvious links with the observatory's traditional field of investigation. Research related to radio propagation thereafter remained a feature of the observatory's work for many years, and in due course linked up with work being done elsewhere in Australia under the aegis of the Radio Research Board set up in late 1926 by the Commonwealth Government's newly created Council for Scientific and Industrial Research

39 *AAAS Report*, 15 (1921), 357.

40 R.W. Home, 'To Watheroo and Back: The DTM in Australia, 1911-1947,' forthcoming in Gregory A. Good (ed.), *The Earth, the Heavens, and the Carnegie Institution of Washington: Historical Perspectives* (Washington, DC: American Geophysical Union, 1994).

41 Johnston's having given a paper at the Hobart meeting is not mentioned in the official congress report, but he evidently told his headquarters in Washington that he had done so; see Carnegie Institution of Washington, DTM Directors' files (1904-1934), (IV), J.A. Fleming to J.C. Merriam, 29 February 1928.

(CSIR). In 1928 a directional atmospherics recorder on loan from CSIR was installed at Watheroo, and during the 1930s a formal agreement was struck with CSIR to exchange data on the varying height and structure of the ionosphere that was by then being generated by both sides, using automatic recording equipment. This work of data-recording was, in fact, a straightforward extension of the old Humboldtian research program in terrestrial physics into upper reaches of the atmosphere that could now for the first time be systematically investigated, using reflected radio signals. During the 1930s, ionospheric physics became one of the leading fields of research for Australian physicists. In due course, changes in the ionosphere were shown by the Australian, D.F. Martyn, and others to be linked directly with the changes in the Earth's magnetic field that were being recorded at Watheroo and elsewhere, and also with the occurrence of major flares on the Sun.[42]

It was perhaps symbolic that when in 1928 Australia's physicists held their first separate meeting, they met in the newly founded national capital, Canberra. It is certainly germane to the argument of this paper that the host institution on this occasion was not a university physics department — there was no university in Canberra in those days — but the likewise newly founded Commonwealth Solar Observatory, recently installed on nearby Mount Stromlo and already becoming another significant new centre for observational physics. In due course, its long-running program of recording solar disturbances was to play a key role in D.F. Martyn's successful analysis of the behaviour of the ionosphere.

The program for the Canberra meeting also gives a good indication of the major emphases in Australian physics at the time.[43] Like the programs of Section A at AAAS congresses at this period, it reveals a definite increase in the amount of laboratory physics research being done, following a modest expansion in university physics departments during the preceding few years. It also, however, reveals a continuing if no longer predominant presence of observationally based terrestrial physics. Eleven of the twenty 'work in progress' reports presented originated from physics departments in higher educational institutions. One of these was devoted entirely to theoretical computations, and a second to a field survey of the signal intensity deriving from a Melbourne commercial radio station; but all the others reported laboratory-based experimental investigations of one kind or another. So, too, did two papers on spectrometry originating from the Mount Stromlo Observatory, while three others from Observatory staff reported photometric and astrophysical measure-

42 D.F. Martyn, 'Tidal Phenomena in the Ionosphere,' *U.R.S.I. Special Report*, no. 2 (1950); H.S.W. Massey, 'David Forbes Martyn,' *Biographical Memoirs of Fellows of the Royal Society of London*, 17 (1971), 497-510; Home, *op. cit.* note 13.

43 *Conference of Australian Physicists, Canberra, 15th to 18th August, 1928: Proceedings and Abstracts of Papers.*

ments. One paper from Mount Stromlo and the two contributed from Watheroo were much more Humboldtian in orientation, being concerned, as H.F. Johnston's earlier presentations to Section A had been, with the recording of atmospheric electrical potential gradients. Finally, there was one paper on a purely astronomical topic, the director of the Sydney Observatory, James Nangle, reporting on the stage that had been reached with the section of the great astrographic chart of the heavens that was his observatory's responsibility.

More striking, from the point of view of this paper, are the topics set for the three discussion sessions that provided the main focus for the conference. One of these was devoted to 'the new quantum theory,' and in fact constituted the first public airing of quantum mechanical ideas in Australia. Another saw T.H. Laby lead a discussion of the prospects for radio research in Australia. This was evidently inspired by the CSIR's decision to establish the Radio Research Board, and marked the emergence of radio and the ionosphere as a major field of investigation within Australian physics. While Laby in his introductory remarks mentioned research that needed to be done on developing techniques of high-frequency measurement and on the design of transmitting and receiving stations, he especially drew attention to the need that he saw for 'observational data on the propagation of waves in Australia and the incidence of atmospherics,' that is, for a program of observational data recording in this new field of terrestrial physics. It was to precisely this kind of work that he put the Radio Research Board group that was set up in his department soon afterwards.[44]

The third discussion session was even more revealing of the continuing strength of the terrestrial physics tradition in Australia at this time, being devoted to the question of geophysical prospecting. It was prompted by the launching in Australia, shortly before, of an imperial initiative, the Imperial Geophysical Experimental Survey, the aim of which was to undertake field trials of various geophysical methods — gravimetric, magnetic, electrical and seismic — of prospecting for minerals. Here again, then, we see the classical Humboldtian emphasis on precision physical measurement applied in an observational context, though applied now with new instruments of a sensitivity and accuracy that Humboldt would not have dreamed possible, to issues of immediate economic importance.[45] From an institutional point of view, once again no clear lines of demarcation were drawn, with several members of university physics departments becoming involved in the work. E.H. Booth from the

44 W.F. Evans, *History of the Radio Research Board, 1926-1945* (Melbourne: CSIRO, 1973).

45 A.B. Broghton Edge and T.H. Laby (eds), *The Principles and Practice of Geophysical Prospecting; being the Final Report of the Imperial Geophysical Experimental Survey* (Cambridge, 1931); Barry W. Butcher, 'Science and the Imperial Vision: The Imperial Geophysical Experimental Survey, 1928-1930,' *Historical Records of Australian Science*, 6 (pt. 1), (1984), 31-43.

physics department at Sydney was in charge of the seismic program, and T.H. Laby was eventually persuaded to become consultant physicist to the Survey and joint editor of the its final report following the sudden and unexpected death of the assistant director, the Canadian geophysicist E.S. Bieler.

A second conference of this kind was held a year later, in Melbourne. Those attending came from a similar range of institutions, and the program covered a similar range of topics. It is thus clear that, from both an institutional and an intellectual point of view, the physics discipline in Australia continued to include, on a more or less equal basis, laboratory-based experimental work, almost all of it done in universities, and traditional observatory-style data recording and analysis of geophysical variables. To be sure, the university laboratories were now somewhat stronger than the observatories, so that the experimental approach now tended to predominate whereas, a generation earlier, the reverse had been the case. The difference was, however, a matter of degree only, not a difference in kind: the physics discipline had not redefined its boundaries to any significant extent in the meantime.

It follows that in studying the historical development of physics as either a profession or a discipline in Australia, it would be a mistake to confine our attention to the narrowly defined laboratory-based experimental style of work that conforms with current notions of what physics is. It would likewise be a mistake to confine our attention to the institutions that support such work. Instead, we need to pay attention to the way in which, at different times and places, those involved have either explicitly or (more often) implicitly sought to draw boundaries between what they regarded as their scientific field and others. Sometimes, as with Humboldt himself, the boundaries were drawn wide for conceptual reasons; at other times, as in Australia during the period we have been discussing, at least part of the reason for doing so was a purely pragmatic concern with the small numbers of workers involved and a desire to form a group of a viable size. In either case, however, the consequence for the historian is the same: the science of physics, in its evolution in Australia, included and for a time was dominated by a great deal of work of a non-experimental, data-recording kind, much of it done in institutions other than laboratories. If we do not include in our analyses the people doing this work and the institutions that supported them, we shall gain a very misleading impression of what was going on.