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Résumé de l'article

George Christian Hoffmann, d'origine allemande, est né à Londres. Il a étudié à la Royal School of Mines et a travaillé à Londres comme analyste chimique avant de se lancer dans une carrière qui l'a mené au Natal, dans le sud-est de l'Afrique, à Melbourne, dans la colonie australienne de Victoria, puis au Canada, où il a eu une longue carrière au sein de la Commission géologique du Canada (CGC); il en est devenu le directeur adjoint en 1880, et a pris sa retraite en 1907. À la Commission géologique, il déterminait la composition chimique d'échantillons minéraux recueillis ou reçus par la CGC et définissait ainsi leur identité, et en évaluait le potentiel économique.

Practising Chemistry in the British Empire: George Christian Hoffmann (1837–1917) and the Geological Survey of Canada

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Abstract: *George Christian Hoffmann, of German extraction, was born in London. After studying at the Royal School of Mines and working in London as a chemical analyst, he set out on a career that took him to Natal, in south-east Africa, to Melbourne in the Australian colony of Victoria, and to Canada where he had a long career with the Geological Survey, becoming Deputy Director in 1880 and retiring in 1907. In his work with the Geological Survey, he determined the chemical composition and identity of mineral samples collected by and submitted to the Survey, assessing their economic potential.*

Résumé : *George Christian Hoffmann, d'origine allemande, est né à Londres. Il a étudié à la Royal School of Mines et a travaillé à Londres comme analyste chimique avant de se lancer dans une carrière qui l'a mené au Natal, dans le sud-est de l'Afrique, à Melbourne, dans la colonie australienne de Victoria, puis au Canada, où il a eu une longue carrière au sein de la Commission géologique du Canada (CGC); il en est devenu le directeur adjoint en 1880, et a pris sa retraite en 1907. À la Commission géologique, il déterminait la composition chimique d'échantillons minéraux recueillis ou reçus par la CGC et définissait ainsi leur identité, et en évaluait le potentiel économique.*

Keywords: Chemistry; Analysis; Phytochemistry; Minerals; Geological Survey of Canada

MANY NATIONAL AND STATE GEOLOGICAL SURVEYS were established in the nineteenth century, explicitly to support the mining industry through scientific study of the geology of the region and the nature of its rocks and minerals. Canada's geological survey was one of the earliest, being established in 1842 under the direction of geologist William Logan (Sir William from 1856) (1798-1875).¹ In 1846 the Survey appointed Thomas Sterry Hunt (1826-1892)² as chemist and mineralogist. Hunt, an American from Yale, had learned his mineral chemistry while working with the Silliman's, father and son, after his graduation as a medical doctor. Appointments like that of Hunt recognized that the complementary skills of geologists, mineralogists and chemists were needed for a full understanding of minerals, particularly those of economic importance such as metal ores.

There is a long history of the involvement of chemists in mineralogical work, and indeed there had been a reciprocal relationship between the mining industry, which needed chemistry to guide important aspects of its work, and the field of chemistry that was developing an understanding of materials as composed of combinations of elements. In the eighteenth century, the investigation of the

chemistry of mineral chemistry was a major activity of the Swedish Bureau of Mines, and Hjalmar Ford has written extensively about the role of chemists at the Bureau of Mines who brought together academic chemistry, natural history, and artisanal practices that amounted to building a bridge from ‘chymistry to chemistry’.³

Schools of Mines offered training in assaying chemical analysis of minerals, especially ores and those containing precious metals such as gold. Their graduates found employment with mining companies, in technical institutions and with government agencies like geological surveys. As with Hunt’s employment by the geological Survey of Canada, the British Geological Survey, which began under the leadership of geologist Henry de la Beche in 1845 (after a tentative beginning in 1835 under Ordnance Survey),⁴ immediately appointed Lyon Playfair (1818-1898) as chemist.⁵ Similarly, the US Geological Survey, founded in 1879⁶ sought applicants with knowledge of mathematics, physics, chemistry, geology and mineralogy and appointed Andrew A. Blair, an expert in chemical analysis of iron and steel, as their first chemist.⁷

In Canada, in 1869 Logan was succeeded by Alfred Selwyn,⁸ British born and trained in the British Geological Survey under the direction of Henry de la Beche (1786-1855). He had left in late 1852 to take up appointment as geological surveyor for the colony of Victoria at the time of the first gold rushes in the Australian colonies, and later became Director of the Geological Survey of Victoria.⁹ When the Victorian survey was closed down in early 1869 due to lack of funds, and Selwyn’s appointment was terminated, he was on the point of accepting the directorship of the Geological Survey of Canada, a position made available by the retirement of Sir William Logan. As well as welcoming “imports” like Selwyn, Canada was in advance of other British dominions in developing chemistry schools where local students could take baccalaureate degrees in which chemistry was often associated with geology. John William Dawson (1820-1899), born in Nova Scotia, studied both subjects in Edinburgh before returning to Canada where he became Principal of McGill in 1855. Hoffmann’s colleague at the Geological Survey, Canadian-born Bernard Harrington (1848-1907), was a graduate of McGill (BA 1869) and Yale (PhD 1871)¹⁰. Another was Henri-Marc Ami, born in Geneva of Swiss parents, immigrating with them to Ottawa in 1862. He studied at McGill under Dawson, graduating with an MA and DSc in 1882, before joining the Geological Survey.

Chemistry and associated fields like mineralogy in Canada benefitted greatly from the influx of graduates from Britain and the opportunities for Canadians to study in the United States, Britain and Europe before returning to take up appointments at home.¹¹ Some of the “imports from Britain” arrived by circuitous paths, and the career of George Christian Hoffmann shows how one chemist made his way from the Royal School of Mines through British colonies in Africa and Australia to end up with a substantial career in Canada. Demonstrated expertise, personal networks, and the development of science and technology in the British Empire saw him on his way.

George Christian Hoffmann: birth and family

Hoffmann's father, George John Hoffmann (1801-1874), was born in Cassell, Hesse, in Germany. He trained as a brewer and migrated to England to take up a post as master brewer. English breweries hired chemists trained in German laboratories, more for their chemical expertise than their knowledge of traditional German brewing technology. Lager beers in the German style became popular in England only later in the nineteenth century.¹² In 1825 George married Elizabeth Hurst (1797-1857) and their sixth child, George Christian, was born in London on 1 September 1837.¹³ Christian Hoffmann, as he was generally known, was educated at home and in private academies in England, but the family kept their German connections alive by sending him to Darmstadt for private tuition under Hofrat (Aulic Councillor) Friedrich Haas, who was Professor in the Gymnasium at Darmstadt, then at the Grossherzogliche Provinzial-Realschule, and finally at the Provinzial-Realschule in Darmstadt.¹⁴

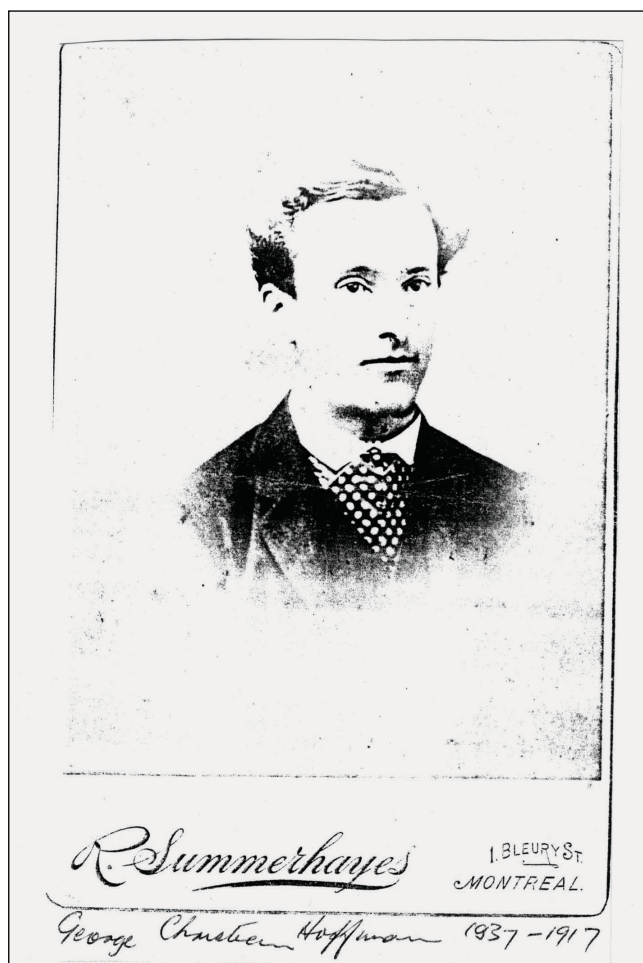


Figure 1. The young George Christian Hoffmann (courtesy of the Hoffmann family).

Royal School of Mines

The Royal School of Mines in London, founded in 1851 by geologist Henry de la Beche, later merged with other institutions to become, in 1907, the Imperial College of Science and Technology, part of the University of London. According to the Royal Society of Canada obituarist, Hoffmann entered the Royal School of Mines in 1853, taking courses in chemistry with Professor A. W. Hofmann¹⁵ and in metallurgy, mining and mineralogy, physics, geology, natural history, applied mechanics, and assaying.

The records of the Royal School of Mines show his enrolment as a ‘matriculated’ student in 1853-1855, attending classes six days a week.¹⁶ His name is not on the list of undergraduates and graduates¹⁷ and nor does it appear in the school’s register of old students.¹⁸ Students at the Royal School of Mines were classified as ‘matriculated’ or ‘occasional’, those in the former group proceeding to formal qualifications after three years of study, but Hoffmann appears not to have formally graduated after course completion, but instead taken selected courses that would fit him for employment in particular fields. In 1856-1857 he was an ‘occasional’ student while working as a private assistant with A. W. Hofmann. To be employed by Hofmann as a junior assistant and later a research assistant at the Royal College of Chemistry, he must have been well regarded as a laboratory chemist. Hoffmann was not a co-author of any of the work that A. W. Hofmann published in the *Quarterly Journal of Chemical Society* and nor was his assistance acknowledged as was that of more senior assistants such as Peter Griess.

Hoffmann left England in May 1861 and travelled to Natal, a small British colony in south-east Africa,¹⁹ where he worked with R. J. Mann, superintendant of education in Natal and honorary secretary to the Natal Commission. Hoffmann had been engaged to arrange the material displayed by the colony at the International Exhibition held in London in 1862, but his contribution was not acknowledged in the exhibition catalogue.²⁰

It is not known what else Hoffmann did in Natal, but he spent several years there, and the colonial economy had a heavy basis in plant-derived materials so he may have exercised his chemical skills in investigations of plant products. It is known that he visited Mauritius, 2500 km away in the southern Indian Ocean, to familiarize himself with the flora of that island, and from there travelled to Melbourne in *Hannah Nicholson*, one of the ships travelling regularly between Melbourne, Mauritius, Natal and the Cape of Good Hope in support of the reciprocal trade in sugar and phosphate fertilizers between Melbourne and Port Louis, Mauritius.

Melbourne and the Phytochemical Laboratory

Hoffmann arrived in Melbourne in October 1865 and was soon employed by the Director of the Melbourne (later Royal) Botanic Garden, Ferdinand Mueller (1825-1896)²¹ to work in the laboratory he had established for the investigation of plant products that might have commercial uses. Mueller was born in

Mecklenburg and qualified as a pharmacist and chemist in Schleswig-Holstein, later completing his PhD at the University of Kiel and arriving in Australia in December 1847. He was appointed Government Botanist in the colony of Victoria in 1852 and Director of the Botanic Garden in 1857. Although the operation of the phytochemical laboratory was sanctioned by his employers, since it concerned economic botany, no designated funding was provided for it and Mueller had to fund it as best he could out of the annual grant. A typical consequence of his ingenuity was that Hoffmann was employed as a gardener, although his real job was in the laboratory. Hoffmann's work there has been covered in detail in our earlier publication.²² Briefly, it involved the dry distillation of wood yielding acetic acid; the composition of wood ash; preparation of paper from various plant materials; plant resins and tannins; and the isolation and examination of volatile essential oils, especially those of *Eucalyptus* species.

In the late 1860s Hoffmann was thinking of moving on, and Mueller, recognizing that he sought a higher position, wrote a testimonial in which he praised Hoffmann's "great skill, much circumspection and scrupulous accuracy" and his ability to find "many references in the extensive chemical and technological literature of several nations not otherwise equally accessible to others".²³ It was not clear where Hoffmann might have been seeking "a higher position" but if it were in Victoria it would seem that he was unsuccessful because in 1871 he returned to London, leaving Melbourne in February, with the intention of studying medicine at a German university.²⁴ The fact that he did not take this course may have been due to tensions between France and Germany that had led to the Franco-Prussian war and remained unresolved, even after the Truce of Frankfurt in May 1871. Whatever the reason, he turned his face in the opposite direction, crossing the Atlantic to America. He found no suitable position there, but moved to Canada where he was employed as a chemist in Toronto and Montreal before being employed by the Geological Survey of Canada in Montreal.

Hoffmann at the Geological Survey of Canada

On 5 January 1872 Hoffmann wrote from Toronto to Alfred Selwyn, Director of the Geological Survey of Canada, seeking advice about employment in Canada and obviously (although Hoffmann's letter has not been located) asking about openings at that institution. Hoffmann and Selwyn would have been known to each other since they had been members of the relatively small scientific and technical community in Melbourne in the late 1860s. Selwyn replied a few weeks later,²⁵ offering sympathy but no opportunities for employment at the Survey, nor with a manufacturing chemist in Montreal whom he had asked. He did, however, mention that his brother, Captain Selwyn RN, was a consultant to some large mining operations in Utah Territory, US, and might have openings for young analytical assayers. He promised to let Hoffmann know of any opportunities and offered to meet should he be visiting Montreal. Hoffmann's approach to Selwyn led eventually to success. In September 1872 he was

appointed as Assistant Chemist. Selwyn wrote to Mueller two months later to say that “your late chemical assistant Mr Hoffmann is now in our laboratory.”²⁶ The opportunity to make such an appointment probably arose when Sterry Hunt left to become professor of geology and mineralogy at the Massachusetts Institute of Technology: Hoffmann served under Hunt’s successor Bernard Harrington. In 1879 Harrington returned to a teaching position at McGill and Hoffman was promoted to a leading position as Chemist and Mineralogist, as a consequence of which Selwyn wrote again to Mueller that Hoffmann “now presides in our laboratory”²⁷ and later that he was “quite well and sends his regards”.²⁸

Hoffmann was a versatile chemist: his work at the Geological Survey involved rocks and minerals, and represented a transition from the organic chemistry of London and the phytochemistry of Melbourne into assaying and therefore a concentration on inorganic chemistry. As a student at the Royal School of Mines he would have attended lectures on mineralogy by Sir George Stokes and he had taken a special course on assaying under Dr John Perry. He was quickly absorbed into the scientific community in Montreal, where the Geological Survey was based, but in a last gesture to his career in phytochemistry, in early 1873 he spoke about his previous experience in a paper on Australian eucalypts that he read to the Montreal College of Pharmacy.²⁹ Drawing on his Melbourne years with Mueller, he made specific mention of the medicinal properties of the gum resins and essential oils of the eucalypts. He also showed results of his wood distillation experiments, and the tannic and gallic acids from the bark of the eucalypts. His paper gave details of yield, specific gravity, boiling range, taste and odour of the oils from thirteen species of eucalypt; their suitability as oil for illuminating lamps; and their power as solvents for resinous materials such as rosin, asphalt and beeswax. Although his work at the Geological Survey lay in quite different fields of chemistry, Hoffmann evidently maintained his association with the pharmacists, who appointed him to an honorary membership of the Pharmaceutical Association of the Province of Quebec in 1885.

Hoffmann’s work at the Geological Survey

At the Survey, Hoffmann was mainly confined to the laboratory, analyzing the samples brought in by field geologists who had often made preliminary identifications, subsequently to be confirmed by chemical analysis. His results were included in the annual *Reports of the Geological Survey of Canada* in the section entitled “chemical contributions to the geology of Canada”. The reports went into considerable detail, covering coal from eastern Canada (1873-4); graphite and orthoclase (1876-7); apatite (1877-8); and coals and lignites of the Northwest Territory (1882-3-4). In 1889 he published an annotated list of minerals found in Canada.³⁰ This drew largely on the work of his predecessors, notably Dr T. Sterry Hunt.³¹ It included 281 mineral species and varieties, mentioned important locations where they were found, and in many cases described their properties and provided references to publications in which the minerals were described. In 1893 he produced a major work of 246 pages, a catalogue of Section 1 of the Museum of the Geological Survey of Canada.

Table 1. Analyses of platinum ores from several locations reported by Hoffmann

Constituent	British Columbia	Oregon	Australia	California	Colombia	Russia
Platinum	72.07	51.45	61.40	85.50	86.20	76.40
Palladium	0.19	0.15	1.80	0.60	0.50	1.40
Rhodium	2.57	0.65	1.85	1.00	1.40	0.30
Iridium	1.14	0.40	1.10	1.05	0.85	4.30
Copper	3.39	1.10	1.40	1.40	0.60	4.10
Iron	8.59	4.55	4.55	6.75	7.80	11.70
Gold	<i>Note 1</i>	1.20	1.20	0.80	1.00	0.40
Osmiridium	10.51	26.00	26.00	1.10	0.95	0.50
Gangue/Sand*	1.69	1.20	1.20	2.95	0.95	1.40

Note 1: Hoffman separated the small proportion of gold before conducting the analysis.

* This fraction contained 'imbedded chromite.'

Platinum

Perhaps the most significant analytical challenge that Hoffmann faced was from the ores containing platinum and kindred metals that were found in British Columbia, the platinum being in the form of grains of size 0.5 mm to 8 mm having a specific gravity of 16.656.³² The platinum metals were at that time the subject of great interest around the world; Hoffmann's predecessor Sterry Hunt had investigated platinum minerals found in the province of Quebec in 1851-2. In both cases the platinum was accompanied by alluvial osmiridium and gold, and the ore from British Columbia also contained magnetite and pyrite. Hoffmann reported analytical data for the Canadian samples and tabulated them [**Table 1**] with data for other platinum ores reported by Deville and Debray.³³

The Paris laboratory of Henri Étienne Sainte-Claire Deville (1818-1881) and Jules Henri Debray (1817-1888) had for several decades led the world in the art of analysing platinum and associated metals, and the results they reported came from samples submitted by mineralogists around the world. In their long 1859 article they reported analyses for three Colombian and three Californian samples, two each from Australia (the results of which were almost identical) and Russia, one from Oregon and one from Spain. They noted that the ores from Oregon and Australia contained comparably low proportions of platinum, but considerable proportions of osmium and iridium, 37.3% for Oregon, 25.0% and 26.0% for Australian ores.

It is likely that Hoffman would have used Deville and Debray's method, fire assay with lead as the collector, to begin the comprehensive analysis of the British Columbia ores.³⁴ The sequence of operations began with a mixture of the ore with lead, heated to a high temperature in a clay or bone-ash crucible in an oxidizing atmosphere. This is an ancient process known as cupellation, during which molten oxides are absorbed by the cupel. Lead oxide sequesters many of the impurities and the platinum metals remain as a button at the bottom of the cooled mass. This is broken up and treated with dilute hydrochloric acid that removes iron, lead, palladium and rhodium, although small quantities of these metals remain in the solid residue. This solid residue is boiled with *aqua regia* (a mixture of strong hydrochloric and nitric acids), taking the lead and platinum into solution and leaving iridium undissolved. Traditional analytical methods were then applied to the simplified mixtures. Lead was separated by precipitation as sulphate, and platinum as ammonium platinum chloride. In some forms of the assay the cupellation was conducted with silver or a mixture of lead and silver in the presence of borax, but the subsequent acid treatments and selective dissolution of the metals followed the same course. Although this method held sway well into the twentieth century, criticisms of it began in the late nineteenth century and Beamish provided a critical review of their accuracy.³⁵

Blowpipe Analysis

Once he became Assistant Director of the Geological Survey in 1882, Hoffmann was less involved in the laboratory work and in his publications he acknowledged other analysts employed by the Survey with whom he had collaborated. The first of these was R.A.A. Johnston whose work was acknowledged in an article reporting the identification of six Canadian minerals.³⁶ They had been examined by elemental analysis and by the use of the blowpipe, a technique in common use in mineral laboratories in the nineteenth century. Analysis of minerals by blowpipe had been developed by Swedish researchers in the mid-eighteenth century, notably by Axel Fredrik Cronstedt (1722-1765) who introduced the use of fluxes such as soda, borax or sodium ammonium phosphate (microcosmic salt).³⁷ Cronstedt's work was popularized by Torbern Olof Bergman (1735-1784)³⁸ and Jöns Jakob Berzelius.³⁹ By suitable breathing techniques, an analyst could direct a continuous stream of air through a flame so as to strongly heat the sample, usually contained in a depression in a charcoal block, under oxidizing or reducing conditions, and make deductions about which elements were present, based on vapour emissions, flame colours and the nature of residues.

Typical of Hoffmann's reporting of minerals' behavior under the blowpipe was that for lepidolite, a potassium fluoro-alumino-silicate that "fuses easily and with much intumescence to a light yellowish-brown glass, simultaneously coloring the flame intense carmine-red". A mineral judged to be a mixture of newberyite (a magnesium phosphate) and struvite (magnesium ammonium phosphate) that had been recovered from the tusk of a mammoth found buried



FIG. 7.

Figure 2. *The blowpipe in use with a Bunsen burner flame and a charcoal block from Kahlenberg and Walter, Qualitative Chemical Analysis, 1915. <https://catalog.hathitrust.org/Record/012154748>*

in the swamp adjacent to the Yukon River in the Northwest Territory, “imparts a green color to the inner flame”. Newberyite, as a product of bat guano, had been discovered in caves at Skipton, near Ballarat in Victoria, Australia, and named by von Rath in 1879 after the discoverer, James Cosmo Newbery, another member of the small community of scientists in Melbourne during Hoffmann’s time there.⁴⁰

Fusion on a carbon block under the action of the blowpipe was also instrumental in the identification of spodumene (lithium aluminium silicate), a mineral now much sought after in the twenty-first century as a source of lithium. It “swells up and fuses ... to a white glass, imparting at the same time a bright purplish-red color to the flame”, that is typical of the element lithium. Likewise uranophane (a calcium uranium silicate) “affords with salt of phosphorus, in the oxidizing flame, a yellowish green bead, which, on reheating in the reducing flame, assumes a fine green color”, quite typical of uranium minerals. The analyst F.G. Wait was also acknowledged in this article for his analysis of a mineral rich in titanium, a silicate of the garnet group that the Canadians iden-

tified as schorlomite, collected at Kicking Horse Pass in the Rocky Mountains of British Columbia. Johnston's analyses were also critical in the identification of datolite (a calcium borosilicate).⁴¹ Under the blowpipe, a sample fused "with a slight intumescence, at about 2⁴² to a clear glass, simultaneously coloring the flame yellowish green" that we can attribute to the presence of boron. Hoffmann's identification of another mineral from the same Quebec mine as faujasite (a complex sodium calcium aluminosilicate) was tentative.

Using the blowpipe, a chemist or assayer could make a qualitative analysis of a mineral, to be followed up if necessary by further analyses. If discrete crystals were available, this would include crystallographic examination "crystallography" in that era being the study of the crystal faces and the angles between them, or chemical analysis for the specific elements whose presence had been revealed by the blowpipe. Blowpipe analysis formed part of the practical curriculum in chemistry and geology (mineralogy) in universities and technical institutions such as mining academies until well into the twentieth century, and numerous books on the technique are still held in their libraries.

Iron Minerals

F.G. Wait also analyzed a nickel-iron alloy recovered during gold dredging operations in western Canada.⁴³ After separating from other minerals, including gold and platinum, the analysis showed 76.48% nickel and 22.30% iron, making it significantly different from iron-nickel alloys occurring naturally in New Zealand (awaruite) and Italy. Hoffmann suggested that the new mineral be named souesite after Mr F. Soues, who had provided the sample. Awaruite (FeNi_2) is recognized as a mineral species and souesite is described as a similar material.⁴⁴

Some of the work reported annually by the Geological Survey was also published in the *American Journal of Science* and in the *Proceedings of the Royal Society of Canada*, of which Hoffmann had become a Fellow when the Society was founded in 1882. The first of these was about native platinum (discussed above), and it was followed closely by fossil fuels, an annotated list of Canadian minerals and an investigation of some unusual specimens of metallic iron.⁴⁵ The elemental iron was found as small spherules (not exceeding 370mm in size) in limonite (iron oxide) deposits in fissures in a quartzite rock stratum. Analysis showed 88.60% iron with small amounts of other metallic elements and 9.76% of siliceous material. There was 0.96% of phosphorus that was probably responsible for a 'phosphoretted odour' observed when the spherules were exposed to dilute hydrochloric acid. Microscopic examination of split spherules showed that each had a siliceous nucleus, suggesting that it had been formed by concretion as limonite was reduced by organic matter. The very low proportion of nickel in the spherules (0.10%) also argued against a meteoric origin for the iron.

From about the turn of the century Hoffmann's publications were also abstracted by a leading international journal that would have brought his work to the attention of European readers. See, for example, his work on the rare mineral chromopicotite, a form of picotite (chrome-spinel) that has a composition within the range indicated by the chemical formula $(\text{Mg,Fe})\text{O} \cdot (\text{Al,Cr})_2\text{O}_3$.⁴⁶

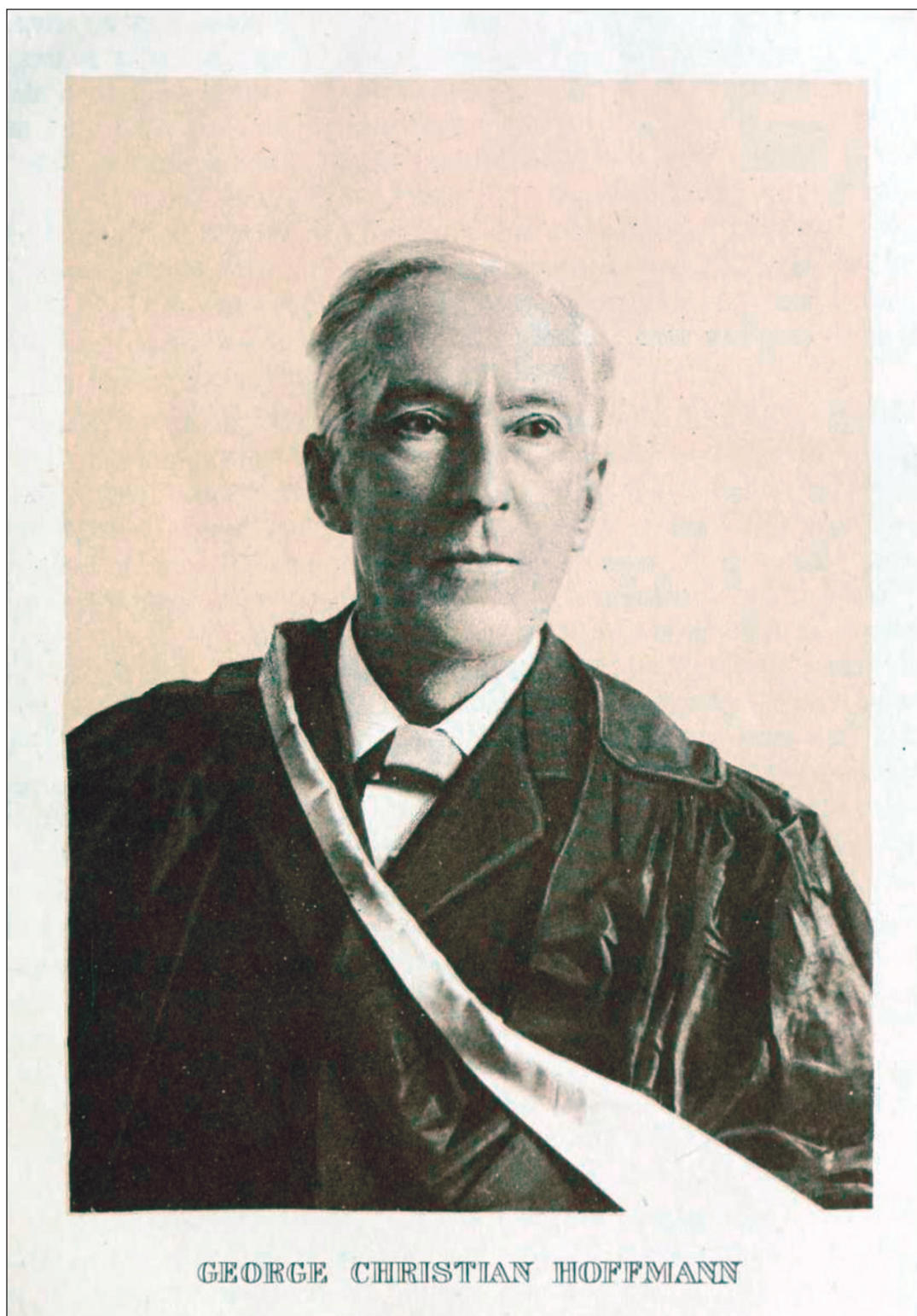


Figure 3. Hoffmann in Queens University academic regalia from his obituary in *Proceedings and Transactions of the Royal Society of Canada*, Series 3, no. 11 (1917). <https://www.biodiversitylibrary.org/item/41905>

Coal

Although Selwyn's personal interest in geology pertained to stratigraphy, especially of older rocks, as Director of the Geological Survey "he always emphasized the economic side of the science of geology without, however, ignoring the claims of original research".⁴⁷ Under this heading, Hoffmann investigated the properties of 72 coal samples obtained from about 40 locations across the country.⁴⁸ The samples were finely ground and dried by storing in a closed system with a drying agent (concentrated sulphuric acid) for 354 hours. Most loss of mass was observed in the first 48 hours. Lignites, lignitic coals and coals including anthracite lost, respectively, 16-20, 4-8 and 2-3% of their weight when dried in this way, most of which was regained when the dried material was re-exposed to a moist atmosphere.

Hoffmann: personal and professional

Hoffmann was a founding member of the Royal Society of Canada's Section IV (geological and biological sciences) when it was formed in 1882. His standing in the international scientific community was indicated by his election as a Fellow of the Institute of Chemistry of Great Britain and Ireland in 1879, and in 1888 as a Member of the Mineralogical Society of Great Britain and Ireland.

In 1895 Queens University in Kingston, Ontario, conferred upon him the degree of Doctor of Laws *honoris causa*. His association with the university is unknown, but he did leave a substantial bequest (\$35,000) to the medical faculty on his death in 1917, sufficient to provide for Fellowships of \$1300 for research in pathology and \$1000 for extended studies in surgery. The Fellowships were to be awarded annually to Queens graduates, and the holders were required to study in Europe or the United States of America where facilities for post-graduate research were more advanced than those in Canada.

Hoffmann retired in 1907 after 35-years service, but continued to live in Ottawa (where the Geological Survey had relocated in 1881), until he died in 1917 and was buried in Beechwood National Cemetery.

Conclusion

There are three aspects of Hoffmann's career that enable us to place him in an international context of the history of science and in particular of analytical and investigative chemistry. The first of these is the way that chemical expertise and professional elites moved from Germany to England. The case study of this aspect was the migration of Hoffmann's father from Germany to practice his profession in England, while retaining links that enabled the Hoffmann's to send their son "home" to Darmstadt for education. The very foundation of the Royal School of Mines in London, where Hoffman studied, had been stimulated by Britain's sense that it was being left behind. And the leadership provided there by A. W. Hoffman, who was called from his homeland (and later returned there), is a potent indication of this Anglo-German link.

This leads to the second aspect, the power of the Royal School of Mines to train students in practical disciplines such as mining and applied chemistry,

equipping them to work in Great Britain or, more often, to leave and work abroad. Employment opportunities arose in colonial countries that drew professionals to their settler societies to take up positions in their universities, industries, and government institutions. The latter two destinations particularly attracted chemists who were members of the Institute of Chemistry (of which Hoffmann was a Fellow). The bias to Empire countries was most evident in the early years (1887-1917) for which data on the careers of those with the FIC postnominal were analyzed.⁴⁹ The Royal School of Mines had a special role in the generation of this diaspora. In MacLeod's analysis of the places where the graduates ("associates") of this institution pursued their careers, he found that of those graduating in the period 1851-1920 for whom data were available, 17% went to the United States and Canada, 10% to Australia, 19% to South Africa and other African colonies, while 34% remained in Great Britain.⁵⁰ Such an associate might work in many countries, some as many as ten, and MacLeod described these cohorts as "a crimson thread of kinship tied to imperial loyalties" tracing "lines of radiation along which tradition and practice have travelled." As we have seen, Hoffmann's trajectory within the empire took him to the colonies of Natal in southern Africa and Victoria in Australia, and finally to the newly confederated provinces of Canada. Chemistry and associated fields like mineralogy in Canada benefitted greatly by the influx of graduates from Britain and the opportunities for Canadians to study in the United States, Britain and Europe before returning to take up appointments at home.⁵¹

Finally, the second half of the nineteenth century, when Hoffmann pursued his career, was a period when chemistry was changing. It became gradually separated from physics, and as sub-disciplines like organic, inorganic and physical chemistry were becoming formalized. Chemists coming into the profession during that half century, more and more frequently specialized in a single branch of chemistry whereas previous generations had roamed widely. There are numerous examples in the history of chemistry and Hoffmann fits nicely into the old, undifferentiated category.⁵² According to the nature of his employment, he developed expertise in organic chemistry, working with A. W. Hofmann in London; phytochemistry with Mueller in Melbourne; and mineral chemistry (assaying) with the Geological Survey of Canada. In the last of these he made substantial contributions to chemistry in his adopted country.

*Ian Rae recognizes the assistance of Professor Victor Snieckus of Queens University, a good friend, colleague, and a champion of chemistry in Canada and Australia, who passed away in December 2020. Ian Rae is an Honorary Professorial Fellow in the School of Chemistry, University of Melbourne, Australia. He writes about the history of chemistry, concentrating on the nineteenth and twentieth centuries, developing Australian and international themes. His most recent publications are the chapters 'May Sybil Leslie and the Disintegration of her Element – Thorium' and 'Four Women Chemists Review the Elements' in **Women in Their Element**, eds. Annette Lykknes and Brigitte Van Tiggelen (2019). With Dr Sara Maroske, he is Editor of the Australian Academy of Science journal, **Historical Records of Australian Science**. <http://orcid.org/0000-0002-7579-3717>*

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