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CANADA'S METALS

With the authors
kindest remembrance

CANADA'S METALS

CANADA. GEOLOGICAL FEATURES

The Edinburgh Geographical Institute

John Bartholomew & Co.

CANADA'S METALS

A LECTURE

DELIVERED AT THE
TORONTO MEETING OF THE BRITISH ASSOCIATION
FOR THE ADVANCEMENT OF SCIENCE

AUGUST 20, 1897

BY

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PREFACE

THIS lecture was delivered during the Meeting of the British Association at Toronto under the presidency of Sir John Evans, and before His Excellency the Governor-General of Canada.

It was repeated recently, by the request of Sir Frederick Abel, at the Imperial Institute where the economic resources of the Empire are so fittingly represented. On that occasion the chair was taken by Lord Strathcona and Mount Royal, High Commissioner for the Dominion of Canada. It is published in accordance with a wish expressed by him, and the author feels it to be the privilege of one who loves the Dominion to insist on the mutual dependence of the Mother Country and her majestic Daughter. Hence the following attempt to make the mineral wealth of Canada better known.

W. C. R-A.

BLATCHFELD, CHILWORTH,
December, 1897.

LIST OF ILLUSTRATIONS

CANADA'S METALS

IN one sense Canada's metals do not differ from those of any other country, but in relation to our empire as a whole, the metals of the Dominion occupy a very distinct position. The title of this address was, therefore, chosen because the strength of a nation depends, in no small measure, on its metals, and it may be hoped that in the near future the mother country will turn to Canada, her eldest daughter, and the one who is nearest home, for the supply of those products of the metallurgic art upon which the material welfare and industrial progress of the empire must depend. Quite apart from imperial questions, it would be well to choose metals as the subject of this lecture, for, since the British Association met in Canada in 1884, the ancient love of the study of metals has revived, and they are now regarded with almost as much respectful admiration as they were in the middle ages.

I propose therefore—

First—To indicate the nature and distribution of Canada's mineral wealth; and

Second—To base the experimental illustrations which tradition prescribes for such a lecture as this, on the metal nickel, which is especially Canada's own.

That the task before me is no light one may be gathered from the fact that the area of the whole of British North America, that is, of Canada and Newfoundland, is about 3,617,000 square miles, an area somewhat greater than that of the United States of America with Alaska and slightly less than that of Europe. This vast continent of more than three millions and a half square miles, is rich from end to end in minerals. It will be well, therefore, at the outset to refer to those who have done so much to reveal stratigraphically the mineral wealth of the Dominion, for Canada has been splendidly served by the officers of her Geological Survey. Its first Director-General claimed, in a charming book on Acadian geology, that the name "Acadia," by which Nova Scotia and New Brunswick were formerly known, means "plenty here." This name is suggestive, and in connection with the metals distributed throughout the whole Dominion of Canada, a picturesque combination of words, which would mean "a region of plenty and abundance," might well have been adopted, for I shall have to speak of rich possessions.

Turn to the geological map[1] which, from ocean to ocean, embodies the results of the labours of Logan, of Selwyn, of Dawson, of Bell, and of many others whose names are as well known in England as in the Dominion. Guided by Dr. Dawson, Canada and Newfoundland may be divided into three parts, the eastern, central and western. The eastern division extends from the Atlantic to Lake Superior, and northward by the chain of lakes to the Arctic Ocean, near the mouth of the Mackenzie River. The central division extends from the western boundary of the eastern division to the base of the Rocky Mountains, and runs northward with narrowing dimensions to beyond the Arctic Circle, while the western division comprises all the territory, including the Rocky Mountains, to the Pacific. Reference to the sketch geological map will show the way in which the formations are distributed, and will render it unnecessary to say more than that the eastern division consists mainly of the very

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[1] The lecture was illustrated by a geological map which was specially prepared and was thirty feet long. A sketch map, showing the prominent features geologically coloured, is given as a frontispiece, for which I am indebted to Dr. Ramsay Wright and the local Executive Committee in Toronto of the British Association.

ancient Archæan and Palæozoic rocks, with some Laurentian, Permian and Triassic deposits. The great central division, on the other hand, is Cretaceous, approximating to the chalk period of Europe, the beds having been deposited horizontally and being scarcely disturbed. Passing to the western division, and taking the fiftieth parallel as a base, Palæozoic rocks are again met with, among which limestones predominate and exist as bold peaks of great beauty, ranging in height from 10,000 to 16,000 feet, and then, after descending the great valley, through which course the upper waters of the Columbia and its tributary, the Kootenay, the Selkirk range is reached, with rocks which appear to be Archæan.

Canada's principal metals are the following:—gold, silver, copper, nickel, lead and iron. Manganese, antimony, mercury, chromium and zinc,[1] are met with, and there is platinum with the associated

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[1] Of these metals the amounts actually extracted are inconsiderable. Of manganese some 386 tons were mined in 1883, and of manganese ore 1,194 tons. [Canadian Economics, British Association Meeting, 1884.] In 1896 the amount of chromite is given as 2,362 tons, and of manganese ore only 12 tons. *Mineral Statistics and Mines. Summary of the Mineral Production of Canada for* 1896, by Elfric Drew Ingall.

There is an excellent collection of minerals at Ottawa, and there is also one at the Imperial Institute, London, to which the Curator of the Canadian section, Mr. Harrison Watson, is constantly making additions.

metals of its group. There are the rarer metals such as molybdenum[1] which, though sparsely distributed in nature, seem to exert, when alloyed with other metals, an influence on their physical properties which is out of all proportion to the amounts of them which are present. Turning again to the geological map, the distribution of Canada's metallic wealth may be briefly stated as follows. The gold is, at present, mainly obtained from the provinces of British Columbia, Ontario, Nova Scotia and the new region in the North-West, the Yukon and the Klondike, to which the attention of the whole world has been directed so suddenly and so vividly, that many who have never thought of Canada in connection with mineral wealth, are dazzled by the reports which have been published, and forget that the search for gold in this inhospitable region must, in the coming winter, be attended by privation and death. In the province of Nova Scotia an early discovery of gold was made in 1860, and in 1867 alone, no less than £108,000 worth of gold was produced, and it is stated that there is now more technical skill and professional knowledge devoted to gold mining in this province than at any other period of its history. I have made this statement here because, in speaking of the Dominion generally,

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[1] I was shown, at Ottawa, some excellent samples of molybdenite from the township of Egan, about 20 miles north of Maniwanki.

it is rather of the richness of the deposits and of future prospects than of immediate output that I shall have to speak. It should, however, be borne in mind that since the last visit of the British Association to the Dominion, in 1884, its mineral production has nearly doubled. At the Imperial Institute I hope in the following winter to offer my countrymen some facts which will make the mineral wealth of the Dominion better known to them. The time has fully come when such knowledge should be widespread, for, as Professor Seeley points out, "if the Colonies are not, in the old phrase, possessions of England, then they must be part of England, and we must adopt this view in earnest."[1] Although it is already widely understood that Canada possesses great riches, we are apt to forget how recent the recognition of the extent and variety of her mineral wealth is, and how comparatively slow its development has been. This is due to many causes, one of which is that the early history of the western portion of Canada is closely interwoven with that of the "Company of Adventurers of England trading into Hudson's Bay," to give them the picturesque title in the Charta granted by King Charles II. in 1670 to a body of men who achieved results of which our nation has good reason to be proud, although

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[1] *Expansion of England*, by Professor J. R. Seeley, M.A., Macmillan, 1891.

their efforts were not directed to the development of the mineral industries. The early policy of this great company was to preserve forests in their primeval state, as the home of animals useful for their fur. Hence, to name only the smaller animals, the silver skin was more eagerly sought for than silver ore, and the fisher and fox than gold.

Some thirty years ago this policy changed; specimens of ore began to reach England, and in the year 1865 I received from Lord Strathcona, now Chairman of the Hudson's Bay Company and Canada's High Commissioner to the mother country, some samples of ore together with a chisel-shaped mass of copper. This was found near the Lake of the Woods, and had evidently been cast and fashioned by hand. I examined all the specimens with special interest, as they constituted absolutely my first metallurgical commission, and although there was not sufficient evidence to show whether the implement bore testimony to the local use of copper[1] in a pre-bronze age, there could be no doubt that the ore which was sent with it was valuable. I have mentioned this circumstance because it was typical of a changed order of things;

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[1] Dr. Selwyn states that native copper has been fashioned by hand and used by Indians in British Columbia from time immemorial. *Descriptive Catalogue of the Minerals of Canada.* Indian and Colonial Exhibition. London, 1886.

development became comparatively rapid, and when, in 1884, I visited the district in which the minerals had been found, there was at Rat Portage a population of some 870, destined to grow in the following decade to some 4,000, as a great trading and mining centre was established. Rapid progress was, however, not to be expected, for, favoured as Canada is for water transit by her magnificent network of lakes[1] and rivers, it was not until the continent was traversed from ocean to ocean by railway that the development of the mineral industries could be hoped for. In establishing the Canadian Pacific railway system the Hudson's Bay Company nevertheless played a very important part.[2] There is yet another reason why British efforts have slowly been directed to the mineral riches in Canadian territory. We in England are not as familiar as we should be with the real facts as to your beautiful climate, which is "hot in summer, cold in winter, always dry," as Sir Wilfrid Laurier has justly represented it to be. The descriptions of it are often inadequate, for even the poet of the Empire, the "interpreter of the nation," who sang for us the song of the English, and told

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[1] The geology of the northern portion of the Lake of the Woods is published in the *Annual Report of the Geological Survey*, 1885, vol. i. For geology of the Rainy Lake regions, consult *Report* by Andrew C. Lawson, M.A., Geological Survey, 1888.

[2] Paper by the Hon. Sir Donald A. Smith, G.C.M.G. (now Lord Strathcona), Colonial Institute, 1897.

us of the "swift shuttles of an empire's loom that weave us main to main," has identified Canada with "Our Lady of the Snows," though we must all wish he had dwelt on the fact that "a summer flush of tropics in her blood" reveals another phase of the Dominion's loveliness. This is true even in the far north, for if parts of the Yukon basin lie within the Arctic Circle, there is a warm and nightless summer in which time for mining and industrial work is doubled.

To return, however, to the consideration of the auriferous deposits of the Dominion. As regards the province of Quebec, Dr. Ellis pointed out[1] in 1890 that the gold fields of Quebec, although known for more than fifty years, have not attracted so much attention as their actual importance would appear to warrant. In the ancient channels of nearly every stream tributary to the Chaudière above St. Joseph, gold can be obtained in paying quantities if due precautions be observed as to management and appliances. In the province of Ontario, discoveries of gold-bearing veins have been made, over an area of some 2,000 square miles, through a tract 100 miles wide, and 200 miles long, but gold ore seems to be limited to Laurentian rocks of eruptive granite, and to Huronian beds of the Keewatin series. As

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[1] *Report on the Mineral Resources of the Province of Quebec*, by R. W. Ellis. LL.D. Montreal, 1890.

is pointed out in the *Report* of a Royal Commission on the mineral resources of Ontario,[1] the mineral wealth is enormous, and although the examination of the country is incomplete, enough is known to satisfy the careful observer that vast regions north of Lakes Huron and Superior, once believed to be an inhospitable waste of rock and muskeg, are possessed of an amount of mineral wealth which will probably make them the most valuable portions of this great province. For further information as to the gold-fields of Western Ontario, reference must be made to the excellent papers and reports by Professor Coleman,[2] who, in a late report,[3] pertinently observes "that the region is not an inaccessible desert, nor covered with malarious swamps, nor cut off from civilisation by precipitous mountains. Supplies of all sorts are cheap, efficient labour can be obtained on easy terms, the labour of white men, not of negroes or Indians ; and life and property are as safe as anywhere on the globe."

At the present time, apart from Ontario, interest is mainly centred in British Columbia as the gold-

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[1] Printed by order of the Legislative Assembly. Toronto, 1890, p. 206.

[2] *Bulletin No.* 1 *of the Bureau of Mines;* Toronto, 1896, p. 7. *Fifth Report of the Ontario Bureau of Mines;* Toronto, 1896.

[3] *Northern Districts of Ontario, Canada*, fourth edition, 1897, p. 91 ; extract from Report of Dr. A. P. Coleman.

producing region of the west. The literature of this portion of my subject is voluminous, and of deep interest, and I wish it were possible to refer to it fully.

So long ago as 1888 Dr. Dawson[1] recorded his "belief that the northern moiety of the range of mountains will ultimately prove to be susceptible of development corresponding in importance to that which has already been attained in the southern," that is, in the gold region of the United States. The first authenticated discovery of gold within the limits of what is now the province of British Columbia, was made by an Indian woman, who found a nugget on the beach on the west coast of one of the group known as Queen Charlotte Islands, in 1851. As Dr. Dawson points out, the Hudson's Bay Company first found gold on the banks of the Thompson and Fraser River, and the discovery becoming known, changed the whole fortunes of the country, and he shows "how general and throughout the whole extent of the great area of British Columbia the deposits of alluvial gold have proved to be." I may be permitted to quote also a paper read by Mr. Hobson before the General Mining Association of the Province of Quebec, in which he does not hesitate to predict that the day is not far

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[1] Geological Survey of Canada. *The Mineral Wealth of British Columbia.* 1888, p. 14.

distant when the gold output from the auriferous placers of British Columbia will surprise not only Canadians, but will astonish the civilised world. From the placer workings of the Cariboo district[1] alone, some £12,000,000 worth of gold dust and nuggets have issued, and this "from a densely forested mountainous region which, because of its inaccessible character, had remained unknown even to the wandering native hunters." It is hardly necessary to state that the occurrence of gold placer deposits in the old channels and river courses points to the existence, at no great distance, of auriferous veins whence the gold in the placer deposits was derived.

There is, in the North-West Territory another gold-bearing district of great interest, not only from its extraordinary richness, but from the problems it presents to the explorer and miner. I refer once more to the great gold field of the Yukon River and its tributaries, more especially the Klondike. In 1887 an expedition was despatched by the Canadian Government to the Yukon country under the direction of Dr. Dawson, and his exhaustive report was published in 1888. So long ago as 1860 men employed by the Hudson's Bay Company are stated to have found gold in the Yukon basin. Its

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[1] For geology of Cariboo district consult *Report* by Amos Bowman, M.E., Geological Survey, 1888.

principal city, Dawson, lies in Canadian territory, near to and about the centre of the boundary between Canada and Alaska; a land of singular grandeur; of volcanic peaks and vast glaciers. One of the most magnificent mountains in North America, Mount Elias (18,100 feet),[1] also lies in Canadian territory. I cannot do more than refer you to some salient points borrowed from a recent official report of Mr. W. Ogilvie on a district near the confluence of the rivers Klondike and Yukon. Writing in January of the present year from Forty Mile Creek, Yukon district, he states that the prospects of placer mining continue to be more and more encouraging and extraordinary. It is beyond doubt, he states, that three "pans" on different claims turned out respectively $204, $212, and $216 worth of gold; "but it must be borne in mind," he adds, "that there were only three such pans, though there were many running from $10 to $50." Moreover, a rich quartz lode, which assayed over $100 to the ton, has also been discovered. Writing from Fort Cudahy in 1896 Mr. Ogilvie said: "it is certain that millions will be taken out of this district in the course of the next few years." These are glowing words, but

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[1] According to the measurement of the Duke of the Abruzzi, who ascended the mountain in August, 1897. *The Times*, Sept. 13, 1897, p. 10.

I may add that nothing has struck me more than the reticence with which Canadian officials describe in a few words, which are as dignified as they are picturesque, not only prospects of mineral wealth, but incidents in lives of hardship, of adventure, and of devotion to duty, which compel the reader's attention and enlist his sympathy.

In the report to which I have referred, Mr. Ogilvie writes to the Surveyor-General at Ottawa as follows: "You will learn how I came to be caught in this country and why I have not attempted to get out in winter. Should it be necessary for me to do so before summer I will try to leave by dog team, starting in the last days of February and getting out early in May." It will be evident that in this district means of communication are much needed; and as Inspector Constantine has recently said, in order to develop properly this vast country, a route from the south to the head waters of the Yukon is much required. Writing from Forty Mile Creek in January 1896, Inspector Constantine states[1] that "there is hardly a creek within 300 miles south-west or north-west of here in which more or less gold is not found."

Since the above was written, Mr. Ogilvie has stated that the Bonanza and Eldorado creeks on the Klondike River alone would produce gold to the

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[1] *Report to the Canadian Government*, Jan. 20, 1896.

value of £15,000,000, and that Canada has in the Yukon district 100,000 square miles, over the whole of which rich prospects have been found.[1] The area extends south-eastward from the 141st meridian into British Columbia. Rich bits of quartz have been picked up in the vicinity of certain creeks, and Mr. Ogilvie considers that it is only a question of time until the mother lode of the gold is discovered close to where it now lies, as the gold and the rock associated with it in the drift, bear no evidence of glacial action or of having been transported to any great distance from its original site. He thus describes[2] the conditions of getting out placer gold as the work is carried on now :—

"The valleys of these creeks are generally wide at the bottom and flat, being seldom less than 300 feet to 400 feet. This is covered with a dense growth of underbrush and small spruce, with occasionally balsam, poplar, or cottonwood. Much of the wood is suitable for sluice-box purposes, which require boards at least 10 inches wide and 1 inch thick. The rest is all suitable for firewood, which is an important factor in developing the mines of this region. The moss and ice covering a space 8 feet or 10 feet long by 7 feet or 8 feet wide, are cleared away from the surface, or a hole some 6 feet long by 4 feet wide is dug and a fire built. During the

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[1] *The Times*, Nov. 8, 1897. [2] *Ibid.*, Nov. 11, 1897.

night the ground is thawed to a depth of from 6 inches to 12 inches. Next morning this thawed ground is pitched out and the process is repeated until the bedrock is reached, which is generally at a depth of from 15 feet to 20 feet. About 10 feet down we leave the vegetable matter, the alluvial deposits, and enter a stratum of coarse gravel, the gravel showing very little rounding or wearing. At the bottom of this, close to the bedrock, the pay streak is found, and is seldom more than three feet in depth, the best paying part being immediately on the bedrock. This is not solid rock, but a mass of angular, broken rock lying, no doubt, in its original location in space. Between these masses clay and fine gravel have become imbedded. Into this the miner proceeds a foot or more. . . . No one has yet gone down to solid beds of rock, so we cannot say what might be found below the so-called bedrock. To burn the hole requires about three weeks' time and a good deal of labour."

As regards climate it may be remembered that snow-clad defiles are not always a disadvantage. They necessitate the adoption of the strange method of transit which involves the use of snow slides.[1]

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[1] "Report on the Slocan, Nelson, and Ainsworth districts in West Kootenay," by W. A. Carlyle; "Report on the Trail Creek Mining District," by W. A. Carlyle, *Bureau of Mines Bulletin*, No. 3, 1897.

The ore is packed in raw hides, and glides from elevations, it may be of thousands of feet, over jagged snow-covered rocks at a smaller cost for transit than it would be possible to effect in summer.

I should perhaps add that while we rejoice that the wealth of the Dominion will be increased by the new finds of gold in the Yukon territory, it is to be regretted that the conditions are such as to render concurrent development of the mining and agricultural industries impossible, and this regret is, I know, shared by the Minister of Agriculture.

The great silver and argentiferous lead deposits of Canada can only be briefly mentioned, though they well deserve more attention than they can possibly receive from me. The wealth of the Dominion in gold may have caused silver to be despised, not for the first time in history, for you will remember that it was nothing accounted of in the days of King Solomon. (1 Kings x. 21.) I can, however, do but little more than indicate the principal districts. When I visited Canada in 1884, the Thunder Bay region on Lake Superior, Ontario, was the centre of successful silver mining. It is now evident that so far west as the Selkirks, enormous bodies of argentiferous galena exist, especially in the northern and eastern portions of these mountains. The Slocan silver mines,[1] those of East

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[1] *Report* by R. G. McConnell, Geological Survey, 1896.

Kootenay, Trail Creek, and West Kootenay are of extraordinary richness. The projected railway through the Crow's Nest Pass is already begun, and when it is complete it will open up the East Kootenay and will, at the same time, make the coal deposits, traversed by the line, available for smelting the ores. Argentiferous grey-copper ore is also widely distributed over West Kootenay. As showing the great development of Canada's wealth in silver, it may be stated that when the British Association visited Montreal in 1884, the amount of silver exported was only some £2,580, while in 1895 it had risen to £130,347. The amount of silver produced in 1896 was 1,429,660 ounces more than in 1895[1]. The amount of lead exported in 1896 was six times as much as in the previous year.

Before leaving questions connected with the precious metals, I may perhaps plead for extreme caution with regard to mining enterprise. It has been stated that the old miners used to open holes on the hill sides, but that modern miners content themselves with opening offices in leading thoroughfares. There is, I fear, much danger of reckless speculation, but when we see what Canada is doing for technical education, and when it is re-

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[1] *Mineral Statistics and Mines Summary of the Mineral Production of Canada for* 1896, by E. F. Ingall.

membered that our own Royal School of Mines in England and Canadian Schools of Mines are sending out thoroughly trained men, there is much ground for hope that the professional skill, which Canada will much need in the future, will not be wanting.

I have, hitherto, said nothing as to the great future which Canada seems destined to play in regard to the production of iron ores, and the adequate treatment of this subject would demand an entire lecture. We may remember that it is in the essay entitled "Of the true greatness of Kingdoms and Estates," that Bacon quotes Solon's warning to Crœsus, which was to the effect that the possessor of iron would secure his gold. This transfer was not to be effected by the peaceful operation of the law framed by Bacon's youthful contemporary Gresham, which states that "a cheaper metal will displace the noble one." Solon was contemplating the possession of superior armaments, and his lesson has not been forgotton. When we read of the riches of the Yukon and Klondike, and are told that in one miner's hut "several five-gallon cans might be seen full of gold dust and nuggets," and of "a bank out of which nuggets stuck like pebbles,"[1] it is well that we should remember the greater importance of iron, as compared with gold. Indeed, the

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[1] *The Times*, July 26, 1897.

Premier of Newfoundland, speaking in London recently, said that "better than gold, they had iron and coal,"[1] and there was much to be said for Sir William Whiteway's claim. We, at the present day, are not unmindful either of the amount or quality of our iron and steel, and it will not be forgotten so long as our empire endures, that a prominent incident in the first official visit of Her Majesty the Queen in connection with the celebration of the sixtieth year of her reign, occurred at Sheffield, where Her Majesty witnessed[2] the rolling of a 56-ton armour plate for the battleship "Ocean." It is well to be mindful that the best guarantee for peace is readiness to defend the empire, and the gracious act of Her Majesty, emphasises Bacon's monition embodied in the Essay already quoted "Let . . . . no estate expect to be great that is not awake upon any just occasion of arming." Canadian visitors to the Naval Review on the 26th of June last, must have realised the importance of the part played by the metallurgist and engineer in enabling our empire to maintain her great place in the world. The cost of this is vast, for out of an aggregate revenue of a little less than £102,000,000 the United Kingdom spends no less than £21,250,000 on the naval defence of the empire.[3] We, who were

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[1] *The Times*, July 29, 1897. [2] *Ibid.*, May 22, 1897.

[3] *Ibid.*, Nov. 22, 1897, p. 9.

present at the magnificent demonstration of power, will never forget the five main lines in which the fleet was disposed, so that there were twenty-five miles of warships moored as close to each other as safety would permit, and it is stated that the flag is carried over the ocean by another fleet almost as numerous.[1]

Sir William White, K.C.B., Chief Constructor of the Navy, has enabled me to give you the estimate that not less than 400,000 tons of iron and steel were afloat at Spithead in ships of the Royal Navy. Bearing in mind that only about one half the steel produced in the United Kingdom is derived from British ores, and that our ships require about half the amount which is so produced, is it necessary for me to do more than plead that the resources of the Dominion, as regards the manufacture of iron, should now be fully developed, and more especially that suitable iron ores should be carefully sought for, and that facilities of transit, both for iron ores and coal,[2] should be established, so that the iron may be made available, as quickly as possible, for the service of the empire? The history of iron-making in Canada dates from 1737, and "the iron ores of the Dominion have a wide range, both geographically and geologic-

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[1] *The Times*, June 26, 1897.

[2] A readily accessible and excellent account of the coal deposits of Canada will be found in *The Great Dominion*, by Dr. G. R. Parker, p. 73. Macmillan and Co., 1895.

ally. From Cape Breton in the east to Vancouver in the west they are found in abundant variety in almost every province."[1] What Canada needs is some great deposit of first-class ore in such a situation as would make it commercially valuable. On this point I have had the advantage of consulting a very eminent authority, Professor J. B. Porter, of McGill University, and it would seem that the chief hope lies in the region near Lakes Huron and Superior, where transportation charges would be comparatively low.

I must now pass to the experimental portion of my lecture, for there is a tradition that a lecture delivered before the British Association should, if possible, be illustrated by experiments.

It is difficult to borrow illustrations from many of Canada's metals. I will, therefore, select a particular metal, nickel, which is more distinctively Canada's own, than others. It possesses, moreover, much interest both in relation to iron and steel and from its occurrence in connection with platinum. It is, however, impossible to understand the relative importance of the metals of one country, as compared with those of any other, without possessing some insight into the distinctive character and physical behaviour of metals generally. Take, for instance, steel; no material is as trustworthy or as

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[1] *The Canadian Mining Manual*, 1896, p. 287.

"true as steel" is, if it is properly understood, but, on the other hand, no material so readily recoils from and, as it were, resents either association with unsuitable elements or unsympathetic treatment. This is true of all the metals which are in industrial use, though in a less degree, and I hope to show that nickel is the one of Canada's metals, which is of special interest in connection with the constitution of steel, and incidentally affords valuable evidence as to the properties of other metals. We will, therefore, examine some of these properties. Viewed in connection with the advancement of science, which it is the object of the British Association to promote, the whole tendency of modern work has been to break down the barrier between metals and the so-called non-metallic elements. Alloys are known to behave very much like ordinary salt solutions, and further, it has been proved that, even in the case of metals, the three states of matter, solid, liquid, and gaseous, merge imperceptibly into each other, for even in a solid metal some molecules retain the freedom of motion characteristic of a gas. It is easy to show that the behaviour of a solid metal may closely resemble that of a fluid one, and that a fluid metal in turn shares the properties of an ordinary non-metallic fluid. I propose, therefore, to take an ordinary variety of steel used in the construction of armour plates, as a basis for consideration, and, with the aid of fluid water and molten gold, to trace certain analogies between solid steel and a viscous fluid.

Water flows readily through a fine vertical pipe and its continuous stream soon breaks into characteristic drops and tiny droplets. By the aid of what is called instantaneous photography, several experimenters, among whom Lord Rayleigh and Professor Boys may be specially mentioned, have taught us how to study such water drops. For the purposes of this lecture I have photographed for you a stream of molten gold issuing from a fine pipe in the crucible containing the molten metal, the stream being illuminated by a bright instantaneous electric spark. If the image of the gold stream and the water stream be projected, side by side, on the screen (Fig. 1), it will be evident that the drops and droplets are similar in form. There are even tiny droplets of fluid gold, just as there are tiny droplets of water. It may have been obvious that such would be the case, but until now the fact has never been demonstrated.

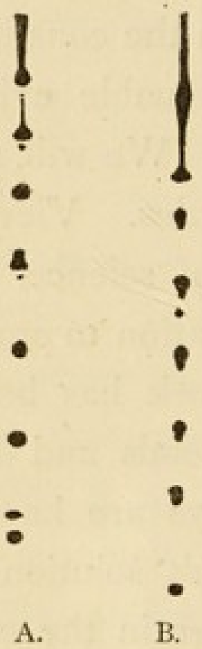

FIG. 1. Comparison between, A, stream of molten gold, and, B, stream of water.

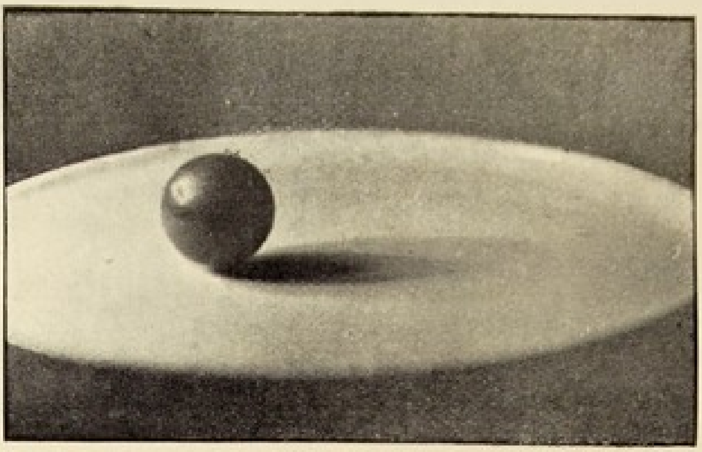

Fig. 2.—A falling marble, photographed at the instant of contact with the surface of milk.

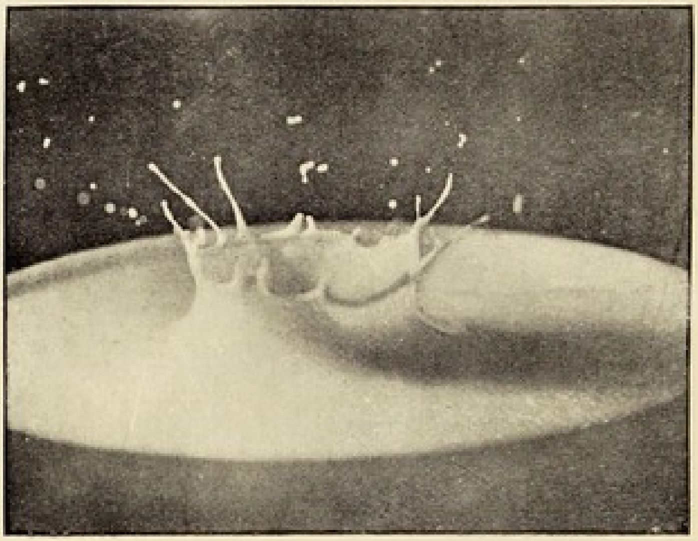

Fig. 3.—Splash produced by the marble about $\frac{1}{100}$th of a second after contact with milk.

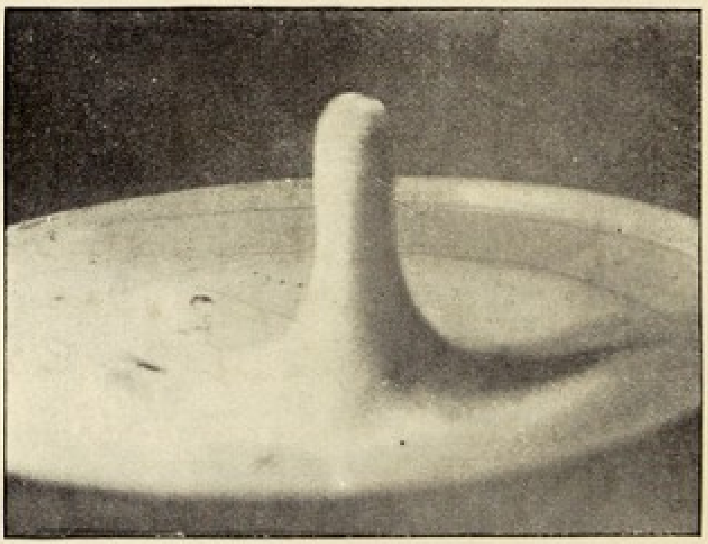

Fig. 4.—Splash produced by same marble about $\frac{1}{10}$th of a second after contact with milk.

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Proceeding a step further; when either a drop of water or a solid sphere falls into a mass of liquid, a splash is produced. Professor Worthington[1] has taught us how to photograph such splashes, taking, for the sake of convenience, milk, the white surface of which renders it easy to photograph. I have repeated his experiments and if a series of the photographs are projected on the screen, it will be seen that in the first a picture of a marble has been caught just as it touched the surface of the milk (Fig. 2). A splash was, however, instantly produced, and within a space of time not exceeding one-tenth of a second this splash rapidly changed from a coronet shaped to a columnar splash (Figs. 3 and 4), and then the surface of the milk gradually regained tranquillity. In some experiments specially made for you, I have replaced milk by molten gold. It is unnecessary to dwell on the difficulties of manipulation, though they were very great, for first, gold, molten in a crucible, had to be kept from freezing, and gold solidifies at 1062° C. Second, the light emitted from the surface of the molten gold is continuous, and while it is not sufficiently brilliant to enable the gold to be photographed without another illuminant, it emits enough light to "fog" the plate. It is, therefore, necessary, first, to keep

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[1] *Nature*, vol. 50, 1894, p. 222; and *Phil. Trans. Roy. Soc.*, vol. 189 (1897), pp. 137—148.

the gold melted ; second, to adjust the time of the fall of the drop into it ; third, to ensure the opening at the right instant of the camera shutter ; and fourth, to produce at the right fraction of a second the illuminating electric flash. I must, however, refer to the nature of the material composing the drop in this experiment. There is an old tradition that success, even against the powers of evil, may be attained by the use of a silver bullet ; but in this case gold was chosen because it is not liable to oxidation, and I therefore cast a bullet of pure gold, omitting the precautions observed by Caspar in *Der Freischütz*. Here are two photographs which show, first, the golden bullet approaching the pool of fluid gold, Fig. 5 ; and second, the splash of the gold, Fig. 6. You will see that it is almost identical with the splash of milk, Fig. 3. Again, you may say "we accept this first demonstration of the fact as you tell us it is, but we should have anticipated that the metal splash and the milk splash would resemble each other closely." Let me proceed one step further. What will be the result when a solid projectile of steel is urged against a solid armour plate of steel with a velocity of some 1,600 feet a second? The results may vary within wide limits ; the object of the maker of the projectile, that is, of the solid drop, is to fracture and penetrate the armour plate, while on

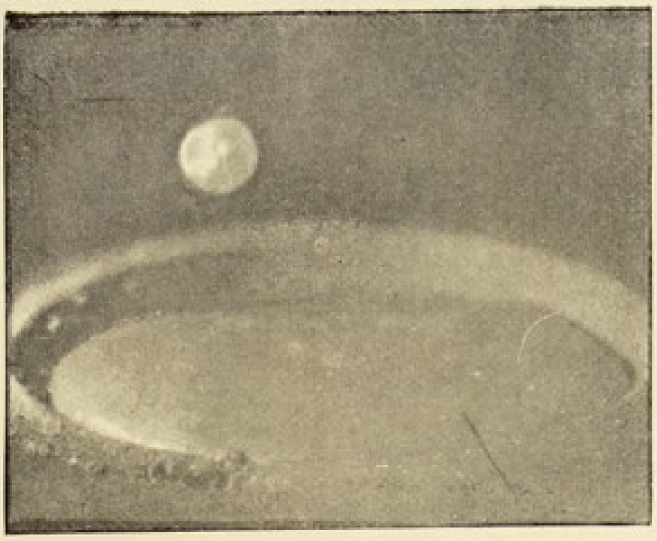

Fig. 5.—Gold bullet approaching a pool of molten gold.

Fig. 6.—Splash produced by the same bullet about $\frac{1}{100}$th of a second after contact with the molten gold.

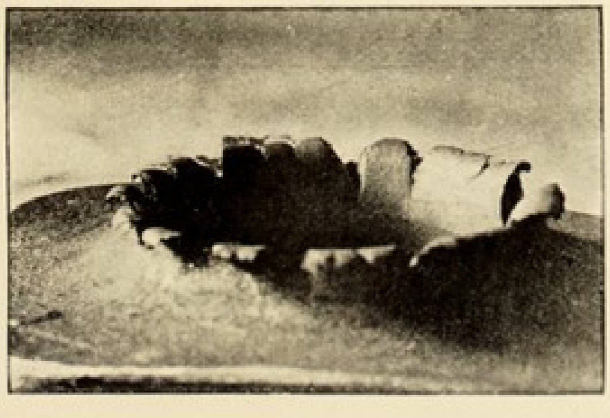

Fig. 7.—Splash produced by steel projectile on steel armour plate, in $\frac{1}{3000}$th of a second.

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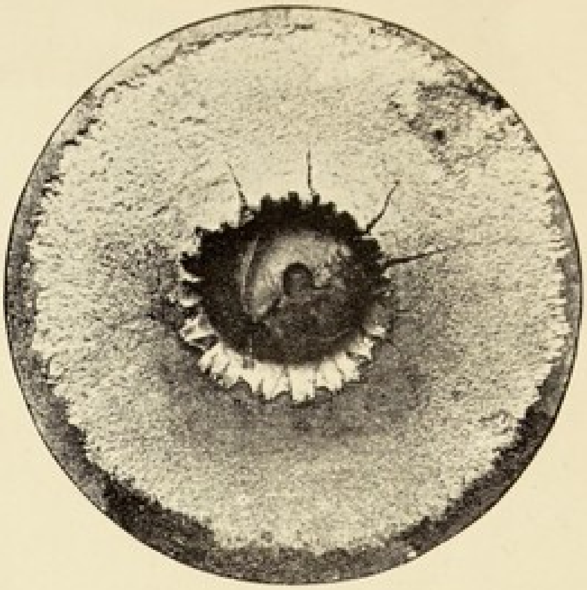

Fig. 8.—Splash produced on hard armour plate by projectile (plan).

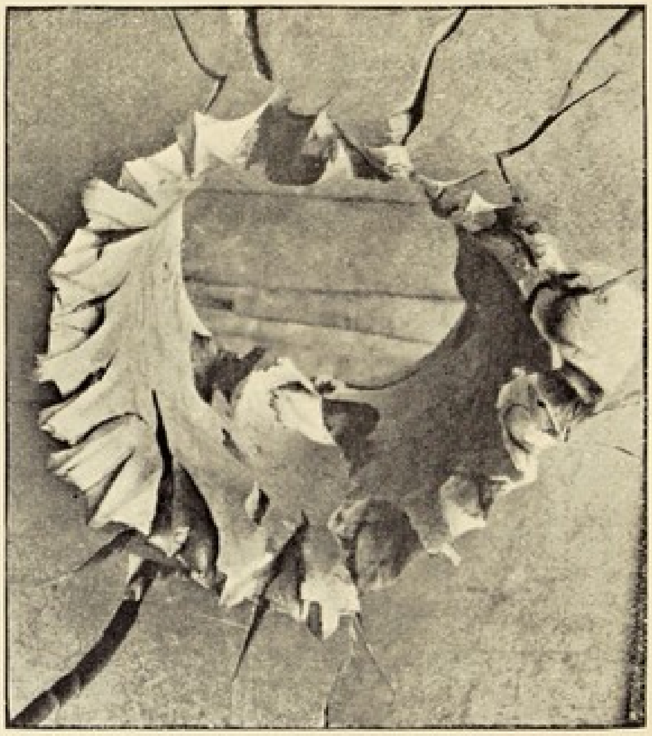

Fig. 9.—Another splash produced by projectile on armour plate (plan).

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the other hand, the maker of the plate hopes to shatter the projectile. If the former wins, and the plate is wholly or partially penetrated, a splash will often be the result, and allowing for the difference between the flow of a solid and the flow of a liquid, the splash of the solid steel strangely resembles the splash of the fluid gold. That this is the case you will see from photographs of splashes of armour plates for which I am indebted to Sir W. Anderson, K.C.B., Director-General of Ordnance Factories, and to Lieutenant-Colonel C. F. Hadden, R.A., Chief Inspector, Royal Arsenal. Fig. 7 shows a case in which a steel projectile, weighing 6 lbs. with a charge of $7\frac{3}{4}$ ozs. of cordite, was fired with a muzzle velocity of 1,756 feet per second, against armour plate of rolled mild steel 3·0 inches thick, and it produced in the $\frac{1}{3000}$th of a second this beautiful splash of the steel plate which seemed so solid.[1] Fig. 8 shows a similar steel splash in "plan," and Fig. 9 another splash, but in this case the plate bears signs of fracture. The importance of the point I have been trying to make clear is this. Now that it is known that solid steel behaves like a viscous fluid, we are guided as to the steps which should be taken with a view to its suitable treatment so as to

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[1] Krupp; for similar cases in unhardened nickel-steel plates, consult *Brassey's Annual*, 1896, p. 361.

enable it to serve for defensive purposes. Its toughness or its rigidity may be increased at will, either by varying its treatment or by the introduction of suitable metals. If in the first illustration it were necessary to prevent the marble from entering the milk, the surface of the fluid might be hardened by freezing it. An armour plate in the same way can have a face of rigid steel to break up a projectile, and a tough back which will save the plate from fracture. Now it is conceded on all hands that the best way to enable the maker of the armour plate to triumph, is to instruct him to introduce into the steel some 4 to 5 per cent. of one of Canada's metals. This metal is nickel, and in the production of it she exceeds any other country in the world.

The discovery of nickel in Canada and in Europe presents a curious historical parallel, for in Canada and on the European continent nickel ores were originally supposed to be valuable as a source of copper. Chronstet isolated nickel in 1751, and Bergman confirmed his discovery in 1774. Canada's famous deposits of nickel in the district of Algoma in Ontario were worked as a source of copper so long ago as 1770, so that not twenty years after Chronstet had established the existence of metallic nickel, a great nickeliferous district had actually been discovered in Canada. The true nature of the

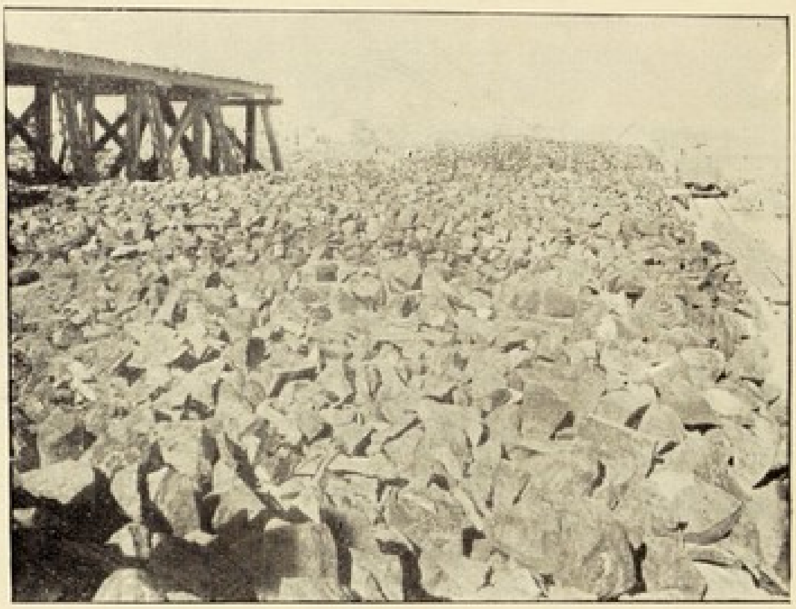

Fig. 10.—Heap of nickeliferous regulus, Copper Cliff Mine, Sudbury, Canada.

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deposit was, however, hardly recognised until the officers of the Geological Survey pointed out[1] that the deposits of nickel would probably prove to be workable. The recent history of these deposits shows that in no country of the world could such a mass of nickeliferous regulus — a metallurgical product—be matched as is shown in the photograph[2] (Fig. 10), which represents the stock of the Copper Cliff Mine in July, 1890.

It is impossible to deal in this lecture with the extraction of nickel from its ore, but a new process may be mentioned on account of the great scientific interest it possesses. It is based on the fact that nickel and carbonic oxide will form a volatile compound, from which nickel is released at a temperature of over 150° C. By the kindness of Dr. Ludwig Mond, I have been enabled to prepare a micro-section, Fig. 11, which shows concentric layers of nickel released from the nickel-carbon oxide, and deposited on a nucleus of ordinary nickel.

The maximum annual production of metallic nickel in Canada was 2,750 tons,[3] and in my opinion the

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[1] Paper on "The Nickel and Copper Deposits of Sudbury, Ontario," by A. E. Barlow, M.A., March, 1891. Reprinted from the *Ottawa Naturalist*. A brief description of the nature of the ore and its treatment will be found in the *Canadian Mining Journal*, 1895, p. 131.

[2] "Report on the Sudbury Mining District," *Geological Survey Annual Report*, part F, vol. 5. p. 55, by R. Bell, LL.D.

[3] Moissan and Ouvrard, *Le Nickel*, p. 170.

nickeliferous ores of the Dominion are of great and imperial importance, for nickel steel has "proved itself to be worthy of the confidence placed in it by those to whom its remarkable qualities are best known."[1] The author of the words just quoted, Mr. Beardmore, states that in his opinion, "if propeller shafts were made of nickel steel, the question of failures would seldom, or never, be raised." A very recent trial proving the suitability of nickel steel for defensive purposes may be quoted from a readily accessible source, the "Naval and Military Intelligence" of the *Times* of July 21st of the past year (1897). It states that there was a "most successful trial of a 4-inch special nickel steel armour plate on board the *Nettle* yesterday, under the direction of naval officers at Portsmouth. The plate was 4 feet square, 4 inches thick, and had no wood backing behind. It was attacked by a 5-inch gun with Palliser projectiles. The first shot was fired with a velocity of 1,406 feet per second, but the plate showed no sign of having been hit. The 50lb. projectile simply splashed on the face. The second shot was fired with a velocity of 1,750 feet per second, the plate being indented about three-quarters of an inch, but the face was not in any way broken. The third shot also had a velocity of 1,750 feet, but the indentation was only half an inch.

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[1] Paper by W. Beardmore, Inst. of Naval Archietcts, *Engineering*, April 30, 1897, p. 589.

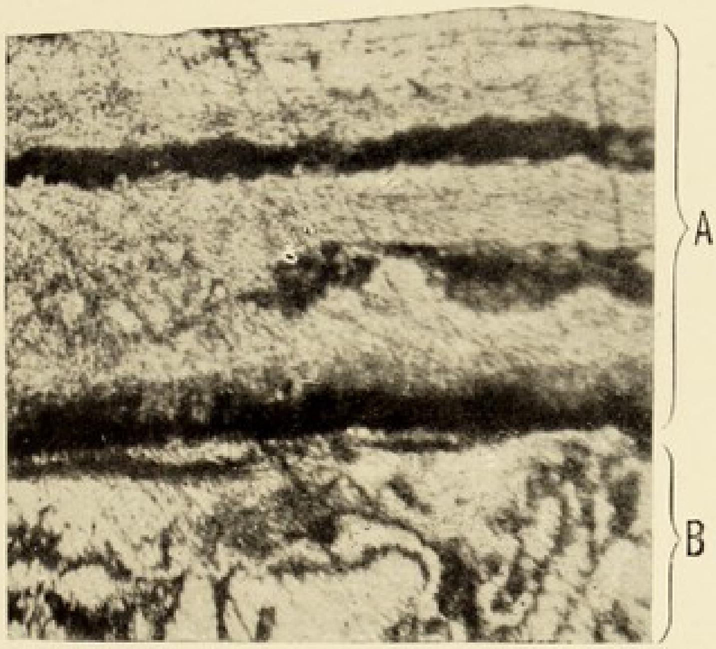

Fig. 11.—Section through a nodule of metallic nickel showing concentric layers of nickel, A, released from its compound with carbonic oxide and deposited on a nucleus of ordinary nickel, B. The nodule was ¾ inch in length. The magnification is 140 diameters.

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There were no cracks of any kind in the plate, but the projectiles were in every case broken to fine pieces. Great satisfaction was expressed with this result, as the plate will prove invaluable where thin, unbacked armour is desired."

There is another curious point connected with the relations of iron and nickel. Iron alloyed with 25 per cent. of nickel has its density permanently reduced by an exposure to a temperature of −30° C., that is, the metal expands at this low temperature. Supposing, therefore, that a ship of war were built in an ordinary climate of ordinary steel and were clad with some three thousand tons of nickel steel armour containing 25 per cent. of nickel, we are confronted with the extraordinary fact that if the ship visited the Arctic regions, it would actually become some two feet longer, and the shearing which would be produced by expansion by cold would destroy the ship. This is a curious but purely hypothetical case, for an alloy so rich in nickel is not used for armour plate. Further than this, M. C. E. Guillaume[1] has shown that there is a singular anomaly in the expansion of nickel steels. An alloy containing 22 per cent. of nickel expands when heated, considerably more than ordinary steel does, but an alloy of iron with 37 per cent. of nickel

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[1] *Comptes Rendus*, vol. 124, 1897, pp. 176, 752, and 1,515, and vol. 125, 1897, p. 235.

hardly expands at all, so that the presence of an additional 15 per cent. of nickel in nickel iron alloys is sufficient to entirely change the nature of the metal. An experiment arranged to show these peculiarities of expansion, made it clear that if thin rods of ordinary steel and nickel steel containing 37 per cent. of nickel are raised side by side to the same temperature, an index attached to one moves rapidly, while the index attached to the other hardly moves at all. One explanation of the singular behaviour of iron under the influence of nickel and of other elements, is afforded by the evidence which has been elicited that iron, like carbon, phosphorus, or sulphur, is capable of assuming an allotropic form possessing widely different properties from those which characterise its normal condition. In the lecture I delivered before the British Association in 1889,[1] the views of my friend M. Osmond on this important question were dealt with and the laborious investigations which he and others have conducted during the past ten years have strengthened the position we then occupied. In these investigations the microscope has played a very important part, but in relation to the condition of metals and alloys we want to penetrate far beyond the limits of microscopic vision and to ascertain what is the inner molecular movement of a seeming inert mass of

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[1] At Newcastle-on-Tyne, 1889. *Nature*, Nov. 7 and 14, 1889.

metal. Evidence that there is such molecular movement in solid metals may be gathered in various ways. It can be shown that solid metals will diffuse into each other, slowly of course but, precisely in the same way that a salt diffuses against gravity into water or another solvent. The curves for the diffusion of gold or platinum into lead or bismuth are precisely of the same form as the curve which represents the diffusion of common salt into water.[1]

Another fruitful method of studying the changes which occur in *solid* metals and alloys is to measure the rate at which they cool, and to ascertain by the aid of curves not only what takes place as they pass from the fluid to the solid state, but what happens when they cool down to the ordinary temperature or below it. If a thermometer be placed in water which is steadily losing heat to a cold environment, the mercury will fall continuously until the water begins to freeze, then the fall will be arrested and the mercury will remain stationary until all the mass is frozen, and then the rate of fall will be resumed. It is just the same with a metal, say nickel, except that as the melting point of nickel is far above the range of the ordinary glass thermometer, some other means of measuring the temperature must be adopted, and this is afforded by the use of platinum wires. I

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[1] Roberts-Austen, "Bakerian Lecture," *Phil. Trans. Roy. Soc.*, vol. 187, 1896, p. 383.

may thus present to you another metal found in Canada, for, although the maximum amount of platinum produced in any one year (1891, some 600 ounces) is not very large, it would more than satisfy the growing demands of physicists and metallurgists in our whole empire for the particular purpose in view, which is the measurement of high temperatures.

Fig. 12 shows a fragment, rich in platinum, probably sperrylite, the arsenide of platinum, part of a series of specimens, which I panned out during a recent visit to the Dickenson Mine in the Sudbury district. Platinum is, in the experiment I am about to show, drawn into a fine wire and employed as a thermo-junction which consists of a wire of platinum, twisted at one end with another wire of platinum alloyed with a small quantity of another metal, preferably iridium or rhodium. The free ends of this thermo-junction are connected with a galvanometer, and the electric current produced when the junction is heated is proportional to the temperature, and enables it to be measured, so that the movement of the spot of light of the galvanometer across a graduated scale, has the same significance, though the range is more extended, as the rise or fall of the mercury in a glass thermometer. It will be easy with the aid of a thermo-junction to measure the freezing point of gold. In this little fluid mass of gold a thermo-

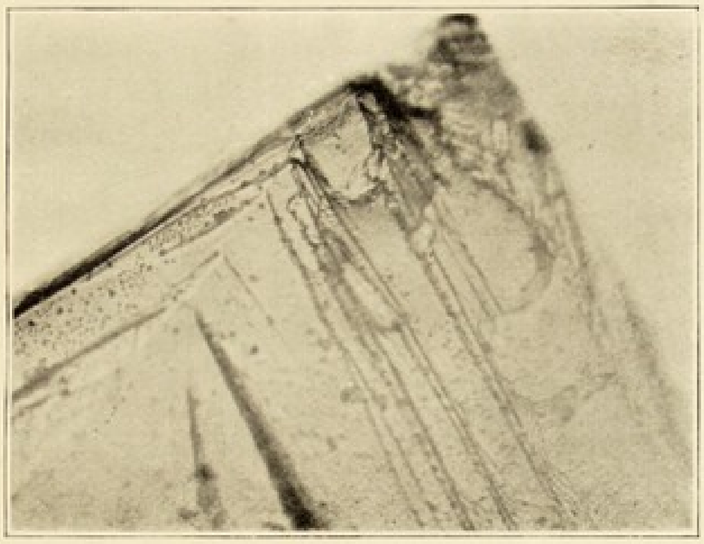

Fig. 12.—Crystal of a platinum mineral, magnified 450 diameters.

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junction is placed and the spot of light from the galvanometer passes slowly across the scale from the hot to the cold end, and when a point, which is known from other measurements to represent 1,062°C. is reached, there will be an arrest, that is, the gold begins to freeze, and then, when the whole mass is solid, the movement of the spot of light is resumed. If the spot of light be caught either on a sheet of paper or on a plate of smoked glass which is kept moving steadily and continuously at right angles to the line traversed by the spot of light, it will be possible to trace by hand the cooling curve of the gold. Repeating the above experiment with nickel, it is found that the nickel freezes at about 1,600°. It will be seen that in the case of most alloys and in that of some metals, there is, in addition to a single break at the freezing point, a second break, and this occurs long after the mass of the metal has actually become solid. These breaks indicate either the falling out of some definite groups of constituent metals in alloys or an atomic rearrangement in the case of metals. This method of investigating the nature of metals and alloys by the aid of cooling curves is, therefore, a very fruitful one, for the curves not only indicate the change of state from liquid to solid, but any molecular change which is accompanied by either absorption or evolution of heat, changes of great significance and value in enabling the mechanica properties of the mass to be studied.

An appliance which will probably be much used in future metallurgical practice enables the properties of such metals as fuse with difficulty to be studied. It is only necessary to pass a current of some 200 ampères and 230 volts between the carbon poles suitably enclosed in a receptacle of lime, and platinum, chromium or nickel may be melted and boiled off into vapour. A simple optical arrangement enables the molten contents of such an electric furnace to be projected on to the screen and the results are of exquisite beauty. At Toronto the projection on the screen was no less than thirty feet across, and in some cases resembled a sunset behind a sea of molten silver, with clouds of blue, gold, orange, mauve and russet. The beauty of the results you have just seen reminds me that I must not forget to offer my warmest thanks to those in Toronto who have so kindly helped me in arranging

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The accompanying plate indicates the general arrangement of the electric furnace. Fig. 13 shows a sectional elevation on the line E F of Fig. 15. Fig. 14 is a sectional elevation on the lines A B and G H of Figs. 15 and 13. Fig. 15 is a plan in section on the line C D, Fig. 14.

a is the furnace of fire-brick lined with magnesia, and *b* is the crucible or receptacle in which the metal is to be melted. The carbons, *c*, *c′*, at the beginning of the operation must be long enough to touch each other, and they are advanced by slides, *d*, *d′*, actuated by handles, *e*, *e′*. The crucible rests on a sheet of asbestos, covering an iron plate, which is independent of the supports of the furnace, and slides up and down guiding rods. It is raised or lowered by the handle *g*, working rolling supports on the iron plate. The position of the furnace in relation to the carbon holders may be adjusted by the screws, *h*, *h′*. A lens and an adjustable mirror, *m*, reflect the glowing contents of the furnace on to a screen. The arc between the poles, *c*, *c′*, is deflected on to the material in the crucible by means of a magnet, *n*. A fan, *o*, drives the vaporised metal away from the lens and mirror, which would otherwise be rapidly obscured. This fan is worked by a small electric motor.

The cables, *p*, *p′*, are flexible, and bring the dynamo current to the carbon holders. An adjustable resistance, capable of carrying a current of 200 ampères, must be provided, and is not shown in the drawing.

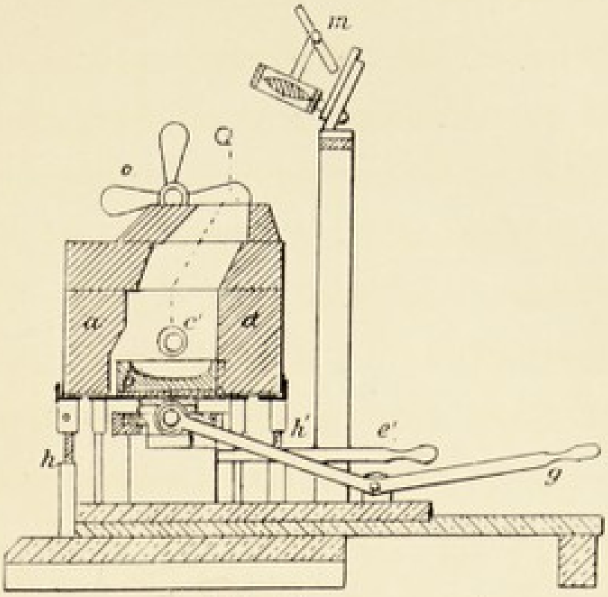


Fig. 13.

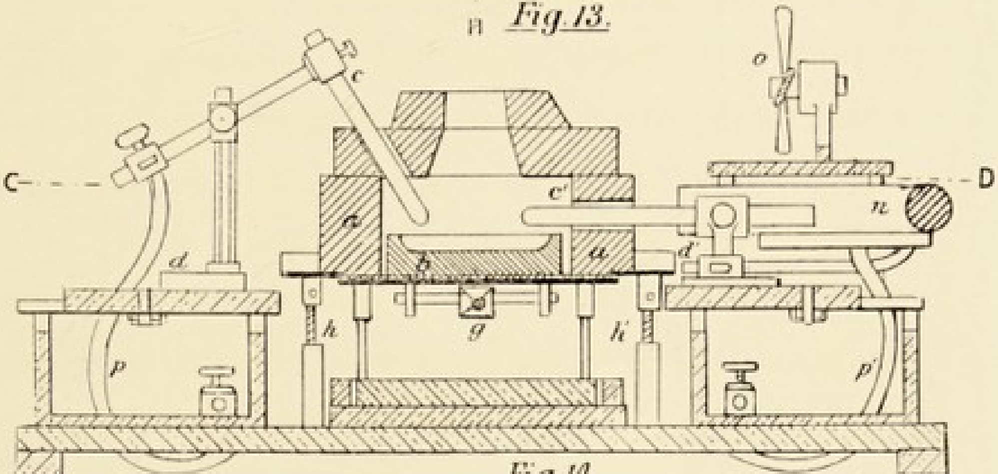


Fig. 14.

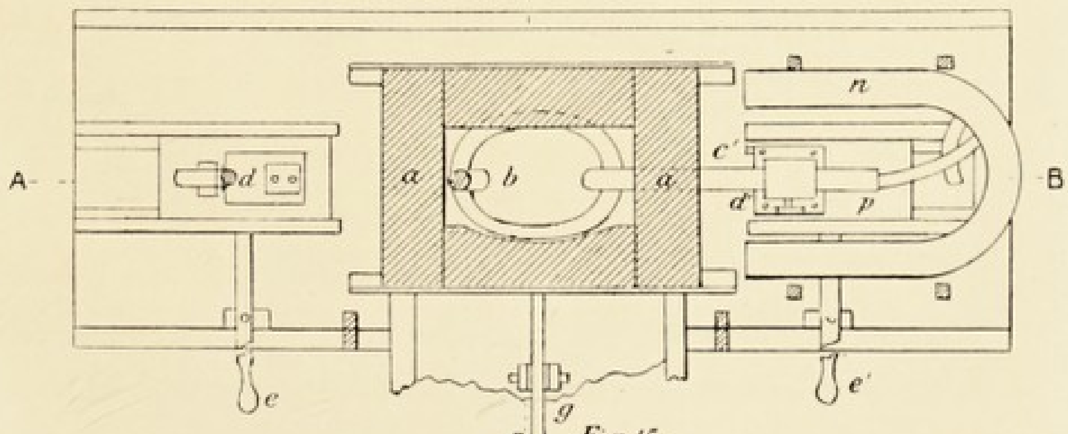
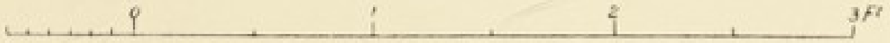


Fig. 15.



ELECTRIC FURNACE

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this lecture. Kind as many have been, to none are warmer thanks due than to Mr. Plaskett, of the University of this City, who has been untiring in his efforts to make the experiments a success. It would have been difficult for me to have given the lecture at all if I had not been aided so efficiently by my assistant, Mr. Alfred Stansfield. It is by the aid of such an appliance as the electric furnace that we can pass from the study of solid and molten metals to that of metallic vapours. These experiments teach that metals are not the inert things they are supposed to be ; they really are, even when solid, vibrating masses of great complexity. The vaporisation of metals in the electric furnace leads to the consideration of what happens to metals in the glowing atmosphere of the sun. Metals are, in fact, sensitive things, almost sentient in their organisation, strangely life-like in their behaviour. Our President has, in his address, dealt with the antiquity of man, but of the genesis of metals much might be written ; and many physicists and chemists are now ready to accept in principle at least, as the results of the life-long work of Sir Norman Lockyer, the hypothesis that the phenomena of the inorganic world are dominated by an evolution not less majestic, although much more simple, than that now universally accepted in the case of organic nature.

The President of Section B has, in his suggestive address, indicated the way in which molecular simplification may have been brought about, but for the main evidence on which this hypothesis of the evolution of metals rests, we have hitherto trusted to the solar physicists. There may be some who dread the extension of the great principle of evolution which these words imply, and shrink from recognising that the elements as we know them are derived, like our own species, from simpler forms. If there are any here who fear the extension of the great principle of evolution to the genesis of metals, I would remind them that Sir Thomas Browne, in 1642, anticipated these fears by stating, in his *Religio Medici*, that "there is surely a piece of Divinity in us, something that was before the elements, and owes no homage unto the sun." It is the province of the British Association to consider such questions as the origin of metals. The metallurgist is beginning to study the molecular motion in solid metals, which makes them so like living organisms. The miner, on the other hand, takes metals as he finds them, and may be content to accept the splendid heritage which Canada's metals present. This heritage has been won by skill and endurance, qualities which are conspicuously possessed by the Canadian people, and we may, therefore, hope that our metals and our men will enable us to maintain the empire.

THE END.

exploration

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