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The Resources of Canada in Relation to its Geological Structure

By Professor W. A. Parks, Ph.D., F.R.S.C.

President Daly:—Gentlemen, the importance of the contribution of the science of geology to commercial life can hardly be overestimated. Practically all of our industries depend in some measure at least on knowledge which geologists have accumulated. Canada particularly, where our mineral resources are only commencing to be realized, owes a special debt to the invaluable information and data collected by these scientists who have carried on their researches from purely scientific motives, regarding, as they do, specific portions of the earth's crust rather as interesting and academic chapters in the oldest of history books than as possible sources of wealth. The various honors which our guest has received from the leading geological and palaeontological societies are ample evidence of the high esteem in which he is held by his fellow scientists. Besides his important work in the Precambrian region of Northern Ontario he has extended his researches into the province of Alberta during the last ten years as leader of the University expeditions in search of dinosaurs, and I understand there have recently been set up in the Royal Ontario Museum several specimens of these animals which apparently flourished in this part of the world some millions of years ago. It is a great pleasure to introduce to the Canadian Club Dr. W. A. Parks, Professor and Head of the Department of Geology of the University of Toronto; and I shall now ask him to address us.

Dr. W. A. Parks:—Canada is a political division of North America—not an area defined by natural geographic boundaries, except along the great lakes and part of the St. Lawrence river. The Dominion extends 3500 miles east and west, and 1400 miles north and south; its area is 3,603,910 square miles. The development of this large part of the continent is necessarily bound up with that of North America as a whole.

Before inquiring into the structure of Canada it would be well to glance briefly at the outstanding features of the North American continent as they are today.

We find (1) an elevated, even mountainous, area extending from Gaspé through the Appalachian mountain system, (2) a broad, comparatively flat region stretching from the Gulf of Mexico to the Arctic ocean, (3) a great rugged area comprising about half of Canada and lying north and west of (1) and east of (2), (4) the great western cordillera composed of several systems of mountains reaching from Alaska into Central America, (5) the Arctic islands.

These different physiographic provinces are possessed of very different potentialities, and their relative areas in Canada and the United States are widely divergent. It is apparent, therefore, that these primary structural differences have determined for all time that the development of Canada cannot run parallel to that of the United States.

The present-day condition of Canada in respect of the distribution of these provinces was not ever the same but has been brought about by a succession of great events reaching back to the dawn of time. These events express themselves in the growth or development of the country and are intimately related to its economic resources.

We may compare the development or building of Canada to the construction of an edifice, and we can recognize three chapters that may be compared to the laying of the foundation, the erection of the superstructure, and the final finishing and ornamenting.

The first chapter—that devoted to the foundation—was a very long one—as much as two-thirds of the whole history of the continent, and probably not less than a billion of years. We do not know the exact extent or configuration of Canada during this long time, but we do know that both heat and water played a part in moulding the primary

framework. Mighty mountain ranges were formed and were worn away to mere cores, and the débris was spread out in unknown bodies of water to make new rocks. Volcanic eruptions were common and vast masses of molten earth-matter invaded the ancient lands. The net result was the formation, from coast to coast, of a complex assemblage of hard, crystalline, and contorted rocks the detailed history of which is not yet perfectly known. It is probable, however, that there was a decrease in the intensity of the terrestrial forces towards the close, and that the later stages of this long chapter were less violent than its earlier periods. The rocks and formations made during this great era are divided by geologists into many subdivisions differing in different localities, but it is generally admitted that an earlier period in which igneous activity and earth-crumpling played a major part was followed by a later period in which decay and the accumulation of sediments were more pronounced.

Let us imagine a giant at Halifax at one end of a crosscut saw and another at Victoria at the other end. They saw a vertical cut straight across Canada with the result that appears on the chart. (See Figure No. 1).

With the close of this ancient era it may be said that the foundation of Canada has been laid but the edifice as we know it today has not yet been reared.

The second chapter, that referring to the superstructure, is also a very long one, extending over some 700,000,000 years up to about 1,000,000 years from the present. It might be said that this long time was required for the erection of the framework and that the last 1,000,000 years has been required for finishing and decorating.

The principles involved in this second chapter are practically two: first, that the crust of the earth is not at rest but moves slowly up and down—up enough to form great mountains at times and down enough to allow the oceanic waters to flood over the continents. The second principle is that all land is a prey to the elements and its débris is carried into the water, falls to the bottom, and is slowly consolidated into new rocks. Wherever we have land, we have destruction; wherever we have water, we have the formation of new land.

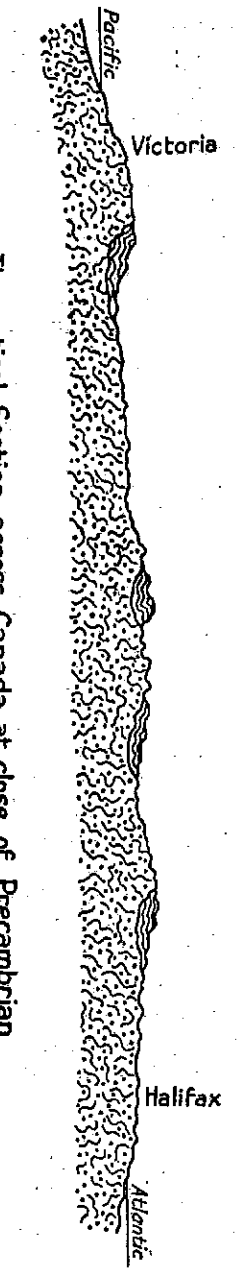


Figure No. 1

Now if we can picture Canada at the close of the first chapter we have a land stretching from coast to coast and probably even farther, rough, irregular, elevated, but probably not exactly mountainous, and barren, as land vegetation has not yet appeared.

The second chapter opens with the sinking of the land mass along two major lines—the Cordilleran and Appalachian troughs, the coming-in of the seas and the consequent deposition of new layers of rock.

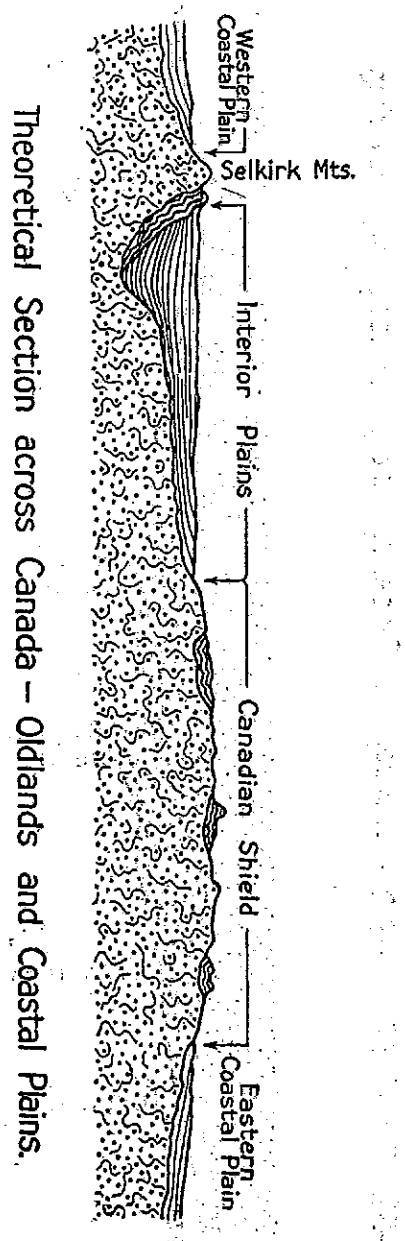
Throughout the long time we are now considering, the development of Canada consisted, at least from one point of view, of a series of sea invasions and retreats with the consequent addition of layer after layer of new rocks on the flanks of the old crystalline axis. These great invasions occurred sometimes in one region, sometimes in another, some from the Atlantic, some from the Pacific, some from the Arctic, and at times these floods became confluent and vast areas were under water at one time.

The net result of this long series of invasions is to cover over about half of the old crystalline formation in Canada with flat-lying layers of secondary rocks, thus producing the two primary physiographic units of "oldland" and "coastal plain". Vertical sections across Canada at the close of this time, provided that no other events interfered, would be as shown in the figures 2 and 3.

This representation, however, is ideal and not quite in accord with the facts, as during this long era of sea invasion and retreat there were other outstanding events that had a great modifying effect on the layers of new rocks as well as on those of the old crystalline base.

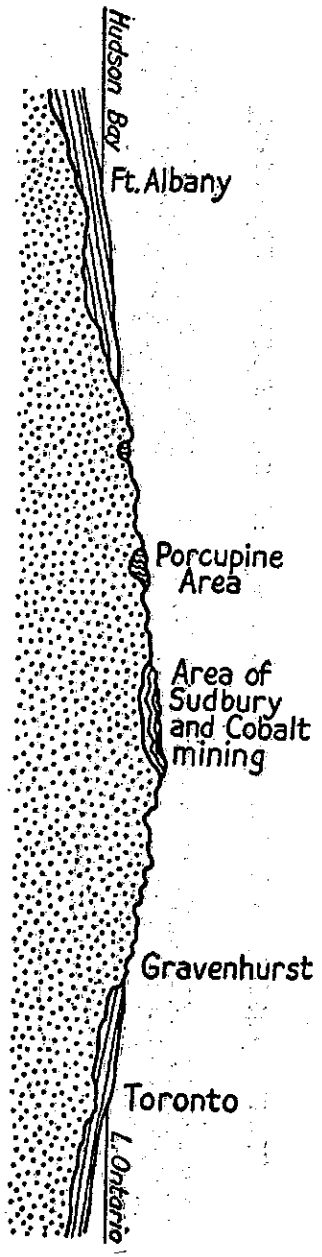
The first of these major events was a great crumpling of the eastern seaboard—Acadia, and the thrusting of the mass against the rest of Canada. It is for this reason that a part of Canada, east of a line through the lower St. Lawrence river and thence to Lake Champlain, is included in the Appalachian province so widely developed in the United States.

The second great modifying event occurred probably 100,000,000 years later and consisted in the birth of the Coast range of British Columbia. This range, one thousand miles long and from fifty to one hundred and



Theoretical Section across Canada – Oldlands and Coastal Plains.

Figure No. 2



Diagrammatic Section from Ft. Albany to Toronto – Oldland and Coastal Plains.

Figure No. 3

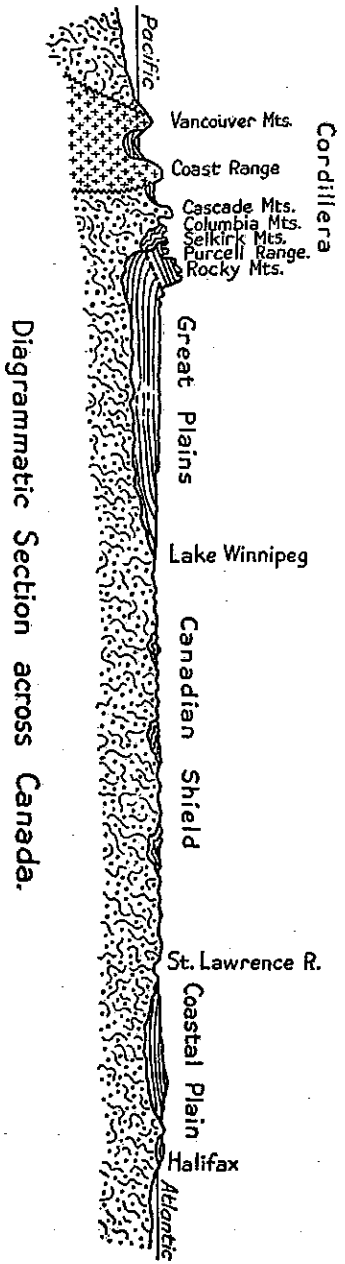
fifty miles wide, consists of granitic rocks that invaded, uplifted, and more or less destroyed the sediments along the Pacific coast and on Vancouver island. The Coast range now towers 9000 feet above the sea, and from the time of its origin has been an efficient barrier that has so divided the waters from the waters that the subsequent layers of sediments lie either to the east or to the west of it and are essentially different.

The third event during the construction of the great series of covering rocks was the birth of the Rocky mountains, perhaps 10,000,000 years after that of the Coast range and some 50,000,000 years ago. This great event was occasioned by a great splitting, folding, uplift, and overthrust of the great mass of sedimentary rocks on the old Precambrian foundation. (See Figure No. 4).

The final event of this second chapter was the further elevation of the mountain regions east and west, and probably of the whole continent.

The foundation was laid in our first chapter, the superstructure was erected in the second; we are now ready for the finishing and decorating. This operation constitutes our third or final chapter and was effected during the last million years of earth history. Without any considerable structural change, the forces of nature have carved and modified the surface of the country into the condition we now know. Heat, frost, rain, running water, and many other agents played a part, but the outstanding carving and decorating was effected by the action of ice.

The great uplift that occurred at the close of our second chapter was followed by a cold period known as the Great Ice Age. During this time snow and ice gathered in the highlands and gradually formed great rivers of solid ice known as glaciers. With increasing cold these glaciers crept lower and lower, advanced over the flat-lying lands, and eventually covered practically the whole of Canada with slowly-moving masses of ice, thousands of feet thick. Geologists recognize at least three centres of dispersion from which the ice advanced in all directions—Cordilleran, Keewatin, and Labradoran. They recognize, also, that this Glacial Period was not a single event but that the ice came and went a number of times with warmer intervals between.



Diagrammatic Section across Canada.

Figure No. 4

At present this great ice sheet is gone over the most of Canada but remnants are still left in the glaciers of the Cordillera; and the icecap that covers Greenland is but the shrunken remains of the great continental glacier of the Ice Age. It needs little imagination to picture the profound effect on the surface of Canada of the passage of this tremendous agent of destruction. As a matter of fact the whole surface owes its immediate features to the Ice Age. The effects may be summarized as follows:

(1) Elevated areas and sharp angles all ground off.
(2) The powdered débris from the grinding and vast quantities of loose stones transported and deposited.
(3) All the ancient channels of drainage were blocked by clay and other débris; as a result, a new or highly modified drainage developed on the retreat of the ice.

The final finishing touches to the structure we call Canada were given during and after the final retreat of the ice. The melting was a long and slow process and the retreat naturally proceeded from the west and south-west. The result was that vast lakes spread over the country, as the water was yet unable to escape into the St. Lawrence or into Hudson bay by reason of the ice. In these lakes were deposited silt, sand, and clay over the true glacial deposits. This deposit of superficial materials profoundly affected the agricultural soils of the country.

The foundation is now laid, the superstructure erected, and the finishing touches applied. We must now examine the relation of this whole structure to the chief natural resources of the country. In the first place we must consider the mineral industry, as that most obviously related to the structure, and it may best be considered in two sections—the metallic ores on the one hand, and those substances not metallic (the so called non-metals), on the other.

Of metallic ores the production was about $116,000,000 in 1926—nearly all derived from the old crystalline foundation or from the igneous region of British Columbia. The accessible areas of these rocks, for the reasons we have seen, are much less than their original extent. In the first

place we must note the Canadian Shield, Archaean V, Continental protaxis, with an extent of over 2,000,000 square miles or more than half of the whole Dominion. Nowhere else in the world is there an extent of these rocks at all comparable, and, as these hard crystalline rocks, largely of igneous origin, are the source of many valuable metallic ores, we are indebted to their wide extent for the production of gold, silver, nickel, copper, lead, zinc, cobalt, etc., to the value of about $62,000,000 in 1926, and for the promise of vastly greater returns in the years to come. Ancient rocks of this era also occur in British Columbia and in small areas in Nova Scotia and New Brunswick. The metallic ores of British Columbia are related to the great intrusion of the Coast range—$50,000,000 a year.

Each and every ore body is intimately related to the structure of the formations, hence a knowledge of the relationship is essential to successful prospecting or to the mining of the ore. Normally we can see only the surface, but an intimate knowledge of that surface backed by a wealth of experience enables us to see a little deeper, and, in recent years, man has invented new eyes to penetrate the rocks—diamond drills, and the various electrical and gravitational devices to enable him to visualize better the conditions underground.

The non-metallic substances to a value of $125,000,000 in 1926 are derived chiefly from the stratified rocks of our second chapter: coal from the older rocks of Nova Scotia and New Brunswick, and from the later rocks of Saskatchewan, Alberta, and British Columbia. Building stone, oil and gas, gypsum for plaster, salt, lime, and innumerable other substances are derived from these rocks.

The salt-bearing rocks of Ontario are responsible for an industry of $1,500,000 a year. The gypsum-bearing rocks yield products valued at $500,000 in both Ontario and Manitoba, and $1,200,000 in the maritime provinces. The product of the eastern coalfields is about $28,000,000 a year and that of the western fields approaches $40,000,000. The reserves of easily minable coal in the west are estimated at 410,000,000,000 tons.

With the non-metallics as with the metallics, the intimate structure is of the greatest economic importance.

Given two quarries in stone of precisely the same quality, the wet quarry cannot compete with the dry one, nor can the irregular or cracked formation yield stone in competition with even and undisturbed strata.

Agriculture is still Canada's greatest industry. It is estimated that we have 560,000 square miles of arable land, a wealth of $7,832,942,000, and a production of $1,708,567,000 for the year 1925. Speaking roughly, the determining factors in agriculture are: heat, rainfall, and soil.

Heat is primarily a matter of latitude and of altitude but certainly not of either of these factors alone. The actual latitude of any locality is quite independent of the structure of the country but the altitude is intimately related to the structure. In eastern and central Canada, there are no considerable elevations, except in Labrador. The highest point in Ontario is but little more than 2000 feet above sea level, and across the great plains little more than 3000. Latitude, therefore, is a potent controlling factor in the distribution of heat. Further, the absence of east-west chains of mountains is a significant feature. The flow of the summer heat northward is not checked, nor is the northern cold bottled up by transverse mountains as, for instance, in Asia. In the Cordillera of Canada on the other hand the temperature is directly related to the altitude, and latitude is a less immediate factor. The result is that the temperature, rainfall, and consequent floral zones run north and south in accord with the direction of the mountains.

Rainfall is directly related to the great atmospheric circulation. In the latitude of Canada the prevailing winds are from the west. These winds are greatly modified, however, by the relation of land to water, by summer and winter, by night and day, and by the structure of the country. Here in Eastern Canada, we frequently have the moisture-laden east winds pressing back the prevailing circulation from the west. This could not occur if a high range of mountains extended down our east coast. A very striking example of the influence of structure on rainfall is afforded by the effect of the Cordillera in modifying the moist westerly winds from the Pacific. These winds are forced upward by the Coast range and cooled; in con-

sequence there is a heavy precipitation along the coast. Similarly the Selkirks and the Rockies bring about further precipitation and the winds, devoid of moisture and warmed by descent finally blow out over the prairies (Chinook winds). (See Figure No. 5).

Soils are decayed and disintegrated rock and consist chiefly of sands, silts, and clays, varying greatly in both chemical and physical properties. Some soils are loose and open, others are dense and impervious, some have an alkaline reaction, while others are acid, and they all vary in the relative percentages of the necessary plant-foods—lime, and other alkalies, phosphates, and nitrates, in particular.

As the soils are derived from the underlying rocks it is apparent that they are in relation to those rocks with respect to both their chemical and their physical nature. Consequently the soils are dependent on the structure of the country. In most parts of Canada, however, they are quite as much dependent on the effects of the Ice Age. In a single farm in Ontario one may find fields composed of sand, gravel, lake clays, or stony clays of the Glacial Period. In Manitoba and part of Saskatchewan the soils are preeminently old lake-bottoms of Postglacial time. Farther west are stony clays, soils due to wind action, and gumbo soils; and, in the Cordillera, soils of ice-made origin and talus soil from the decay, essentially in place, of the mountain masses. Now, every soil, with due regard to the two other factors of rainfall and heat, is particularly suited to the raising of some definite crop. It is an economic waste to sow a field to the wrong crop, and maximum production can be obtained only when every field in Canada is sown to the seed that is most likely to thrive. The Geological Survey of Canada has performed a great service to agriculture in mapping the soils over extensive areas, but much remains to be done; it is gratifying to note that the Prime Minister of Ontario has announced a more detailed soil survey of this province. A noteworthy example of intensive cultivation is afforded by the sugar planters of the Hawaiian islands who themselves maintain a laboratory in which the soil of each field is analyzed annually and advice given as to the exact type of cane to be planted and

Diagram showing the effect of the Cordillera on Rainfall and consequently on Agriculture.

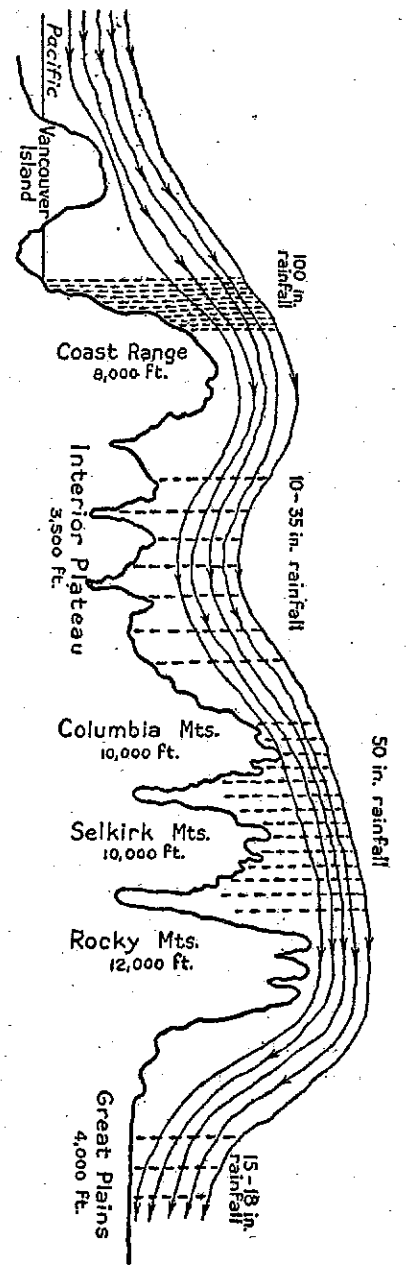


Figure No. 5

the proper fertilizer to be used. The result is that both in tonnage per acre and in quality of sugar the Islands far surpass any other sugar-producing area—even Cuba.

The *forests* of Canada are a third great natural resource. It is estimated that we have 1,227,000 sq. miles of forest as compared with 560,000 of arable land. The estimated resources are:

Softwoods	198,320,142,000 cu. ft.
Hardwoods	47,971,699,000 cu. ft.
Total	246,291,841,000 cu. ft.

The total production in 1924 as raw material is estimated to represent 2,898,506,073 cu. ft. of standing timber. Adding to this the loss by fire, insects, and other causes, the annual depletion is about 5,000,000,000 cu. ft. of standing timber. It is apparent that at this rate all the timber would be gone in 25 years. There are, however, about 534,000,000 acres of growing forests; allowing a growth of 10 cubic feet per acre per year, this would meet the consumption as given above. The primary revenue from the forests of Canada for the year 1924 is given as $213,146,710.

Unlike the man-controlled agricultural crops, the forests, in the course of nature, have already occupied the areas most suitable for their growth. Foresters recognize very definite zones for the different type of trees. Owing to the comparatively flat nature of Canada east of the mountains the zoning is more in accord with latitude and rainfall than with the structure of the country. Within the zones, however, the distribution is closely related to the character of the soil and the drainage, both of which are directly determined by the underlying structure.

In the Cordillera the zones run north and south and are evidently in direct accord with the altitude which is responsible for variation in heat and rainfall. The forest zones in the mountains are clearly and sharply defined as follows:

Coastal belt—Douglas fir, Western red cedar, Western hemlock.

Dry belt—Partly treeless with sage brush, but Yellow pine, Interior Douglas fir, Western larch.

Wet belt—Douglas fir, Red cedar, Western white pine, Engelmann spruce, Lodgepole pine.

Rocky mountain belt.

Great Plains.

In the San Francisco mountains of Arizona, no less than seven distinct forest zones are clearly defined—so sharply demarcated that within one hundred feet one passes from one forest to another.

The *fisheries* of Canada have an average output of about $50,000,000 a year over a period of 10 years. In 1925 the production was as follows:

Sea	$41,576,199
Fresh water	6,365,932
Total	$47,942,131

It might be thought that the sea fisheries are independent of continental structure. As a matter of fact there is no great industry more intimately related to structure.

In the first place it is to be noted that the continent is not limited by the shore line; it extends seaward as a submerged shelf on which the water is not over six hundred feet deep. This shallow water constitutes the fishing grounds; it is apparent that their extent is directly related to the continental structure.

In the area of the continental shelf the minor structural features exercise the most remarkable control. The direction of the currents is determined by the contour of the sea floor, the temperature is largely a result of the currents, and the actual character of the bottom is a direct structural feature. All these factors determine with remarkable nicety not only the distribution of the mature fish but the vaious stages of their development from the egg.

The fresh-water fisheries are obviously related to the distribution of lakes and rivers. Over the Canadian Shield, in Ontario, Quebec, Manitoba and far to the north, the number of lakes is almost unbelievable. Could we see Canada before the Ice Age a far different picture would

be presented. Throughout untold ages the rivers had dug for themselves deep channels to the sea. The country was thoroughly drained and few lakes existed. Then came the ice and filled the old channels with clay. With the retreat of the glaciers the waters filled the hollows and the innumerable lakes of the present day were formed. Of the Great Lakes, Erie is due entirely to this cause, and if the others existed at all prior to the Ice Age, they were much smaller than at present.

The *water powers* of Canada must be regarded as one of the major sources of national wealth. In 1924 Sir Clifford Sifton estimated the capacity dependable for six months of the year at 32,075,998 horse power. This estimate is founded on definitely known data and is doubtless low rather than high. Roughly, one-sixth of this power is now being developed.

It is apparent that there are two main requisites for the development of power from water—an adequate quantity of water and a sufficient fall within short distance. The actual quantity of water is dependent on the rainfall but its concentration is determined by the configuration of the country—a structural feature. Rivers are powerful eroding agents; given time enough any river will wear down all obstructions and eventually become a slow meandering stream in a broad valley. There will be no waterfalls; such a stream is said to be "old". Waterfalls can exist only on young rivers. In the Cordillera are many normal waterfalls because the mountains are as yet comparatively young. Eastern Canada, however, is old and the drainage should be in accord with its age—long, slow-moving rivers in wide valleys. A drainage of this kind doubtless existed before the Ice Age; but, as this drainage was entirely choked by glacial débris, the whole country was changed from old to new in so far as the drainage is concerned: hence the numerous waterfalls. Both the lakes and waterfalls are due to the same causes. The lakes are the flooded depressions and the waterfalls are the spilling of water from the higher depressions to the lower. The old-land with its hummocky and irregular surface is naturally richer in both lakes and waterfalls than the gentle sloping surface of the coastal plains.

Had the relation of rivers to the underlying rocks been more fully realized the recent disastrous failure of the great dam near Los Angeles would not have occurred. The Commission of Inquiry reported that the primary cause of failure was that a competent geologist had not been consulted in connection with the selection of the site. Similarly, expensive litigation would have been avoided if a geologist had been consulted in drawing up the specifications for the excavating work on the new Welland ship canal.

I have endeavoured, in the briefest manner possible to point out the broad facts of the geological structure of Canada and to indicate the relation of that structure to some of our major resources. I shall be satisfied if I have succeeded in impressing you with the fact that such relationship *does* exist. Further, I hope that you will appreciate that what is true in a general way is true in detail, and that an intimate relation exists between structure and product in every individual attempt to harvest the natural resources of the Dominion.

Canada is a wide expanse endowed by Nature with mountain and plain, field and forest, lake and river, and a wonderfully diversified climate. Its potential resources are correspondingly varied and rich beyond calculation. This is our heritage for which Nature has done much; but Nature goes only so far, man must do the rest. To develop the natural resources and to obtain the fullest possible returns is a duty we owe to Nature itself, and the elimination of waste is an obligation for which posterity will hold us responsible. Many of our national resources are not inexhaustible, particularly the metals, coal, oil, etc. Have we a moral right to waste these substances? Should the rare metal platinum, so essential for many of the arts and sciences, be used for jewelry? Is it necessary to wrap cigarettes in tin foil? Have we a right to crop wheat year after year from the great plains without restoring the essential plant-foods? Is any useful purpose served by the multiplicity and bulk of our daily newspapers? Is there anything like an adequate recovery of scrap material? Is the last word said in the matter of protection against fire? But why lengthen the list?

I fear that posterity will stigmatize the present generation as one of extravagance and waste. Further, I look with apprehension for the future, at the frantic haste to tear minerals from the earth for the benefit of this present generation. Statisticians rejoice if we mine ten per cent. more nickel this year than we did last. It is quoted as evidence of prosperity in the mining industry. But it should be remembered that our nickel deposits are unique and that they are not inexhaustible. As a national asset their value will increase with the passage of time. It is not only a duty, but sound economy, to see that the best possible use is made of everything taken from the earth.

Canada is a goodly part of the age-long handiwork of the Creator—a heritage to be wisely used for the benefit, not only of this generation, but of generations yet to come. To this end scientific research is directing its efforts and more and more research is required that Canadians and the world may benefit more and more from the natural products of the country. There are many types of research: some lead to additions to our comfort and to an increase in our luxuries, but in my opinion the best type of industrial research is that which leads to the elimination of waste. Future generations will thank us little for the radio, television, or ultra-violet rays if we have depleted our minerals, consumed our forests, and exhausted our agricultural lands.